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## **PREFACE**

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Best Regard,

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## PERFORMANCE ANALYSIS OF SIGNALIZED INTERSECTION DUE TO OPENING OF JATIKARYA EXIT ACCESS TO CIMANGGIS – CIBITUNG TOLL SEGMENT USING PTV VISSIM SOFTWARE

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**Abstract.** The advancement of infrastructure, especially road construction, also has an affect on changes in various urban systems in an area. Developments in the transportation system, including the opening of toll road access, will certainly affect increasing traffic flow. With the opening of toll road access, it creates new intersections so that the Cibubur Alternative Road experiences a high increase, especially during peak hours. This study points to deciding the impact of access to the Cimanggis-Cibitung toll road on the performance of the Cibubur Alternative Road. The study method begins with collecting data concurring to the parameters needed as the premise for analyzing road performance, namely the degree of saturation and the level of service based on the 2014 PKJI by comparing the conditions and assumptions of normal conditions (by dividing 75% of the existing conditions) followed by microsimulation of traffic using PTV Vissim to get a comparison of the results of vehicle speed, vehicle composition, and optimization of signal time at intersection under certain conditions. The results of the analysis show that the highest degree of saturation is on Alternative Cibubur Road 0.74 and if it is assumed under normal conditions it is 0.99 (the lowest service level is E with the lowest speed reaching 30.0 km/hour), queue length 194.47 meters and delays time. Reaching 109.87 seconds indicates a conflict at the signalized intersection because the queue length affects the performance of the Cibubur alternative road. After doing the simulation and getting an effective intersection optimization, namely resetting the green time with VISSIM software modeling, it gives better results during peak hours and reduces the highest queue length by 56,58% and delays by 80,16%.

*Keywords : delay; level of service; queue length; signalized intersection; vissim.*

### 1. INTRODUCTION

The trend of regional development to the outskirts of the city has occurred in the last decade which of course has a broad goal of building equitable growth to areas that have not been a priority through the development of regional infrastructures such as roads, buildings, transportations, and others [1]. Growth and development in the Greater Jakarta area proceed to increase rapidly so that support for the growth of road traffic volume is also increasing. This makes traffic flow disrupted, especially during peak hours within the morning and evening. The rapid growth of traffic is also felt on the adjacent intersections and also many median openings for vehicles that want to make a U-turn, causing conflicts and decreasing road performance, especially during rush hour. At the Jatikarya intersection, there was a change in the intersection from an unsignalized intersection to a signalized intersection. this creates waiting times due to signal time as well as queue length of each approach. Especially on the highway exit to the intersection, the long queue of vehicles is very clearly visible because there are only 4 or more wheeled vehicles crossing the road. Therefore, research related to the analysis of the performance of signalized intersections is very necessary. Vissim software is a traffic microsimulation application whose results can be synchronized in this research method.

This study points to analyze the performance of the Cibubur Alternative Road section and the current performance of the Jatikarya intersection and provide appropriate solutions for problems on the road and intersection. The problem at the intersection is a high delay. The current traffic light regulation has not been able to overcome the frequent traffic jams, especially during peak hours. The existing conditions at the intersection are still quite dense, plus there are intersections and roundabouts that are close together so that there are still queues at the green light, and vehicles crossing the intersection often stop or are stuck due to conflict.

When vehicles are moving people in a road space, this is what we called Traffic [2]. The performance of a road segment is a marker of the capacity of a particular road to provide services to vehicles that pass through it. In calculating the performance of roads in this study, the 2014 Indonesian Road Capacity Guidelines (Pedoman Kapasitas Jalan Indonesia/PKJI 2014) were determined by looking at the value of the degree of saturation and speed of travel under certain conditions related to geometry, traffic flow, and road environment. One of the road segment performance criteria is side obstacles, side obstacles are the impact on traffic performance due to activities on the side of the road [3].

Free Flow Speed ( $V_B$ ) is vehicle speed that is not influenced by the existence of other vehicles namely the speed at where a driver can travel comfortably in a portion of the road where there are no other vehicles in the geometric bottom, environment, and transportation traffic control conditions (km/h) [4].

$$V_B = (V_{BD} + V_{BL}) \times FV_{BHS} \times FV_{BUK} \quad (1)$$

Where :

$V_B$  = free flow speed for light vehicles (KR) under field conditions (km/h)

$V_{BD}$  = basic free flow speed for KR (km/h)

$V_{BL}$  = speed adjustment value due to road width (km/h)

$FV_{BHS}$  = free speed factor due to side obstacles on roads that have shoulders or roads equipped with curbs/sidewalks with the distance of the curb to the nearest obstacle

$FV_{BUK}$  = free speed adjustment factor for city size

Capacity is defined as the maximum traffic flow in units of skr/hour that can be maintained by a road section under certain conditions, namely roads include geometry, environment, and traffic flow [5].

$$C = C_0 \times FC_{LJ} \times FC_{PA} \times FC_{HS} \times FC_{UK} \quad (2)$$

Where :

$C$  = capacity (skr/hour)

$C_0$  = base capacity (skr/hour)

$FC_{LJ}$  = capacity adjustment factor related to lane width or traffic lane

$FC_{PA}$  = capacity adjustment factor regarding directional splitters, only on undivided roads

$FC_{HS}$  = capacity adjustment factor related to side obstacles on the shoulder or curb roads

$FC_{UK}$  = capacity adjustment factor related to city size

The degree of saturation is the main parameter used to determine the level of performance of roads. Score saturation represents traffic flow performance quality level, start from zero to one. A value close to zero indicates current no fed up, that is, the current condition relaxed and stable, and the vehicle will not affect it at all. On the other hand, number 1 indicates an unstable capacity condition, with the degree of saturation limit not exceeding 0.85 in the road design. Here are the degree of saturations equations:

$$PA = N_Q \times \frac{20}{LM} \quad (5)$$

RKH, which is the ratio of vehicles on an approach that must stop because of a red signal before passing through an intersection to the magnitude of the in-phase current on that approach [9]. It can be calculated utilizing the following equations and diagrams. The average amount of NH stops is the normal number of stops per vehicle before crossing the intersection (including the number of repeated stops in the queue), which is calculated by the taking after formula.

Delays are calculated at intersections that are equipped with traffic signaling device/priority intersections (APILL) [10]. Traffic delays at the APILL intersections include a. traffic delay is the waiting time caused by traffic interactions and traffic movement conflicts; b. geometric delay is the waiting time caused by abnormally slowing and accelerating vehicles and/or stopping at a red light. In this study, the performance of signalized intersections is examined through the parameters of queue length and delay. The delay is caused by light traffic at the marked intersection [11]. If the green time is below 10 seconds it will cause too many opposite drivers after the red light and make it difficult for pedestrians to cross the road [12].

The level of service (LOS) is a quality level that describes the traffic conditions received by vehicle drivers and is generally used as a measure to measure the effect of restrictions due to an increase in volume from A to F at a certain level [13]. Qualitative measures that explain operational conditions in traffic flow and drivers'

perceptions of vehicle quality are represented by the level of service on the road [14]-[15]. The determination of the level of service at the intersection can be determined based on the delay [10].

Table 1. Intersection Service Level Based on Average Delay.

| Level of Service | Average Delays<br>(s/skr) |
|------------------|---------------------------|
| A                | < 5                       |
| B                | 5 – 15                    |
| C                | 15 – 25                   |
| D                | 25 – 40                   |
| E                | 40 – 60                   |
| F                | > 60                      |

Source: Minister of Transportation Regulation Number 96 of 2015

PTV Vissim is a software simulation used by professionals to make a simulation scene dynamic traffic before planning actually. Vissim simulates the various types and characteristics of the vehicles we used daily, among others vehicles (cars, buses, trucks), public transportation (tram, buses), bicycles (bicycles, motorbikes), and pedestrians. Through pictures in 3D, Vissim displays simulation animation like the original made. Of course, use Vissim will reduce costs to change design becomes a reality. The user software can model various user behavior that occurs on the transportation system [16]-[17].

## 2. METHOD

The flowchart of this research is as follows.

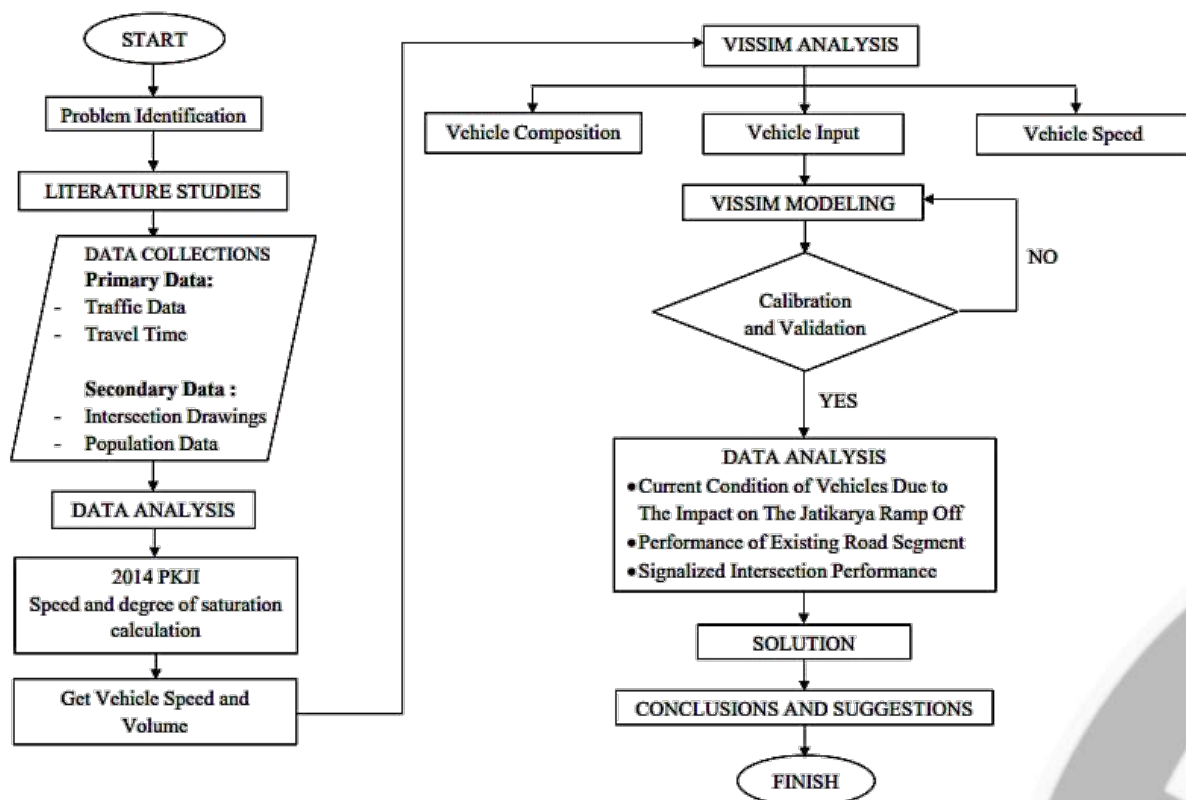


Figure 1. Flow Chart

Based on Figure 1, this research begins with problem identification, data collection carried out by literature studies, field observations, and data from agencies related to research, research, and optimization using PTV Vissim software based on 2014 PKJI. The final results of the study are the performance of the Alternative

Cibubur Road section, the performance of the Jatikarya intersection is based on queue length and delay, and the solution is in the form of intersection optimization.

### 3. RESULTS AND DISCUSSION

#### 3.1 Performance Analysis of Existing Road Segment

##### a. Capacity

One of the parameters for calculating the degree of saturation is capacity. The calculation of the capacity is carried out by way of looking at the adjustment factors for actual road conditions that affect road capacity.

##### b. Degree of Saturation

Based on the capacity analysis, the value of the degree of saturation with a comparison of several conditions, namely in 2019 (before the intersection), in 2021 existing (after the intersection and in a pandemic condition), and 2021 assumptions (after the intersection and normal conditions with a ratio of 1 : 0.75) on the Alternative Cibubur Road.

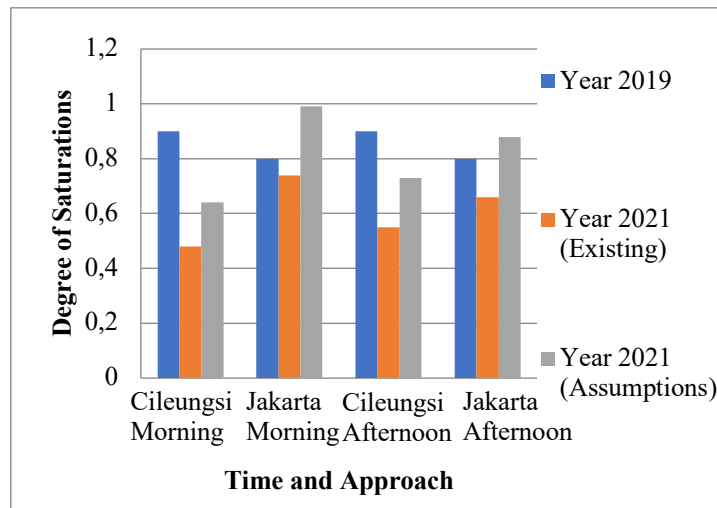


Figure 2. Comparison of Degrees of Saturation

If the existing conditions are adjusted to normal conditions (not affected by the pandemic) by assuming, the results of the road performance towards Cileungsi during the morning rush hour are 0.64 and the afternoon rush hour is 0.73 then the direction to Jakarta during the morning rush hour is 0.99 and the afternoon rush hour is 0.88.

##### c. Speed

The analysis carried out is to compare 2 conditions, namely, speed under normal conditions (before the pandemic) and existing conditions (pandemic conditions) with a comparison between both conditions are 1 : 0.75. speed recapitulation can be seen in Figure 3.

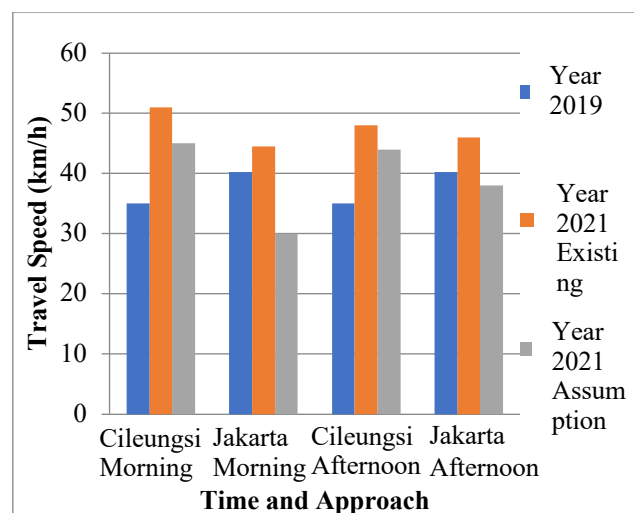


Figure 3. Comparison of Theoretical Travel Speed

From the results of the comparative analysis in the graph above, in 2019, the vehicle travel speed towards Cileungsi was known to be 35 km/hour and the direction to Jakarta was 40.3 km/hour. In 2021, the travel speed towards Cileungsi is 51 km/hour (morning rush hour) and 48 km/hour (afternoon rush hour); the direction of Jakarta is 44.5 km/hour (morning rush hour) and is 46 km/hour (afternoon rush hour). However, if the existing conditions are adjusted to normal conditions (not affected by the pandemic) by making assumptions, the result obtained that the travel speed towards Cileungsi during the morning rush hour is 45 km/hour and the afternoon rush hour is 44 km/hour. Then the direction to Jakarta during the morning rush hour is 30 km/hour and the afternoon rush hour is 38 km/hour.

#### d. Density

Based on the speed quotient, the value of the density of the Alternative Cibubur road towards Cileungsi during the morning rush hour is 45.20 skr/km and at the afternoon rush hour is 55.23 skr/km. While the road density in the Alternative Cibubur Road towards Jakarta during the morning rush hour is 81.00 skr/km and in the afternoon it is 69.28 skr/km.

#### e. Road Level of Service

The results of the service level analysis based on the Regulation of the Minister of Transportation Number 96 of 2015 concerning Guidelines for the Implementation of Traffic Management and Engineering Activities in 2019 the service level is E (unstable flows speed sometimes stops, demand is approaching capacity) for both directions, in 2021 the existing condition of service level is C (stable flow, but vehicle speed and motion are controlled) for both directions and if an assumption is made in 2021, the comparison is C for the Cileungsi direction and E for the direction of Jakarta.

### 3.2 Performance Analysis of Signalized Intersection

In this section, the performance of signalized intersections in terms of queue length and delay is carried out using PTV Vissim. According to the Minister of Transportation Regulation Number 96 of 2015, delays are calculated to determine the level of service at intersections. The data requirements that are inputted to Vissim to get the performance of the intersection are described in the following discussion.

#### a. Vehicle Composition

From the results of the analysis of vehicle traffic flow, the composition for each type of vehicle in each direction is calculated. The composition of the vehicle will be used as input of Vissim. The composition of vehicles for each intersection approach is shown in Figure 4.

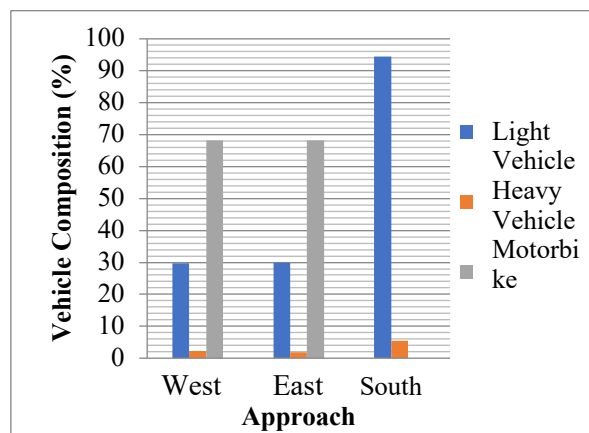


Figure 4. Vehicle Composition

#### b. Existing Vehicle Speed

Analysis of vehicle speed distribution is used as input to the VISSIM program on the Desired Speed Distribution menu. The results of the analysis of the vehicle speed distribution and its graph can be seen in Figure 5.

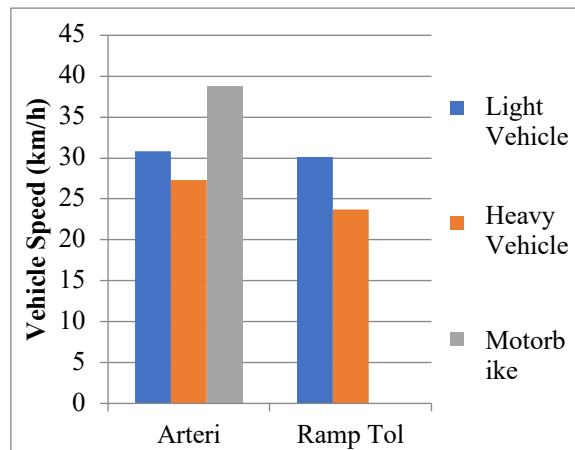


Figure 5. Existing Travel Speed

### c. Signal Time

Traffic signal light settings based on survey results are carried out on the Signal Controller menu. In this menu, inputs are entered in the form of cycle time, signal phase, all red time, green time, inter-green time, and amber. In this study, green time changes are calculated for intersection optimization. Table 2 explains the comparison between the existing condition and optimization as follows.

| Table 2. Intersection Signal Time |                      |                       |
|-----------------------------------|----------------------|-----------------------|
| Movement                          | Existing Condition   | Junction Optimization |
|                                   | Green Time (seconds) | Green Time (seconds)  |
| Jakarta – Cileungsi               | 63                   | 73                    |
| Jakarta – Enter Toll              | 14                   | 18                    |
| Cileungsi – Jakarta               | 53                   | 53                    |
| Cileungsi – Enter Toll            | 53                   | 53                    |
| Toll Ramp – Cileungsi             | 38                   | 42                    |
| Toll Ramp - Jakarta               | 38                   | 42                    |

### d. Calibration and Validation

Calibration and validation are carried out so that the simulation model that is run can represent the actual field conditions in the field. In this study, calibration was carried out using the VISSIM application trial and error driving behaviors. Driving Behavior is entered in the input in the Link window and can be made closer to the real thing. For arterial roads, the Car Following Model uses the *Wiedemann 74*, and for toll ramps, carried it uses the *Wiedemann 99*.

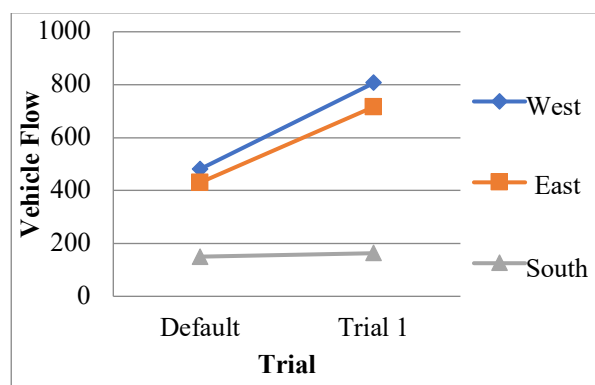


Figure 6. Vissim Calibration Results

#### e. Vissim Analysis and Solutions

After calibration and validation were completed and the model is declared valid, in addition evaluation is completed at the VISSIM modeling. VISSIM evaluation on this observe is an evaluation of the outcomes by comparing queue length and vehicle delays at intersections.

In this observe, traffic management was carried out as one of the answers to research problems. Traffic control is completed in optimizing the intersection cycle time with the aid of using converting the green time and cycle time. The intersection optimization is executed the use of the Optimize All Fixed Time Signal Controllers menu withinside the VISSIM program. For the scholar version, it's far executed with the aid of using trial and error by changing converting optimization by proportional sizing the length of the queue at every arm of the intersection in keeping with the traffic flow that passes through every arm of the intersection in order that the intersection can lessen vehicle delay time and enhance intersection performance. The following is a recapitulation of outcomes of the contrast of vissim evaluation of current situations and optimization answers.

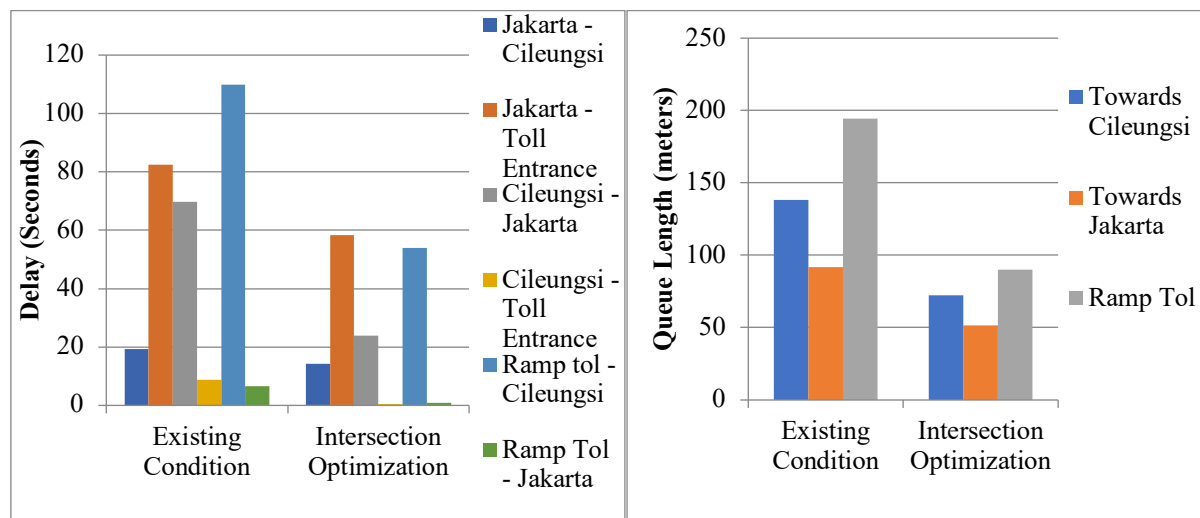


Figure 7. Delay and Queue Length Comparison

From Figure seven above, it will be seen that changing the dynamic time and green time at the intersection leads to modifications in queues and vehicle delays at every intersection approach. The largest change occurred at the East approach intersection (Alternative Cibubur Road) by 56.58% for queues and 80.16% for delays (change in service level from C to B and F to E). Within the Western approach, there has been a decrease in queue length by 52.29% and a decrease in delays by 27.41% (change in service level from F to C and B to A). It can be over that the Alternative Solution by changing the cycle time and green time at the intersection contains a vital result on reducing queues and delays that occur on the Alternative Cibubur Road and Jatikarya Toll Access.

From the results above, to resolve the performance downside of the Jatikarya intersection, it is necessary to adjust the length of green time and cycle time. This is often a recommendation for companies, governments and different stakeholders concerned in political opinions to boost intersection performance.

#### 4. CONCLUSION

From the result of the analysis, it can be concluded that the performance of the Alternative Cibubur Road segment in the existing condition is obtained the largest degree of saturation is 0.74 (morning rush hour) in the direction of Jakarta with service level C. The level of service at the Jatikarya intersection is obtained by the largest queue length and delay, namely the South approach (Toll Exit Access) with a queue length of 194.87 seconds with service level F which affects the West and East approaches (Alternative Cibubur Road). The solution is optimizing the intersection, changing the green time and cycle time, resulting in a significant effect with the largest decrease in queue length and delay, namely 56.58% and 80.16% with changes in service level up to A.

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## DESIGN AN AUTOMATIC TRANSFER SWITCH FOR SOLAR POWER PLANT

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**Abstract.** This paper discusses the automatic transfer switch (ATS) in solar power plants. ATS is used to transfer the main electrical power to a backup power source (battery). PLN power cannot supply electricity continuously due to non-standard ATS installations, blackouts, disturbances to the generating system, and distribution system. Two ATS systems are proposed to control the switching process of PLN and PLTS automatically using inverter standby mode (ISM) and inverter off mode (IOM). The results of the application of ISM to PLN and PLTS can supply power needs based on switching techniques to avoid equipment damage. While IOM can save battery for inverter power supply.

*Keywords: Automatic transfer switch, Solar power plant, ISM, IOM.*

### 1. INTRODUCTION

Solar Power Plants (PLTS) are controlled by Automatic Transfer Switch (ATS) [1], [2]. ATS functions as an automatic switch to transfer the main electrical power to a backup power source (battery). ATS control will switch the main power automatically to PLTS when the PLN source experiences power dissipation [3]. However, when the PLTS power is used as the main power source, the ATS will switch the main power to the PLN source in the condition that the battery is used to supply the inverter [4]. The PLTS power dissipation factor is caused by cable installation, sunlight, ambient temperature, and the angle of inclination of the solar panels [5]. Solar panels charge electrons and protons based on the battery charge voltage. Charging stops when the battery reaches its maximum voltage [6]. PLN's electrical energy source affects the power to the load. The power generated by PLN cannot supply electricity continuously due to non-standard ATS installations, blackouts, disturbances to the generating system, and distribution systems [7]. So that the guarantee of the availability of electrical energy is not optimal [8].

Therefore, electrical energy reserves must be met to supply the load continuously [9]. The power requirement at the load is controlled by the ATS system design [10], [11]. The ATS system is used to transfer power automatically by adjusting the load. The basic principle of the ATS system applies logic to relays, timers, contactors, and MCBs. The greater the power used, the greater the load being controlled. Several types of ATS are distinguished based on the required power capacity or based on the phase and current through the panel. [12]. ATS is proposed to transfer the electricity source from PLN to PLTS in the event of a disturbance. ATS is designed with an inverter standby mode and inverter off mode system. Inverter standby mode is used as a power requirement generated by the ATS. Inverter off mode is used to save battery power on the inverter supply voltage. When the voltage is below 10 volts, the ATS switches to PLN. This process occurs repeatedly. The ATS system is expected to be able to replace electrical power by adjusting the load requirements during blackouts, saving battery power, and changes to the main power source in the backup power source can be controlled automatically.

### 2. METHODS

The method for supplying power from PLTS and PLN alternately uses ATS Inverter Standby Mode (ISM) and Inverter Off Mode (IOM). ISM is used for load power requirements because PLTS supplies power continuously even though PLN resources are used as the main power source [13]. The ISM switching technique is set at high speed to avoid faults in the power grid that cause damage to equipment [14]. IOM is used to save battery power supply to the inverter. IOM switching technique is not like ISM, because the inverter does not supply power

continuously, and the power is supplied during the switching process from PLN to PLTS [15], [16].

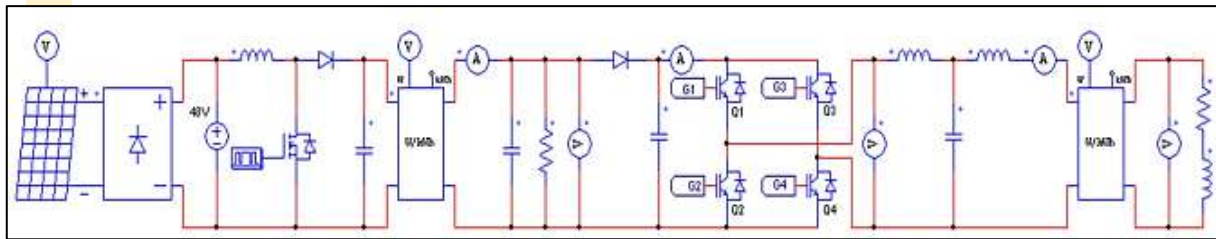


Figure 1 Inverter PLTS [17]

### 3. RESULTS AND DISCUSSION

An ISM applies a 3000 Watt inverter to convert 12 DC voltage into 220 AC voltage with pure sine wave technology at a frequency of 50Hz [18]. Then, the MPPT is connected to a contactor to control the solar panel voltage, battery voltage, and current feedback [17]. Low Voltage Disconnect (LVD) regulates the ATS system based on battery power [19]. ATS is triggered by the LVD when the battery voltage is below the minimum to activate the PLN power source [20]. The selector is used as the main power source of electricity. The auto system indicates the ATS selector is in off mode. The solar panel switches the power source using the MKP2P Relay. while ATS is triggered by the MKP2P relay.

The green and red indicator lights as a sign of the PLTS and PLN power switches. LVD is triggered by the M2Y relay when the condition is off and ATS is triggered by the SPDT relay. MCB 100A 220V disconnects the load when the solar panel exceeds the maximum power, and MCB 6A is used to cut off the maximum power load. However, in its application, this method has a weakness, namely the use of batteries to supply the inverter faster, because the battery is forced to continuously supply power to the inverter, besides that the inverter will heat up quickly and can reduce the life of the inverter. Therefore, this method is highly recommended for consumers who need electrical network stability on consumer electrical equipment. The inverter standby mode is described in figure 2.

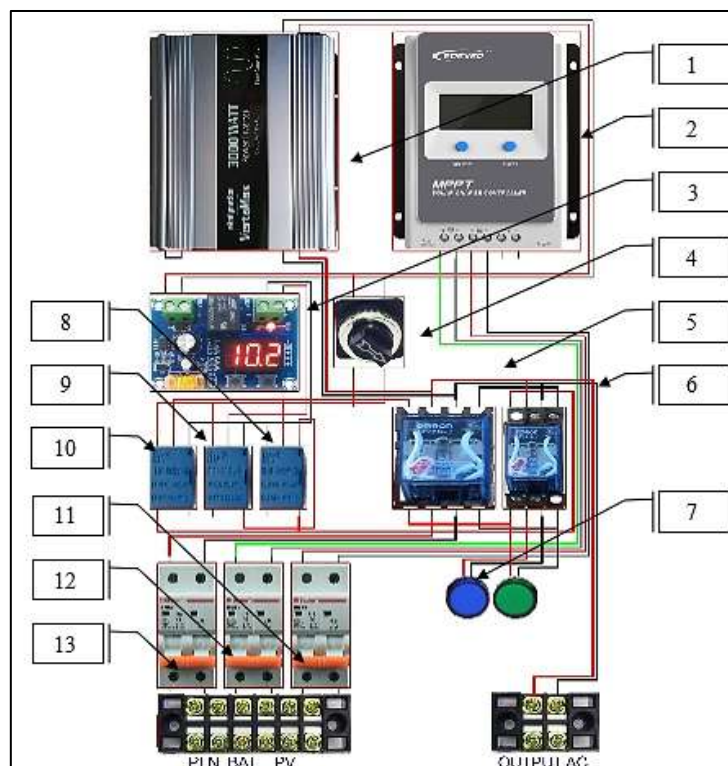


Figure 2. Inverter Standby Mode

The IOM design uses a 3000 Watt inverter which converts 12 DC voltage to 220 AC voltage with pure sine wave technology at a frequency of 50Hz. Then, the MPPT is connected to a contactor to control the solar panel voltage, battery voltage, and current feedback. Low Voltage Disconnect (LVD) regulates the ATS system based

on battery power. ATS is triggered by the LVD when the battery voltage is below the minimum to activate the PLN power source. The selector is used as the main power source of electricity. The auto system indicates the ATS selector is in off mode. The solar panel switches the power source using the MKP2P Relay, while ATS is triggered by the MKP2P relay.

The green and red indicator lights as a sign of the PLTS and PLN power switches. The LVD is triggered by the M2Y relay when the condition is off and ATS is triggered by the SPDT relay. MCB 100A 220V disconnects the load when the solar panel exceeds the maximum power, and MCB 6A is used to cut off the maximum power load. The application of the IOM method is not recommended for electrical loads that use Power Switching Low Energy technology, because long-term use can damage equipment due to unstable voltage when the inverter is working after a switch occurs in the ATS circuit. So that the application of the IOM method is used on electrical loads that use induction technology, capacitors, and electric motor loads. Inverter Off mode is described in figure 3.

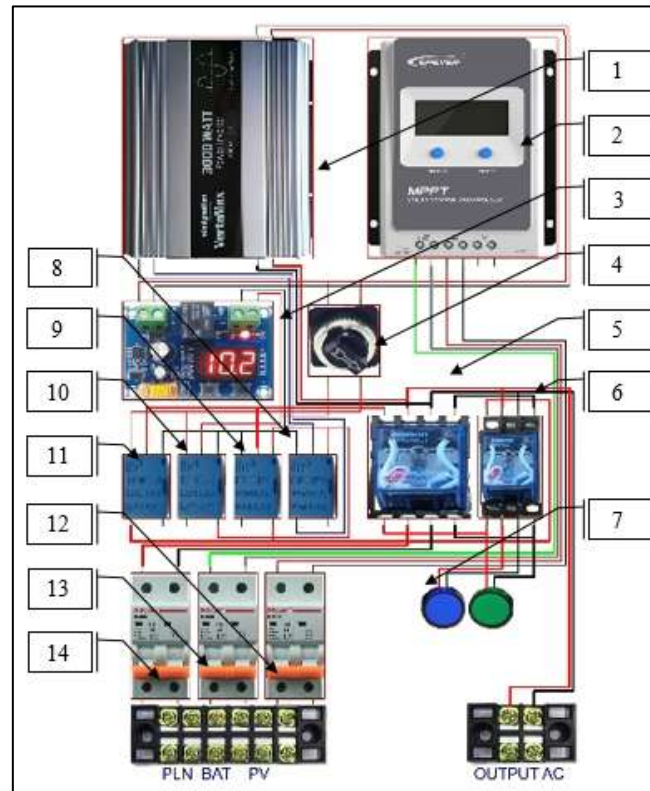


Figure 3 Inverter Off Mode

Table 1 shows the components inverter standby mode and inverter off mode. Inverter 300 Watt, Maximum Power Point Tracking Solar Charge Controller (MPPT SCC), Low Voltage Disconnect (LVD), selector 2 poles, relay MK2P, relay M2Y, lamp indicator, For relays SPDT single command, two MCB DC 100 A, and MCB AC 6A.

Table 1. Inverter Standby Mode and Inverter Off Mode Components

| Components         | Specifications | Volume |
|--------------------|----------------|--------|
| Inverter 3000 Watt | 12Vdc to AC    | 2      |
| MPPT SCC           | 100 Ampere     | 2      |
| LVD                | XH-M6009       | 2      |
| Selector 2 Pole    | CA10-A211      | 2      |
| Relay AC 220V      | MK2P           | 2      |
| Lamp Indicator     | PBT-AD22DS     | 2      |
| Relay DC 12V       | SPDT           | 4      |
| Relay AC 220V      | M2Y            | 2      |
| MCB DC 100A 220V   | 2PDC           | 2      |
| MCB AC 6A 220V     | SCHNEIDER      | 1      |

#### 4. CONCLUSION

The automatic transfer switch (ATS) system design uses two inverter standby mode and inverter off mode systems. Inverter standby mode is used to supply power requirements based on switching techniques. The switching technique is carried out as quickly as possible to avoid equipment damage. Inverter off mode is used to save battery on the inverter power supply. The inverter power supply is regulated by LVD so that when the battery cannot supply the load, the ATS will switch to PLN. But the inverter standby mode has a weakness, namely the use of batteries to supply the inverter faster, because the battery is forced to continuously supply power and heats up quickly. While the inverter off mode is not recommended for electrical loads that use Power Switching Low Energy technology, because long-term use can damage equipment due to unstable voltage when the inverter works after the switching process in the ATS circuit.

#### 5. ACKNOWLEDGEMENT

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## Risk Analysis of Investment Costs in PPP Projects Using Monte Carlo Simulation

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**Abstract.** Infrastructure project investment is a substantial urgency in line with the vision of President Jokowi's administration of developing infrastructure in Indonesia. The Government and Private Sector partnership (PPP) becomes feasible alternative to cover the financial deficit in the provision of infrastructure. The Southern Jakarta-Cikampek II Toll Road Project has been determined to be operated under the PPP scheme. The identification, allocation, and appropriate risk mitigation of the projects are the important success keys to provide clarity and benefits for among the parties. The purpose of this study is to analyze 27 risk variables from PT PII guidelines qualitatively and quantitatively with probabilistic principles using Monte Carlo simulations, by then accurately to estimate the values of the effect of each risk on the project investment value. The research was carried out by collecting project data, identifying risk variables, questionnaires to experts, risk quantification, Monte Carlo simulation, calculating the effect and value of risk, as well as analysis of risk allocation and mitigation based on the Pareto Principle. The study shows that of 26 influential risk categories and one (1) risk does not affect the investment component of the project. There are 12 Risks could be allocated to the Government and 14 Risks could be allocated to Private Sector. The total value of the amount of risk cost is Rp16,424,331,645,796 (21% of total risk investment value). Based on Pareto, 30% risk categories (equal to 8 risks) are the dominant factors of which equal to 70% of the total value of risk. Hence the mitigation may focus to reduce the dominant factors to lower risk by then decrease the value of risk Rp9,885,627,136,618 that equal to 60% become Rp6.538.704.509.178 (equal to 40% of risk value)

**Keywords:** dominant influential risks, monte carlo simulation, PPP, risk allocation, risk mitigation.

### 1. INTRODUCTION

Financing is a substantial hindrance in massive road projects in Indonesia. Directorate General of Infrastructure Financing, Ministry of PUPR calculates that the budget needed to build 1,500 kilometers of toll roads in the period of 2020-2024 period is around IDR 2,000 trillion, while the state budget for PUPR can only meet IDR 623 trillion where the budget must be shared with the development of other important sectors [1]. So that non-state budget funding sources are needed through Public and Private Sector Partnerships (PPP) to meet the needs of the budget deficit. Based on Presidential Decree No. 38 in 2015, PPP is a collaboration in the provision of Infrastructure for the public which partially or completely using financing from Private Sector by paying attention to the sharing of risk between each parties [2]. PPP is a financing scheme as a way for the government to provide services and equitable economic development for all Indonesian people [3].

The important success key of a PPP scheme is the identification, allocation, and appropriate risk mitigation so that it can provide clarity and benefits based on the capacity and capability of each party in the division of roles of controlling the risk in providing infrastructure [4]–[6]. This becomes important for investors to participate in PPP projects in Indonesia [7].

The uncertainty of PPP Projects impacts the reluctance of investors to participate as the result of big risk value costs, long-term business interactions, and subject to rapidly changing environment [8], [9]. An in-depth risk analysis expected to give an appropriate risk sharing which provide benefits in terms of cost, quality, and time as

well as information about how much of the influence of each risk accurately on the investment value which will assist in providing investment decisions on the toll road PPP concession [10], [11]. As the many plans for toll road projects using PPP scheme, it is necessary to conduct an in-depth study of the project's investment costs that are affected by the influential risk identified.

Qualitative and quantitative risk analysis is required with probabilistic principles method using Monte Carlo simulation to be able to analyze and give the possibility of uncertainty that can occur in a project so it can estimate how much the effect of each identified risk on the investment value of the PPP project [12], [13]. Another advantage is Monte Carlo can eliminate uncertainty in reliability modeling because of the ability to stimulate the actual process and behavior of the system [14]. Thus, it is expected to provide an estimate of the allocation as well as risk mitigation with the lowest risk of costs for each parties of the PPP project.

Based on the Toll Road Concession Agreement (PPJT) by the Ministry of PUPR in 2017, one of the toll road projects carried out with the PPP scheme is the Southern Jakarta-Cikampek II Toll Road Project which is one of the National Strategic Projects (PSN) with a track length of 64 km. The project, which is still under construction, is estimated to require an investment of Rp 14 trillion. Therefore, the research objectives is to determine which risks really influential in PPP Project of Southern Jakarta-Cikampek II Toll Road Project using Monte Carlo Simulation then to measure the value of influential risks as well as risk responses based on Pareto Principles to give an effective allocation and mitigation of each risks.

## 2. METHODS

### 1. Data Collection and Initial Risk Identification

At this stage, PPP project agreement data and project investment data are collected, while risk variable data are collected based on the PPP project risk guidelines by PT PII and Financial Management Guidance, by Australian Government [15]. These datas will be used in conducting risk analysis in the next stage.

### 2. Expert Questionnaire Survey

The Questionnaire Survey was conducted by purposive expert sampling method on nine (9) PPP experts who were familiar with the Southern Jakarta-Cikampek II Toll Road project. The questionnaire aims to reduce risk variables that have no effect on investment, find out how much is the estimated effect of the risk (impact and frequency of risk), as well as risk allocation that must be carried out on the influential risk variable.

### 3. Qualitative Risk Analysis

Qualitative Risk Analysis was carried out by categorizing the frequency value and risk impact of the questionnaire results based on PMBOK Guide Sixth Edition (2017) [16].

### 4. Risk Quantification and Monte Carlo Analysis

Risk quantification is carried out based on the mode of likelihood and the consequences of each risk identified. Then it is converted into a numerical indicator based on the risk assessment index in the PMBOK Guide Sixth Edition (2017) [16]. Quantitative analysis was carried out using Monte Carlo Simulation with Palisade Decision Tools @Risk software on the Microsoft Excel add-ins spreadsheet program. Monte Carlo simulation is done by simulating each impact and frequency risk value.

| Likelihood       | Consequences          |                  |                  |                  |                  |
|------------------|-----------------------|------------------|------------------|------------------|------------------|
| Very High<br>0,9 | Moderate<br>0,05      | Moderate<br>0,09 | High<br>0,18     | High<br>0,36     | TerHigh<br>0,72  |
| High<br>0,7      | Low<br>0,04           | Moderate<br>0,07 | Moderate<br>0,14 | High<br>0,28     | TerHigh<br>0,56  |
| Moderate<br>0,5  | Low<br>0,03           | Moderate<br>0,05 | Moderate<br>0,1  | High<br>0,2      | High<br>0,4      |
| Low<br>0,3       | Low<br>0,02           | Low<br>0,03      | Moderate<br>0,06 | Moderate<br>0,12 | High<br>0,24     |
| Very Low<br>0,1  | Low<br>0,01           | Low<br>0,01      | Low<br>0,02      | Moderate<br>0,04 | Moderate<br>0,08 |
|                  | 0,05<br>Insignificant | 0,1<br>Minor     | 0,2<br>Moderate  | 0,4<br>Major     | 0,8<br>Severe    |

Figure 1. Consequences and Likelihood Risk Assessment

Source: PMBOK Guide Sixth Edition (2017) [16]

### 5. Calculation of the Effect and the Amount of Risk on Project Investment Costs

The results of the monte carlo simulation are then used to calculate risk factors to determine the risk rating category for risk response analysis. Each risk is identified its value and risk reference based on agreement data and the project investment value which is then used to calculate the effect of risk on investment costs based on the Toll Road Investment Risk Analysis Guidelines Pd T-01-2005-B of the Ministry of PUPR [17]

## 6. Risk Response Analysis

Risk response analysis consists of risk allocation and mitigation. The foundation for the analysis of this stage is the classification of risks that have been identified based on the ranking of the tornado diagrams which then will be analyzed the value of the effect of risk using the Pareto law principle which rank risks from highest to lowest based on cumulative values which aims to determine the dominant problem that has the greatest influence on the entire project and the greatest potential for improvement [18], [19]. Risk Allocation and Risk Mitigation are formulated based on Guidelines from the Ministry of PUPR, PT PII, PMBOK, and Financial Management Guidance, Australian Government.

## 3. RESULTS AND DISCUSSION

### 3.1 Evaluation of Influential Risk for the Investment Cost

Based on the preliminary study and the results of the expert questionnaire, from 27 potential risk factors, it was found that Utility Risk had no influent on the investment cost of the PPP project. These findings showed differences from the previous study from [20] which showed only 13 risks had an influent on investment cost. The higher number of influential risks on investment cost illustrates that recently there is a lot of uncertainty and trust in PPP projects both for the public and private sectors. The other 26 risks were then analyzed to determine their risk allocation, risk factor category, cost references, and risk value as shown in Table 1.

Table 1. Conclusions of Risk Allocation, Simulation Results, Reference for the Effect of Risk on Investment Cost Components, and Value of Risk of 26 identified risk

| Risk Variables                             | Risk Allocation | Consequences Value after Simulation | Likelihood Value after Simulation | Risk Factor Category | Cost References                                                              | Investment Cost | Risk Value |
|--------------------------------------------|-----------------|-------------------------------------|-----------------------------------|----------------------|------------------------------------------------------------------------------|-----------------|------------|
| Construction Completion Risk               | Private Sector  | 0,431                               | 0,559                             | High                 | Construction Cost                                                            | 8.984.000       | 2.167.929  |
| Delays Due to Force Majeur Risk            | Govern-ent      | 0,480                               | 0,478                             | High                 | Construction Cost                                                            | 8.984.000       | 2.058.741  |
| Risk of Sponsor                            | Private Sector  | 0,431                               | 0,515                             | High                 | Value of Loans to Lenders                                                    | 8.043.764       | 1.786.786  |
| Maintenance Risk                           | Private Sector  | 0,380                               | 0,507                             | Mode-rate            | Maintenance Cost - O&M                                                       | 7.393.362       | 1.424.160  |
| Risk of Hidden Defects                     | Private Sector  | 0,376                               | 0,470                             | Mode-rate            | Maintenance Cost - O&M                                                       | 7.393.362       | 1.307.327  |
| Risk of Demands that Lower than Estimation | Private Sector  | 0,411                               | 0,507                             | High                 | General Administration Cost and Toll Collecting-O&M                          | 4.488.827       | 936.373    |
| Risk of Tariff Didn't Go As Planned        | Govern-ent      | 0,419                               | 0,493                             | High                 | General Administration Cost and Toll Collecting-O&M                          | 4.488.827       | 925.413    |
| Risk of Development Network                | Govern-ent      | 0,398                               | 0,507                             | High                 | General Administration Cost and Toll Collecting-O&M                          | 4.488.827       | 906.848    |
| Assets ownership risk                      | Private Sector  | 0,406                               | 0,478                             | Mode-rate            | General Administration Cost + Toll Collecting-O&M and Project Financial Cost | 4.649.702       | 900.952    |
| Risk of Connectivity                       | Private Sector  | 0,381                               | 0,522                             | High                 | General Administration                                                       | 4.488.827       | 894.256    |

|                                                               |                |       |       |           |                                                                |           |         |
|---------------------------------------------------------------|----------------|-------|-------|-----------|----------------------------------------------------------------|-----------|---------|
| with existing network                                         |                |       |       |           | Cost and Toll Collecting-O&M                                   |           |         |
| Incompatibility of land location                              | Government     | 0,443 | 0,530 | High      | Land Acquisition Cost                                          | 3.069.701 | 719.569 |
| Risk of asset take over                                       | Government     | 0,433 | 0,463 | Mode-rate | General Administration Cost (O&M) and Project's Financial Cost | 2.537.313 | 509.029 |
| Risk of Cost Increase                                         | Private Sector | 0,465 | 0,581 | High      | Project's Escalation Value                                     | 972.410   | 262.824 |
| Risk of regulations and laws changes                          | Government     | 0,456 | 0,507 | High      | Project's Escalation Value                                     | 972.410   | 224.775 |
| Industrial Relations Risk                                     | Private Sector | 0,339 | 0,478 | Mode-rate | Toll Road Service Cost - O&M                                   | 1.320.243 | 213.765 |
| Financial Parameters Risk                                     | Government     | 0,398 | 0,537 | High      | Project's Escalation Value                                     | 972.410   | 207.921 |
| Inequality of Work Quality                                    | Private Sector | 0,400 | 0,500 | Mode-rate | Project's Escalation Value                                     | 972.410   | 194.482 |
| Risk of Permission                                            | Government     | 0,394 | 0,500 | Mode-rate | Project's Escalation Value                                     | 972.410   | 191.781 |
| Developer failure in carrying out its contractual obligations | Private Sector | 0,428 | 0,493 | High      | Administration Cost                                            | 856.086   | 180.395 |
| Risk of Changes in Tax Rates                                  | Government     | 0,380 | 0,470 | Mode-rate | Project's Escalation Value                                     | 972.410   | 173.640 |
| Planning Risk                                                 | Government     | 0,424 | 0,537 | High      | Contingency Cost                                               | 550.423   | 125.355 |
| Financial Structure Risk                                      | Private Sector | 0,435 | 0,537 | High      | Financial Cost                                                 | 160.875   | 37.598  |
| Technology Risk                                               | Private Sector | 0,372 | 0,463 | Mode-rate | Toll Road Equipment Cost                                       | 179.680   | 30.963  |
| Design Risk                                                   | Private Sector | 0,424 | 0,507 | High      | Desain Cost                                                    | 89.840    | 19.332  |
| Land Acquisition Risk                                         | Government     | 0,506 | 0,596 | High      | Overhead Construction Cost                                     | 44.920    | 13.542  |
| Sub-sovereign or parastatal risk                              | Government     | 0,457 | 0,515 | High      | Overhead Construction Cost                                     | 44.920    | 10.578  |

According to Tabel 1, it can be seen the differences from the result of Monte Carlo Simulation of Consequence and Likelihood value than the original number from PMBOK. Those factors are then used to determine the risk value of each 26 influential risks. Based on the analysis, it was found that the total risk value of the project is Rp 16.424.331.645.796 where the risk with the highest value is the Construction Completion Risk

and the lowest is the Risk of Sub-sovereign or Parastatal. By using the data from the expert questionnaire, 12 Risks could be allocated to the Government or with a risk value of Rp. 6,067,190,251 (37%) and 14 Risks are allocated to Private Sector or with a risk value of Rp. 10,357,141,394 (63%). Based on the risk allocation, it is found that Public Sector got a higher risk value allocated than the government, at the other words, governments can get assistance in the allocation of the budget burden in terms of the amount of risk borne and the risk-sharing with the PPP scheme. This can be used as a way for the government to use the PPP scheme in implementing infrastructure development in Indonesia so that it can improve services, growth, and economic benefit for all Indonesian people. On the other hand, the private sector also gets investment assurance in terms of investment returns and a clear risk sharing between the government and private sector.

The results of the risk factor analysis are shown in Table 1 where it is obtained that the allocation of the average risk factor value for the public sector is high risk (0.7224) while the average factor value for private sector is a moderate risk (0.6735). The overall of 26 risks have a high-risk factor value (0.7080) so that risk factor reduction must be carried out to a lower level to give a better benefit for every sector in term of risk value.

### 3.3 Reduction of Risk Value on Dominant Risks

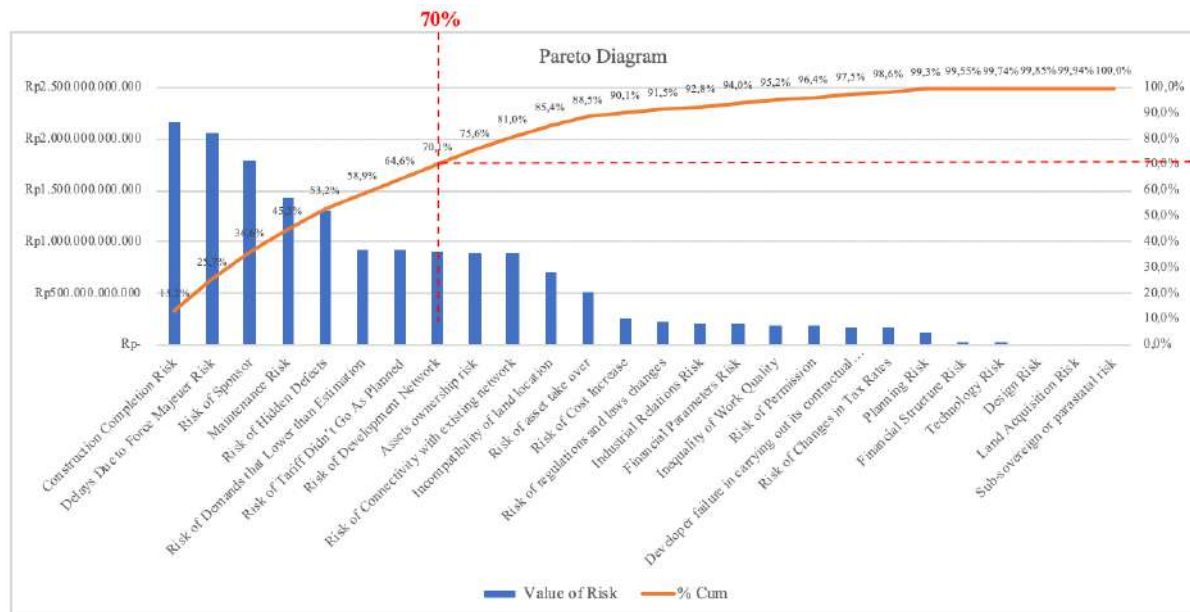


Figure 2. Dominant Risks based on Pareto Diagram

According to Figure 2, the 26 risks then sorted based on risk value from the highest to the lowest which is then analyzed further using a Pareto Principle so that it is found 30% of risks equal to eight risks are the dominant cause of 70% of the total value of the risk value in this project. The Eight Dominant Risks are: (1) Construction Completion Risk; (2) Delays Due to Force Majeure Risk; (3) Risk of Sponsors; (4) Maintenance Risk; (5) Risk of Hidden Defects; (6) Risk of Demands that Lower than Estimation; (7) Risk of Toll Road Tariff Didn't Go As Planned; (8) Risk of Development Network.

The 8 dominant risks then will be the focused analysis to reduce the risk factor values into a lower risk category. The analysis done by testing the consequence and likelihood values of each risk using Monte Carlo simulations and standard values so that the following results were obtained in Table 2 used to re-calculate the value of the risk and its reduction. The consequences and likelihood values in trial 2 with standard number deliver the lowest risk factor.

Table 2. Risk Factor Value Reduction Among Eight Dominant Risks

| Trial       | Consequences | Likelihood | Risk Factor | Conclusion    |
|-------------|--------------|------------|-------------|---------------|
| Real        | 0.4135       | 0.5130     | 0.7080      | High Risk     |
| Monte Carlo |              |            |             |               |
| Tial 1      | 0.3500       | 0.4333     | 0.6317      | Moderate Risk |
| Tial 2      | 0.3167       | 0.4        | 0.59        | Moderate Risk |
| Tial 3      | 0.3000       | 0.3667     | 0.5567      | Moderate Risk |
| Standar     |              |            |             |               |
| Tial 1      | 0.2          | 0.3        | 0.44        | Moderate Risk |
| Tial 2      | 0.1          | 0.3        | 0.37        | Low Risk      |

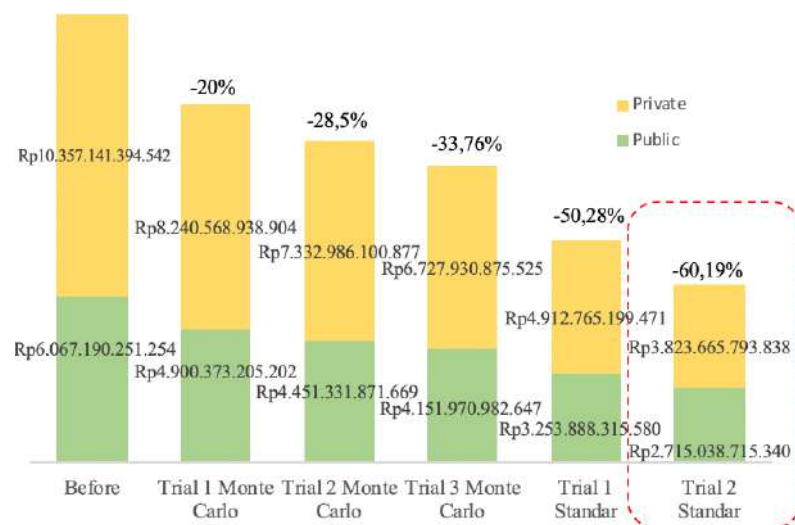


Figure 3. Result of Risk Category Reduction for Risk Value of Investment Cost

Figure 3 is the result of re-calculation data of risk value in graphical form. It can be seen the risk value of 8 dominant risks for 5 reduction attempts of consequence and likelihood value could bring 60% of risk value reduction (equal to Rp 11.242.251.308.178). The risk value reduction for trial 2 with standard number meet the lowest category. It is showed if effective strategies for risk allocation and mitigation applied for those dominant risks could bring benefits in PPP Project for Southern Jakarta-Cikampek II Toll Road regarding risk value reduction for both the public and private sector.

### 3.3 Risk Allocation and Mitigation Strategies

Based on the re-calculation of risk value reduction, it showed if there are focused strategy on risk mitigation and allocation for 8 dominant risks it could deliver reduction up to 60% of the total 26 risk value. Thus, the eight risks were then analyzed for risk allocation and mitigation as shown below in Table 3.

Table 3. Mitigation and Allocation Strategy Among 8 Dominant Risks

|                                                                                                                                                           |                                  |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|
| 1. Construction Completion Risk                                                                                                                           |                                  |
| a. Handling Plans                                                                                                                                         | : Reducing Risk to a Lower Level |
| b. Risk Categories and Risk Events                                                                                                                        | :                                |
| 1. Bad Performances from Contractors;                                                                                                                     |                                  |
| 2. Failure of Provide Civil Works from Contractor;                                                                                                        |                                  |
| 3. Failing to maintain security and safety during work;                                                                                                   |                                  |
| c. Risk Description                                                                                                                                       | : [Construction Stage]           |
| 1. Contractor is unable to carry out the work according to the contract                                                                                   |                                  |
| 2. Contractor failed to complete the contract due to its internal management & financial factors                                                          |                                  |
| 3. High accident rate during construction                                                                                                                 |                                  |
| d. Risk Mitigation Strategies                                                                                                                             | :                                |
| 1. Apply a Penalty in the process of selecting a credible construction works provider                                                                     |                                  |
| 2. Good application of procedures (K3) with Zero Accident, an experienced and reliable EPC, including a penalty clause for K3 violations in the contract; |                                  |
| 3. Periodic supervision and communication is required from the owner and PJPK representatives for each work progress                                      |                                  |
| 2. Delays Due to Force Majeure Risk                                                                                                                       |                                  |
| a. Handling Plans                                                                                                                                         | : Reducing Risk to a Lower Level |
| b. Risk Categories and Risk Events                                                                                                                        | :                                |
| 1. Natural Disasters                                                                                                                                      |                                  |
| 2. Political <i>Force Majeure</i>                                                                                                                         |                                  |
| 3. Extreme Weather                                                                                                                                        |                                  |
| c. Risk Description                                                                                                                                       | : [All Stages]                   |
| 1. A natural disaster occurred so that the Toll Road could not operate normally.                                                                          |                                  |
| 2. War events, riots, public security disturbances.                                                                                                       |                                  |
| 3. Due to climate change or other factors.                                                                                                                |                                  |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                          |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------|
| d. Risk Mitigation Strategies                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | : Insurance and guarantee                                                |
| e. Specific Conditions                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | :                                                                        |
| What is meant by being shared is that the risk is borne by the Private Sector as long as there is insurance covering these events. The part that is not covered by insurance is taken over by the government. Natural disasters can be in the form of force majeure events such as earthquakes, and others that are national, especially for now that affect is Covid-19 Pandemic.                                                                                                                                                                                                                                                                                                                                                                                          |                                                                          |
| 3. Risiko of Sponsors                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                          |
| a. Handling Plans                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | : Reducing Risk to a Lower Level                                         |
| b. Risk Categories and Risk Events                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | :                                                                        |
| <ol style="list-style-type: none"> <li>1. Private Sector Failure,</li> <li>2. Project's Sponsors Failure,</li> <li>3. Project's Lenders Failure,</li> <li>4. Financial risk leads to failure to achieve financial close</li> <li>5. Risk of late support from the government in the form of (incentives, subsidies, etc.) (Financial Risk)</li> </ol>                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                          |
| c. Risk Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | :                                                                        |
| <ol style="list-style-type: none"> <li>1. Private Sector failure leading to contract termination or step-in by the financier [All Stages].</li> <li>2. Failure of the sponsor (or consortium member) [All stages after financial close].</li> <li>3. Failure on the part of financial/banking institutions (or syndications) due to changes in policy/trust towards BU or due to internal lender issues [All Stages after financial close],</li> <li>4. Financial close was not achieved due to the non-optimal project capital structure and uncertain market conditions [Pre-Construction Stage]</li> <li>5. Construction and/or project operations are disrupted due to government support not being on time as promised [Construction &amp; Operation Stage]</li> </ol> |                                                                          |
| d. Risk Mitigation Strategies                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | :                                                                        |
| <ol style="list-style-type: none"> <li>1. The consortium is supported by credible and solid sponsors.</li> <li>2. Pre-qualification process is carried out to get a credible sponsor.</li> <li>3. Selection of lenders according to credible requirements so that Private Sector can carry out the contract,</li> <li>4. Coordination and consortium with potential and qualified lenders with good credibility.</li> <li>5. Ensure timely fund budgeting process; The government ensures that the tender process runs according to schedule, including the implementation of tenders before the budget is set (conditional auction); Providing bailout funds managed by the Public Service Agency Unit</li> </ol>                                                          |                                                                          |
| e. Specific Conditions                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | :                                                                        |
| Could be the precedent conditions are not met the criteria                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                          |
| 4. Maintenance Risk                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                          |
| a. Handling Plans                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | : Corrective steps or changes are needed within a certain period of time |
| b. Risk Categories and Risk Events                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | :                                                                        |
| <ol style="list-style-type: none"> <li>1. Increase in O&amp;M Costs,</li> <li>2. Error Estimating the business plan or financial cycle</li> <li>3. Project Management Failure</li> </ol>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                          |
| c. Risk Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | : [Operation Stage]                                                      |
| <ol style="list-style-type: none"> <li>1. Due to an error in the estimation of O&amp;M costs or other unexpected increase in costs.</li> <li>2. Failure to obtain fixed and current prices from suppliers, causing errors in cost estimation.</li> <li>3. Private Sectors's failure or inability to manage the operation of the PPP Projects.</li> </ol>                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                          |
| d. Risk Mitigation Strategies                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | :                                                                        |
| <ol style="list-style-type: none"> <li>1. Choosing a reliable Toll Road Operator; considering the escalation factor in the contract.</li> <li>2. Carry out agreements or contracts as early as possible with <i>suppliers</i></li> <li>3. Prepare operational management plans that are carried out professionally</li> </ol>                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                          |
| e. Specific Conditions                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | :                                                                        |
| Asset maintenance is becoming more frequent than planned.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                          |
| 5. Risk of Hidden Defects                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                          |
| a. Handling Plans                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | : Corrective steps or changes are needed within a certain period of time |
| b. Risk Categories and Risk Events                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | :                                                                        |
| Failure in Project Control and Monitoring                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                          |
| c. Risk Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | : [All Stages]                                                           |
| Business Entities and/or PJPKs fail to carry out supervision, causing undetected work irregularities                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                          |
| d. Risk Mitigation Strategies                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | :                                                                        |
| Develop a monitoring plan and periodic evaluation of the effectiveness of planning and implementation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                          |
| 6. Risk of Demands that Lower than Estimation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                          |
| a. Handling Plans                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | : Reducing Risk to a Lower Level                                         |

- b. Risk Categories and Risk Events :
  1. Changes in traffic volume projection
  2. Error in demands estimation,
  3. Risks in the early stages of operational stages.
- c. Risk Description :
  1. Resulting in debt loans due to a decrease in income for the Business Entity[Operation Stage].
  2. Model design error resulting in estimation deviation [Operation Stage].
  3. Lack of cash flow at the beginning of the operation resulted in the project being financially viable but not bankable [Operation Stage]
- d. Risk Mitigation Strategies :
  1. Loans of funds or debts at the beginning of operations.
  2. Good traffic survey; Experienced Toll Road modeling consultant
  3. If the risk is allocated to the Government, a certain amount of funds can be provided if the income at the beginning of the operation is not sufficient
  4. Insuring risks or guarantees proposed by BU to the government through PT PII
- e. Specific Conditions :
 

For risks triggered by government actions (political policies and policy changes), guaranteeing a minimum demand can be considered at the beginning of the collaboration.

#### 7. Risk of Toll Road Tariff Didn't Go as Planned

- a. Handling Plans : Reducing Risk to a Lower Level
- b. Risk Categories and Risk Events :
  1. Failure to apply for periodic tariff adjustments
  2. Periodic delays in tariff adjustments
  3. Tariff adjustment rate is lower than planned
  4. Tariff estimation error
- c. Risk Description : [Operation Stage]
  1. As a result of BUJT not being able to meet the minimum service standard according to the PUPR Ministerial Regulation No. 15 of 2014
  2. Determination of the inflation rate on the indexation of rates so as to cause differences if there is a change, especially after indexation and tariff determination.
  3. Tariff estimation that is too optimistic or exceeds the results of the ATP/WTP survey.
- d. Risk Mitigation Strategies :
  1. Good Toll Road operation performance;
  2. Ensure regulatory support that regulates the level and period of periodic tariff adjustments.
  3. Reliable traffic survey
  4. Experienced Toll Road fare modeling consultant.
- e. Specific Conditions :
 

Can consider minimum demand guarantee if there is an action triggered by the Government Supporting regulations from BPJT

#### 8. Risk of Development Network

- a. Handling Plans : Reducing Risk to a Lower Level
- b. Risk Categories and Risk Events :
 

Road and transportation network connectivity risks
- c. Risk Description : [Operation Stage]
 

Government or Developer failed to build and maintain the necessary infrastructure connectivity
- d. Risk Mitigation Strategies :
  1. Good construction synchronization and contract understanding by the Government
  2. Private Sector plays an active role in developing networks in the form of connectivity and regional development

## 4. CONCLUSION

Based on the results of the analysis of 27 risks, it is obtained if Monte Carlo Simulation could show only 26 risks are influential to the investment cost and can estimate a risk value which is around Rp 16,424,331,645,796. The 26 risks were then classified into risk categories as shown in Table 1 which based on the Pareto principle resulted in 8 dominant risks. The focus of the mitigation strategy and allocation was carried out to reduce the 8 risks to a low category so as the risk value decreased became Rp6,538,704,509,178 or reduce the value of the risk amount to 60% of the initial risk.

This study can be a focus for both the government and the private sector to conduct studies and focus strategies of allocation and mitigation on the dominant risks that occurred in PPP Project. So it can provide good

benefits and a clear formulation of agreements for each party in carrying out PPP projects so that it is expected to increase the participation of the private sector in infrastructure development in Indonesia.

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# ANALYSIS OF THE USE OF ERGONOMIC TROLLEY ON MUSCULOSKELETAL COMPLAINTS ON WORKER TRANSPORTING GALLONS OF WATER AND LPG 12 KG

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**Abstract.** The need for drinking water and gas in the family is very urgent. Every day humans definitely need to drink and eat. Each family will also use gas for cooking purposes. Many companies that sell drinking water and LPG gas now produce in quite large sizes, such as 19 liter gallons of water and 12 kg LPG gas cylinders. The weight of gallons of water and LPG cylinders will make it difficult for humans/workers to lift and transport them. The 12kg LPG cylinder in full gas condition weighs 27 kg. The sizes of gallons of water and LPG gas cylinders have similar dimensions. If the family has difficulty in lifting and transporting gallon water or LPG gas cylinders, they will ask workers for help to lift them. Lifting and transporting these heavy gallons of water and LPG gas cylinders will cause muscle complaints and even muscle injury for workers, especially if they do the same job many times a day. Workers will also get tired quickly and productivity will be low. For this reason, research is carried out by making a tool in the form of a trolley which is ergonomically designed to provide solutions to these problems. This research was conducted experimentally using the one short study method and with the same subject to determine the decrease in muscle complaints and worker fatigue. The sample [of the study was 10 workers. Muscle complaints were predicted with the Nordic Body Map questionnaire. Meanwhile, fatigue was predicted using a 30-item fatigue questionnaire in general. The results of the study stated that the trolley design was in accordance with the worker's anthropometry with a width of 70 cm, a height of 140 cm and a weight of 60 kg which could be moved using wheels. Muscle complaints decreased by 24.9% and fatigue in general decreased by 41.0%.

*Keywords : trolley, musculoskeletal disorders, fatigue*

## 1. INTRODUCTION

Doing lifting and carrying heavy loads will cause muscle injury and fatigue very quickly. The work of lifting 19 liter gallons of water and lifting 12 kg LPG gas cylinders is one of the heavy lifting jobs that is carried out repeatedly in a day. Muscle injuries that occur are usually in the neck, shoulders, wrists, arms, and waist. This work will feel more difficult if the lift and haul trip is quite far or on a multi-storey house. In addition to requiring a large amount of energy, it takes quite a long time, and will quickly reduce our productivity.

The main problems of the work process using muscles and working time are long enough to cause an increase in musculoskeletal complaints and fatigue and an increase in workload which in turn reduces work productivity, increases fuel costs and longer working time. Research conducted by Adiputra, N [1] stated that ergonomic intervention in small industries by using ergonomic work tools will significantly reduce the workload and subjective complaints and will ultimately increase work productivity. Alternative problem solving using an ergonomic approach is the design of ergonomic work tools that are expected to reduce musculoskeletal complaints and fatigue levels, so as to increase worker productivity.

Lifting and transporting that is not in accordance with human capabilities and abilities is an ergonomic problem that must be given a solution. one solution is to design a trolley as a tool to lift and transport gallon water and LPG gas. the design of this trolley needs to follow ergonomic principles such as having to match the anthropometry of workers [2][3], easy to use [4], and inexpensive in design [5].

## 2. METHODS

### 2.1. Research Design

This type of research is a one-short case study with a pre and post-test design group. This research was conducted with an experimental design on the working process of the gallon lifter and LPG gas [6][7]. Chart can be described as follows:

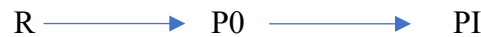


Figure1. Research Design

Information:

R = Random sample.

P0 = manual process.

PI = Process with Trolley.

### 2.2 Research Variable

The variables to be measured in this study include: (1). musculoskeletal disorders before and after work was predicted by Nordic body map questionnaire; (2) work fatigue after work by filling out the 30 fatigues rating questionnaire. The initial condition information data and the final condition were then compared to find out the comparison before using the trolley by manual lifting.

### 2.3 Data Analysis

The trolley design data is calculated based on the routine work activities of workers when lifting gallons of water or LPG gas to. Test data before the use of the trolley and after the use of the trolley includes data on musculoskeletal complaints and data on worker fatigue and working time which will then be analyzed descriptively to obtain conclusions.

## 3. RESULTS AND DISCUSSION

### 3.1 Lifting Gallons And Lpg Gas Manually

Based on the results of interviews with workers lifting and transporting Aqua gallons and 12 Kg LPG gas, they work for 8 hours, from 08.00 WITA to 17.00 WITA with 1 hour rest time. With an average lifting distance of up to 800 meters to lift an average of 150 gallons, either to stalls/shops or to consumers' homes and there are also some consumers who live on the 2nd floor, so they have to climb up to 46 stairs for a 4-storey house. 2 by carrying 8 gallons. From this work, the labor market often complains of pain in the wrist and waist

To overcome this problem, workers are advised to use a trolley as a work aid. The use of this trolley is quite easy, safe and comfortable. By positioning the trolley standing and workers can put 2 gallons of water or LPG gas. Furthermore, the gallon of water or LPG gas is tied up for safety, after that it is laid down to be pulled with light power to the consumer.



Figure 2 Craftsman Work Posture

When working, the use of muscles that receive static loads repeatedly over a long period of time can cause complaints in the form of damage to joints, tendons, and ligaments. These complaints are usually referred

to as injuries to the musculoskeletal system or musculoskeletal disorders (MSDs) [2][8]. Based on recommendations from the Occupational Safety and Health Administration (OSHA), ergonomic measures to prevent disease sources are in two ways, namely engineering through the design of work stations and tools and management engineering through work criteria and organization [9][10][11].

### 3.2 Trolley Design Model

An effort to create a safe and comfortable working condition, it is necessary to have good interaction from the three components mentioned above, namely humans, machines, and the work environment. In ergonomics, humans are the most important component that must be considered with all the limitations it has. In other words, the demands of work tasks should not be too low (underload) and should not be too excessive (overload) because both will cause stress [12]. A good design can be produced by recognizing the characteristics, limitations, and abilities of humans. Humans play a central role in their activities, namely as planners, designers, implementers, and evaluators in every activity (work). Humans as a source of labor are still dominant in carrying out the production process, especially activities that are repetitive. Ergonomically designed equipment needs to be carried out based on ergonomic principles.

Stone tools such as trolleys should be designed to be easy and practical to use. Basically, in making this tool, it aims to simplify the work process of the workers. The product of this trolley design is expected to improve the health and work effectiveness of the workers themselves.

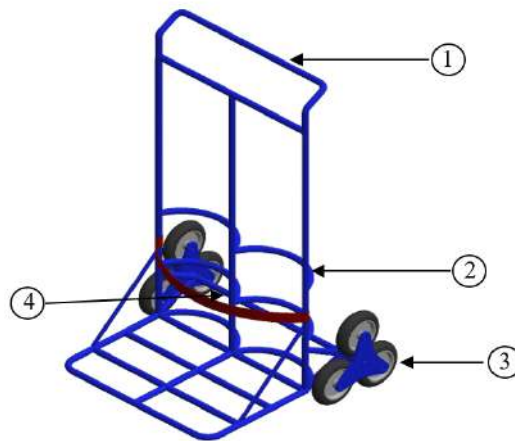


Figure 3 Trolley Design

Information:

- 1. Iron Pipe
- 2. Iron Strip

- 3. Trolley Tires
- 4. Axle

### 3.3 The Result Of Ergonomics Test Using Trolley

#### a. Musculoskeletal complaint

Every human being works, regardless of the type of work done, the muscles of the body will definitely contract and relax alternately [10][13]. This occurs as a result of the activity of the limbs in maintaining a stable body position, or certain movements in carrying out tasks. The more movements that are contrary to physiological rules are carried out, the more energy is used [2][14]. The more the attitude of the body against the neutral stance of the body the more the muscles work. Likewise, if the body is increasingly fixed in a working position in a certain work position, the longer certain muscle groups will contract. Moreover, if it is done repeatedly, it will result in muscle fatigue [2][15][16]. This form of muscle fatigue is accompanied by a sensation of pain or in the muscles. All of which can be detected in the form of complaints in the muscles. Which type of muscle is affected depends on the severity of the task, and the monotony of the movement.

musculoskeletal disorders data were obtained subjectively by the Nordic body map questionnaire. The data obtained were tested with a normality test. Based on the normality test with Shapiro-Wilk, the results are as shown in Table 1.

Table 1. Measurement Results Of Musculoskeletal Disorder

| Descriptions        | Everage difference musculoskeletal disorder |                    | t     | p    |
|---------------------|---------------------------------------------|--------------------|-------|------|
|                     | Mean                                        | Standard deviation |       |      |
| Manual process      | 44,02                                       | 2,56               | 6,578 | 0,00 |
| Process with trolly | 33,04                                       | 4,17               |       |      |

#### b. Fatigue

Each individual provides different fatigue conditions. This fatigue condition will lead to reduced efficiency and ability, and work productivity. There are two kinds of fatigue, namely muscle fatigue and general fatigue. Muscle fatigue occurs due to symptoms of pain when muscles are under excessive tension, whereas fatigue is generally characterized by a reduced sense of readiness to use energy. Fatigue in general can be seen from symptoms of psychological changes in the form of sluggish motor and breathing activity, feeling sick, heavy eyeballs, weak and decreased motivation, decreased physical and mental activity.[2]. Fatigue can start from very light to very tired. This subjective fatigue usually occurs at the end of working hours, when the workload has exceeded 30-40% of the worker's maximum aerobic power.[2], [9][17].

Table 3. Work Productivity Of Craftsmen In The Roasted Grated Coconut Process

| Description    | Mean   | SD   | t     | p     |
|----------------|--------|------|-------|-------|
| Manual process | 159.69 | 2.17 | 0,157 | 0,000 |
| Trolly process | 94.21  | 3.22 |       |       |

This study is in line with other researchers who state that ergonomics aids can reduce muscle complaints, work fatigue, and even increase work productivity [18]–[20].

#### 4. CONCLUSION .

Based on the results and discussion, the conclusions of the study are as follows:

1. Work postures of workers who have to rely on the waist and wrist muscles cause musculoskeletal complaints and increased fatigue complaints due to monotonous or repetitive work attitudes and can even cause work accidents.
2. The dimensions of the trolley design are: 70 cm wide and 140 cm high with a weight of 60 kg, quite simple to move
3. The results of the analysis of musculoskeletal complaints and fatigue in general are:
  - a. The mean of manual musculoskeletal complaints of workers was 44.02 ( $\pm 2.56$ ) and the mean of musculoskeletal complaints using a trolley was 33.04 ( $\pm 4.17$ ) or a decrease of 24.9%
  - b. The average manual fatigue was 152.69 ( $\pm 2.17$ ) and the trolley fatigue average was 94.21 ( $\pm 3.22$ ) or decreased by 41.0%.

#### 5. ACKNOWLEDGEMENT

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# THE EFFECT OF SODIUM HYDROXIDE ABSORBENT ON THE EXHAUST EMISSIONS FROM INTERNAL COMBUSTION ENGINE

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**Abstract.** Exhaust emissions are the residue from burning fuel which can cause air pollution. To overcome this problem, it is necessary to design a system for reducing exhaust emissions of internal combustion engine. This study aims to determine the effect of absorbent concentration on the exhaust emission from internal combustion engine. The research was carried out in 2 stages, namely designing a system for reducing exhaust emissions from internal combustion engines and processing exhaust emissions by channeling exhaust emissions into an exhaust emission reduction system. The internal combustion engine used pertalite. The exhaust emissions consisted of CO, CO<sub>2</sub> and HC. The absorbent concentrations were 0.05 M, 0.1 M and 0.15 M. The engine speeds were 800, 1000, 1500 and 2000 rpm. The paired-t test showed that the exhaust emission reduction system in this study can reduce exhaust emission. The one-way Anova test resulted the absorbent concentration affect the exhaust gas emissions, both CO, CO<sub>2</sub> and HC which are expressed in the efficiency of reducing exhaust emission.. The greatest efficiency in reducing exhaust emission is CO<sub>2</sub> of 67.95%. The lowest efficiency of reducing exhaust emission is CO, which is 46.92%, while the efficiency of reducing HC emission is 62.47%.

**Keywords :** *exhaust emission, emission reduction system, internal combustion engine, engine speed, absorbent.*

## 1. INTRODUCTION

An internal combustion engine is a machine that converts heat energy released by burning fuel in the engine cylinder [1]. Combustion of fuel produces a combination of chemical energy, heat energy and exhaust gases [2]. The internal combustion engine has 4 cycles consists of the intake cycle, compression cycle, combustion cycle and exhaust cycle [1]. Exhaust gas pollutants consist of nitrogen oxide compounds (NO<sub>x</sub>), water (H<sub>2</sub>O), CO gas (carbon monoxide), CO<sub>2</sub> gas (carbon dioxide) which is a greenhouse gas, hydrocarbon compounds (HC) in the form of hydrates of charcoal as imperfections in the combustion process as well as loose particles [3]. These exhaust emissions can cause health problems and respiratory tract diseases as well as acid rain and even air pollution.

Research on the design of the suction device has been carried out by several previous researchers. The design used ejector mechanism [4] and double filters system [5]. Another researches used dual type wet scrubber technology [6], chemical absorbent [3], [7], [8]. Exhaust gas reduction researches included CO<sub>2</sub> capturing from the flue gases [9] and conversion of CO<sub>2</sub> into useful chemical [10]. One of the technologies used in the absorption of exhaust emissions is the wet scrubber technology. Wet scrubber technology is used to describe a tool to remove pollutants using liquid [6]. Over the past decade, wet scrubbing techniques have been widely used to reduce SO<sub>x</sub>, NO<sub>x</sub>, and other pollutants including CO and CO<sub>2</sub> together [10]. In the wet scrubber technique, the flue gas flow is flowed with the scrubbing fluid through a spraying process, where the scrubbing fluid is sprayed in the opposite direction to the flue gas flow. Some of the exhaust emissions that enter the suction chamber can be neutralized or absorbed by the absorbent. Water is the most widely used absorbent in the industrial world [7]. The use of chemical absorbents is based on an acid-base neutralization reaction. In addition, some absorbents

also act as oxidants [8].

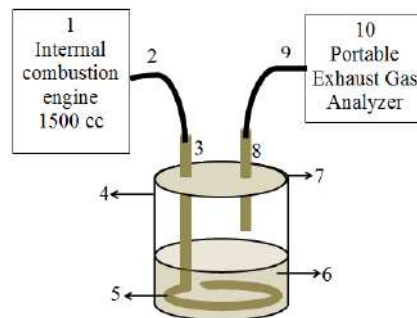
In the wet scrubber technique, the liquids used as absorbents include potassium hydroxide (KOH), sodium hydroxide (NaOH), magnesium hydroxide (Mg(OH)<sub>2</sub>) [6], monoethanol amine (MEA) [9], calcium hydroxide (Ca(OH)<sub>2</sub>), hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>), potassium permanganate (KMnO<sub>4</sub>), calcium hypochlorite (Ca(ClO)<sub>2</sub>) and sodium hypochlorite (NaClO) [8]. The choice of absorbent is based on its ease of use, high absorption efficiency, low cost and appropriate technology.

## 2. METHODS

This research is an experimental laboratory research which consists of two stages. The first stage is to create a system for reducing exhaust emissions from internal combustion engines. The second stage is to process the exhaust gas from the internal combustion engine by channeling exhaust emissions into the exhaust emission reduction system.

### 2.1 Experimental Set up

The reduction system in this study used internal combustion engine. The engine speeds were 800, 1000, 1500 and 2000 rpm. The absorbent solution in this study was a NaOH solution 0.05 M, 0.1 M and 0.15 M with a volume of 5 liters. NaOH solution is made by dissolving solid NaOH in 1 liter of distilled water and then diluting it to a volume of 5 liters. NaOH required at a concentration of 0.05 M is 10 grams while at a concentration of 0.1 M it takes 20 grams of NaOH and at a concentration of 0.15 M as much as 30 grams. The experimental set up is visualized in Figure 1.



Description:

- |                               |                          |
|-------------------------------|--------------------------|
| 1. Internal combustion engine | 6. Absorbent solution    |
| 2. Anti-burn connecting hose  | 7. Reactor tube lid      |
| 3. Inlet pipe                 | 8. Outlet pipe           |
| 4. Reactor tube               | 9. Probe hose            |
| 5. Reactor pipe               | 10. Exhaust gas analyzer |

Figure 1. Experimental set up

### 2.2 Data Analysis

Data was collected based on the measurement of exhaust emission before and after entering the exhaust emission reduction system. The measured exhaust emissions included CO, CO<sub>2</sub> and HC. Measurements were carried out 3 times each and then the average was calculated. Data Analysis used paired-t test [13] and one way Anova test [14].

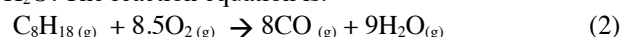
## 3. RESULTS AND DISCUSSION

### 3.1 Reduction of Exhaust Emission

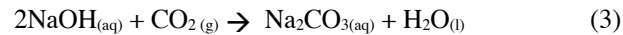
The fuel of internal combustion in this study was pertalite with an octane number of 90 [11], [12]. The main content of pertalite is a hydrocarbon compound consisting of 90% isooctane (2,2,4-trimethylpentane) and 10% n-heptane). The main contents depend on the octane number because the octane number is the same as the percentage of isooctane in fuel and the rest is n-heptane [15]. In the internal combustion engine, gasoline (C<sub>8</sub>H<sub>18</sub>) combustion will produce CO<sub>2</sub>, H<sub>2</sub>O and energy [16]. The reaction equation for complete combustion is:



In inadequate supply of air, CO and H<sub>2</sub>O. The reaction equation is:



CO<sub>2</sub> is a product of combustion and they are exhaust gas that can cause air pollution These pollutants can be reduced by adding absorbent in the reduction system of exhaust emission. NaOH solution will react with exhaust gases, especially CO<sub>2</sub> to produce sodium carbonate (Na<sub>2</sub>CO<sub>3</sub>) and H<sub>2</sub>O [6] with the reaction equation 3.



The design of the internal combustion engine exhaust emission reduction system is shown in Figure 2.



Figure 2. Reduction system of Internal combustion Engine Exhaust Emission

Figure 2 visualizes the reduction system of internal combustion engine exhaust emission. Combustion of fuel produces a combination of chemical energy, heat energy and exhaust gas [2]. Exhaust gas from the muffler of the internal combustion engine is connected to the anti-combustion hose and flowed to the reactor tube pipe through the inlet pipe. In the reactor tube there is a circular reactor pipe with small holes as showed in Figure 3.



Figure 3. Reactor pipe

The flue gas flowing through the reactor pipe then it is flowed into the reactor tube through small holes in the reactor pipe so the flue gas can react with the absorbent solution. The reacted exhaust gas then flowed through the outlet pipe and measured with an exhaust gas analyzer.

Measurement of CO emissions are expressed in volume percent (% Volume) and stated in Table 1.

Table 1. CO emission

| Engine speed (rpm) | NaOH (M) | CO Emission (%V) |                 |
|--------------------|----------|------------------|-----------------|
|                    |          | Before treatment | After treatment |
| 800                | 0.05     | 6.27             | 4.08            |
|                    | 0.10     | 7.21             | 3.41            |
|                    | 0.15     | 7.23             | 2.31            |
| 1000               | 0.05     | 6.55             | 2.47            |
|                    | 0.10     | 6.61             | 2.87            |
|                    | 0.15     | 6.63             | 1.54            |
| 1500               | 0.05     | 5.65             | 2.81            |
|                    | 0.10     | 5.71             | 2.42            |
|                    | 0.15     | 6.18             | 2.74            |
| 2000               | 0.05     | 4.15             | 3.43            |
|                    | 0.10     | 4.15             | 3.32            |
|                    | 0.15     | 4.15             | 3.70            |

Table 1 shows that CO emissions decrease after entering reduction system. The analysis results of the paired-t test using microsoft excel 2010 program shows that t-calc of CO is 6.43. This t-calc of CO is greater than the value of t-table = 1.80, so it can be concluded that there is an effect of reducing exhaust gas emissions from internal combustion engines on the quality of CO. Then, Table 1 is described in Figure 4.

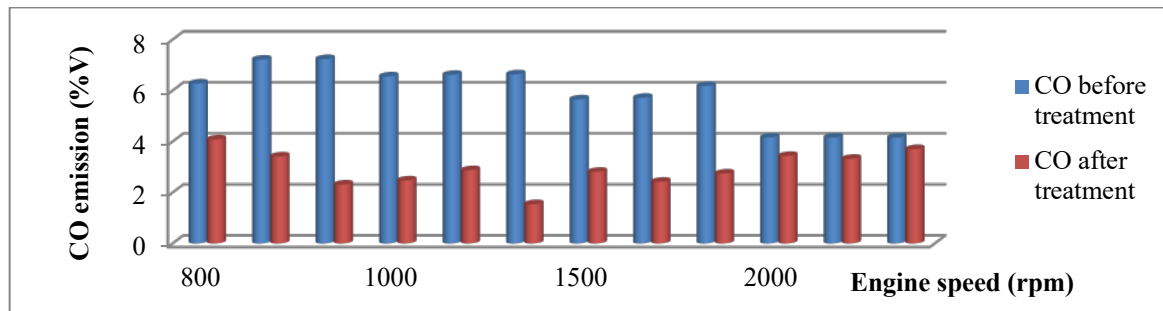


Figure 4. CO emission

Based on Figure 4, the CO emissions after entering the emission reduction system decrease with increasing absorbent concentration. First column in 800 rpm is CO with 0.05 M NaOH solution. Second column for 0.1 M NaOH solution and third column for 0.15 M NaOH solution. This visualization also applies for 1000 to 2000 rpm. This emission reduction indicates that the emission measurement results is lower than before entering the reduction system. A significant CO emission decrease in pertalite occurred in the 800 rpm which is characterized by lower CO emissions with increasing absorbent concentration. At engine speed of 1000 rpm to 2000 rpm CO emission reduction is fluctuating with increasing NaOH concentration.

CO is created from partially burned fuel due to incomplete combustion or due to lack of air. The CO released from the rest of the combustion products is much influenced by the ratio of the fuel and air mixture that is too rich (lack of air) that is sucked in by the engine, to reduce CO the ratio of this mixture must be made lean, but this method has another side effect, namely  $\text{NO}_x$  will arise more easily [17]. CO is very dangerous because it has no color or smell, causing dizziness, nausea.

$\text{CO}_2$  emissions are expressed in volume percent (% Volume) and indicate the results of combustion in the engine.  $\text{CO}_2$  emissions are stated in Table 2.

Table 2.  $\text{CO}_2$  emission

| Engine speed (rpm) | NaOH (M) | $\text{CO}_2$ Emission (%V) |                 |
|--------------------|----------|-----------------------------|-----------------|
|                    |          | Before treatment            | After treatment |
| 800                | 0.05     | 8.33                        | 1.77            |
|                    | 0.10     | 6.37                        | 1.43            |
|                    | 0.15     | 7.63                        | 0.70            |
| 1000               | 0.05     | 8.43                        | 1.70            |
|                    | 0.10     | 8.47                        | 0.87            |
|                    | 0.15     | 7.93                        | 0.40            |
| 1500               | 0.05     | 9.67                        | 5.23            |
|                    | 0.10     | 9.30                        | 2.83            |
|                    | 0.15     | 9.10                        | 4.07            |
| 2000               | 0.05     | 8.37                        | 5.87            |
|                    | 0.10     | 8.37                        | 3.07            |
|                    | 0.15     | 8.37                        | 5.03            |

$\text{CO}_2$  emissions also decrease after entering the reduction system. The results of the analysis of the paired-t test using microsoft excel 2010 program show that t-calc of  $\text{CO}_2$  is 11.89 and this t-calc is greater than the value of t-table = 1.80 so it can be concluded that there is an effect of reducing exhaust gas emissions from internal combustion engines on the quality of  $\text{CO}_2$ . Table 2 can be described in Figure 5.

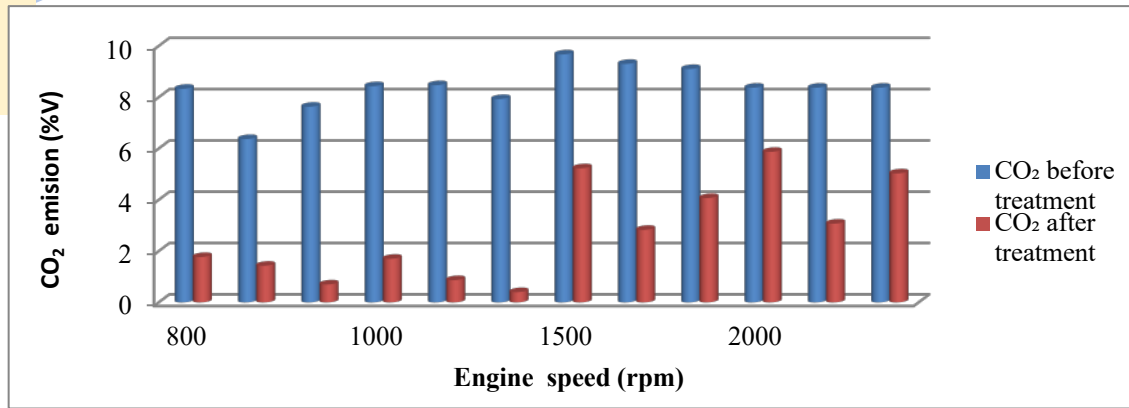
Figure 5. CO<sub>2</sub> Emission

Figure 5 shows CO<sub>2</sub> gas emissions. The results showed that there was a large reduction in CO<sub>2</sub> emissions after entering the exhaust emission reduction system. Three column in each engine speed visualizes CO<sub>2</sub> emission with 3 types of absorbent concentrations, they are 0.05 M, 0.1 M and 0.15 M NaOH solution. The higher absorbent concentration causes a very significant decrease in engine speed of 800 rpm and 1000 rpm, while at engine speed of 1500 rpm and 2000 rpm the emission reduction is fluctuating with increasing absorbent concentrations. CO<sub>2</sub> emissions after entering the exhaust emission reduction system increase with increasing engine speed. This is caused by the higher engine speed lead the combustion process increases so CO<sub>2</sub> emissions also increase. CO<sub>2</sub> emissions also come from burning CO so the emissions increase.

HC is expressed in ppm (parts per million). HC emissions indicate the remaining gasoline in the exhaust. The results of measuring exhaust emissions before and after entering the reduction system with pentalite fuel are stated in Table 3.

Table 3. HC emission

| Engine speed (rpm) | NaOH (M) | HC Emission (ppm)) |                 |
|--------------------|----------|--------------------|-----------------|
|                    |          | Before treatment   | After treatment |
| 800                | 0.05     | 515.67             | 243.67          |
|                    | 0.10     | 526                | 221             |
|                    | 0.15     | 493.67             | 148.67          |
| 1000               | 0.05     | 356.33             | 119.67          |
|                    | 0.10     | 377.33             | 150.67          |
|                    | 0.15     | 373.33             | 91.67           |
| 1500               | 0.05     | 256                | 105.33          |
|                    | 0.10     | 265.67             | 104.67          |
|                    | 0.15     | 285.33             | 118             |
| 2000               | 0.05     | 654.33             | 304.33          |
|                    | 0.10     | 654.33             | 223.67          |
|                    | 0.15     | 654.33             | 198.33          |

Table 3 shows that HC emissions decrease after entering the reduction system. The results of the analysis of the paired-t test using microsoft excel 2010 program shows that t-calc of HC is 6.69. this t-calc of HC is greater than the value of t-table = 1.80, so it can be concluded that there is an effect of reducing exhaust gas emissions from internal combustion engines on the quality of HC. Then, Table 3 is described in Figure 6.

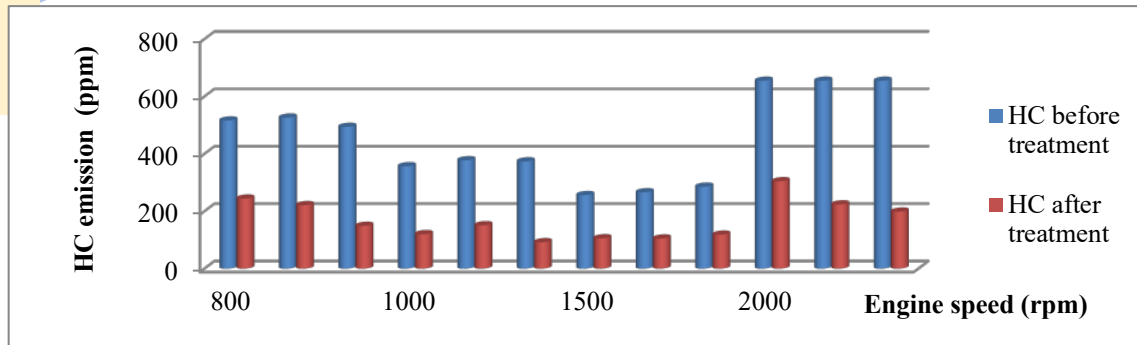


Figure 6. HC Emission

Based on Figure 6, HC emissions also show a decrease in emissions after entering the exhaust emission reduction system. First column in 800 is 0.05 M NaOH solution. Second column for 0.1 M NaOH solution and third column for 0.15 M NaOH solution. This visualization also applies for 1000 to 2000 rpm. The significant decrease in HC emission with increasing NaOH concentration occurred at engine speed of 800 and 2000. While at 1000 rpm it was fluctuating and at 1500 rpm the emission reduction tended to be stable with increasing NaOH concentration. HC emission occurs because the fuel has not been burned but has been wasted along with the exhaust gases due to incomplete combustion and evaporation of fuel. HC are divided into two, namely unburned fuel so that it comes out as raw gas, and fuel that is split due to a hot reaction turning into other HC that come out with exhaust gases [17].

The effect of absorbent concentration to reduce exhaust emission in this study can be tested by one-way Anova test. One-way Anova test analysis was carried out using the Microsoft Excel 2010 program [14]. The results of the one-way Anova test showed that  $F_{\text{calc}} > F_{\text{table}}$  so it can be concluded that the NaOH absorbent affects the exhaust gas emissions of both CO, CO<sub>2</sub> and HC. The results of the one-way Anova test are stated in Table 4.

Table 4. The results of CO, CO<sub>2</sub> and HC one-way Anova test

| No | Exhaust Gas Emission | F-calc | F-table |
|----|----------------------|--------|---------|
| 1  | CO                   | 57.82  | 4.30    |
| 2  | CO <sub>2</sub>      | 86.94  | 4.30    |
| 3  | HC                   | 34.24  | 4.30    |

The effect of absorbent concentration can be efficiency of the exhaust emission reducing device as shown in Table 5.

Table 5. The efficiency of CO, CO<sub>2</sub> and HC

| Engine speed (rpm) | NaOH (M) | CO efficiency (%) | CO <sub>2</sub> efficiency (%) | HC efficiency (%) |
|--------------------|----------|-------------------|--------------------------------|-------------------|
| 800                | 0.05     | 34.93             | 78.75                          | 52.75             |
|                    | 0.10     | 52.70             | 77.55                          | 57.98             |
|                    | 0.15     | 68.05             | 90.83                          | 69.88             |
| 1000               | 0.05     | 62.29             | 79.83                          | 66.42             |
|                    | 0.10     | 56.58             | 89.73                          | 60.07             |
|                    | 0.15     | 76.77             | 94.96                          | 75.45             |
| 1500               | 0.05     | 50.27             | 45.92                          | 58.86             |
|                    | 0.10     | 57.62             | 69.57                          | 60.6              |
|                    | 0.15     | 55.66             | 55.27                          | 58.64             |
| 2000               | 0.05     | 17.35             | 29.87                          | 53.49             |
|                    | 0.10     | 20                | 63.32                          | 65.82             |
|                    | 0.15     | 10.84             | 39.90                          | 69.69             |
| sum                |          | 563.10            | 815.50                         | 749.60            |
| average            |          | 46.92             | 67.96                          | 62.47             |

Based on Table 5 the efficiency of exhaust emissions is between 10.77% (CO at 2000 rpm with NaOH 0.15 M) to 94.95% (CO<sub>2</sub> at 1000 rpm with NaOH 0.15 M). CO emission at 2000 rpm is the lowest emission and it indicates partially burned fuel due to incomplete combustion or due to lack of air [17]. The highest CO<sub>2</sub> efficiency indicates almost all carbon dioxide reacted with sodium hydroxide so the CO<sub>2</sub> emission after entering reduction system is the lowest. HC efficiencies are more than 50% and indicates hydrocarbon emission that come from unburned fuel or fuel evaporation [17]. These results are then depicted in Figure 7.

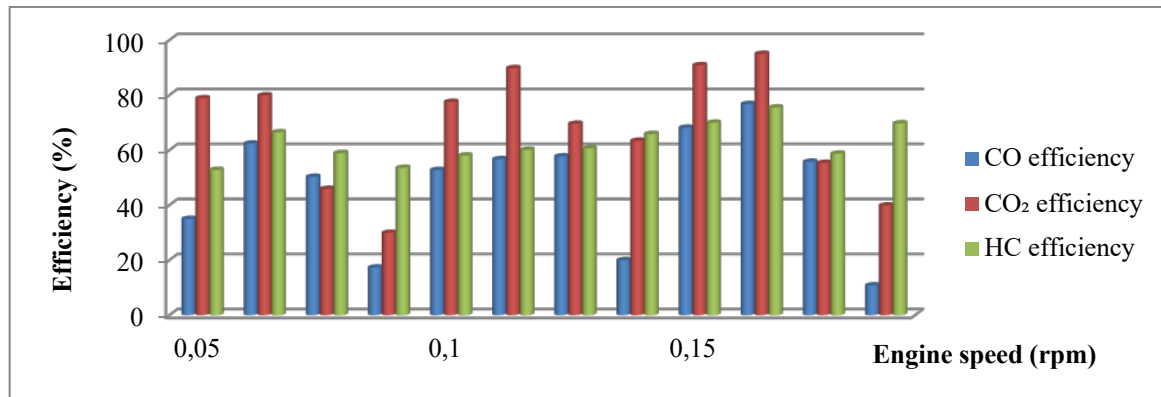


Figure 7. The efficiency of exhaust gas emission

Figure 7 shows that the exhaust emission reduction system of the internal combustion engine in this study can reduce exhaust emissions in various ways. The highest average efficiency of reducing exhaust emissions is indicated by the efficiency of reducing CO<sub>2</sub> emissions, which is 67.95%. The smallest reducing of exhaust emission efficiency is shown by the CO with emission reducing efficiency of 46.92% while the HC emission reducing efficiency is 62.47%. The greater the efficiency of reducing exhaust emissions can indicate the better quality of the exhaust emissions so that the air quality is also getting better because the number of pollutants is reduced.

#### 4. CONCLUSION

Reduction system of internal combustion engine exhaust emission with NaOH absorbent in this study can reduce exhaust emissions of internal combustion engines. The concentration of absorbent affects the quality of the emission. In this study, the greater concentration of the absorbent, the efficiency of reducing exhaust gas emissions also tends to be greater. although there are some fluctuating emissions, there is still a decrease in emissions. The highest average efficiency of reducing exhaust emissions is shown by the efficiency of reducing CO<sub>2</sub> emissions, which is 67.95%. The smallest efficiency of reducing exhaust emission is shown by the CO reducing emission efficiency of 46.92% while the efficiency of HC reducing emission is 62.47%. If the efficiency of reducing exhaust emissions is greater, so the exhaust emissions quality is better. It means the air quality is also getting better because the number of pollutants is reduced..

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## THE EFFECT OF CURRENT AND LAYER IN BIMETALLIC WELDING USING J4-AH36 FILLER ON TENSILE STRENGTH

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**Abstract.** If filler metal AH36 steel is used in bimetallic welding, it has the disadvantage of oxidation in the weld area. Also, the weld crack is encountered if filler metal J4 stainless steel is used in bimetallic welding. In this research, welding methods include the preparation of two types of base metal and a twisted combined filler of AH34 steel and J4 stainless steel as a filler rod applied. The welding of 5 mm thick bimetallic material uses the GTAW (Gas Tungsten Arc Welding) or TIG (Tungsten Inert Gas) process with a current electric welding 60 A, 70 A, and 80 A, one layer and two layers, and angle position 90° to 75°. Preparation of tensile test specimens, provision of shallow notches in the weld where the cross-sectional area of the same as the two-parent metals that have been welded together, tensile testing, and analysis of research data are conducted. The welding results using a current of 60 A with one layer showed a tensile strength of 402 MPa. However, welding with two layers decreased to 200 MPa with a difference of 50 % that means there is a significant difference. In the current of 70 A with one layer, the tensile strength is 433 MPa and with two layers, the value decreases very little at 426 MPa with a difference of 2 %, which means there is a minimal difference and makes the best current selection. For current 80 A with one layer produces tensile strength of 412 MPa. Yet, with two layers, the value decreases slightly to 380 MPa with a difference of 8 %, which means there is a relatively small difference.

*Keywords: TIG Welding, GTAW, Combined Filler, AH34 Steel, J4 Stainless Steel, Tensile Strength, Layer.*

### 1. INTRODUCTION

The obstacle in bimetallic welding is the selection of filler rods that cause cracks or oxidation in the weld area. AH36 steel filler has the disadvantage of oxidation in the weld area for bimetallic steel and stainless steel welding. On the other hand, J4 stainless steel filler may become cracked, which should be avoided. The microstructure of carbon steel and stainless steel interface shows three types: a weakened ferritic layer, a ferritic layer, and austenitic steel dark layer [1]. The microstructure of the weld transforms gradually from ferritic to austenitic. Bimetallic welding defects are influenced by the type of electrode of the filler wire and the electrode coating material [2]. Wire and electrode coating significantly affect the results of bimetallic welding. The L415/316L mechanically coated bimetallic pipe is welded using an internal post-welding process to reduce costs and improve weld quality. The outer carbon layer is welded before the inner bimetallic stainless steel layer [3]. Welding of stainless steel bimetallic pipes is carried out after the outer part is coated with carbon as a composite pipe. Lighter materials are used with a combination of steel and aluminum by welding to achieve maximum benefits to reduce the car's weight [4]. Efforts to reduce vehicle weight are obtained by using lighter materials by welding to get fuel savings.

The joint behavior between AISI 304L stainless steel and copper plate by continuous-wave fiber laser welding at a maximum joint efficiency of 99% achieves a tensile strength of 224 MPa focused on the butt line [5]. The welding between AISI 304L and copper plate by continuous-wave fiber laser welding can achieve maximum joint efficiency. Butt welding on L415/316L bimetallic pipe is carried out by post-internal welding process with two sides of the most suitable groove is L415 V shape 60°, 1 mm blunt edge and 316L stripped 6 to 8 mm [6]. Particular weld joint grooves can provide the best weld results. Bimetallic welding between 2205 duplex stainless

steel and X65 pipe sheet steel, multi-layer, and multi-pass is performed by GTAW [7]. Bimetallic welding has been performed well on 2205 duplex stainless steel and X65 sheet steel pipe, which shows the in-homogeneity of the properties of the welded joint.

An explosive welding process fabricated a circular bimetallic pipe then reshaped it into a square tube by a shape-rolling process. It showed that the micro-crack propagation was accelerated during the shape-rolling process, and the number of micro-cracks was increased, which resulted in a decrease in shear strength [8]. The shear strength decreases due to the shape rolling process because the micro-crack propagation is accelerated, and the number of microcracks is increased. Carbon migration is formed in the soft zone near the interface of SA 516 grade 65 and the weld, and a hard zone forms near the interface of the weld and SUS 304L. The temperature should not be too high and can also be prevented by increasing the thickness of the carbon layer on carbon steel to stop carbon migration [9]. The interfacial zone temperature is not too high to prevent carbon migration.

Explosive welding is used in cladding aluminum plates on ship protective cover plates at different explosive ratios. The results show that the waves at the interface increase with increasing explosive ratio and parallel with their wavelength and amplitude [10]. Explosive welding of aluminum plate cladding on ship steel plates at different volatile ratios produces other waves at the interface. Galvanized steel (EX280) with a thickness of 2 mm was welded to aluminium 5754 with a thickness of 3 mm by MIG welding-brazing resulting in better tensile strength with AlSi<sub>3</sub>Mn filler wire of an average of 188 MPa than with AlSi<sub>5</sub>, and AlSi<sub>12</sub> filler wire [11]. Different filler wires produce different tensile strengths in a bimetallic weld.

Laser hybrid welding with butt joints in stainless steel (304SS) and T2 copper achieves a tensile strength of 215 MPa or equivalent to 200-240 MPa of T2 copper [13]. Butt-joint laser hybrid welding of 304SS and T2 copper provides tensile strength comparable to that of T2 copper. Nd: YAG continuous-wave laser welding of H62 brass and 316L stainless steel with overlapping configuration improves performance [14]. Continuous-wave laser welding on H62 brass and 316L stainless steel shows better performance in the overlap configuration.

Stainless steel and copper laser welds exhibit some micro-cracks generated in the fusion zone due to thermal stress mismatch corrected by molten copper filling. The amount of fused copper must be limited during welding and excess smelting of copper leads to liquid separation and the formation of micro-cracks within the fusion zone [15]. Copper smelting should be limited to prevent micro-cracks within the fusion zone. The bonded CP-Ti/Q345 bimetallic sheet filled with Cu/V solid wire experienced severe cracking which could be reduced by the use of Cu-V flux core wire [16]. Flux wire suitable for bimetallic welded materials can reduce weld cracking.

## 2. METHODS

Bimetallic welding research uses the base metal material in AH36 steel, J4 stainless steel with a combined filler rod between ER304 electrode for J-4 stainless steel electrode and ER50-60 electrode for AH36 steel is twisted together as a joint welding wire.

The research procedure was carried out by:

- 1) Preparation of welding plate. The plates consist of AH36 steel and J4 stainless steel with a size of 100 mm x 100 mm x 5 mm to be later cut into 5 for tensile test specimens.
- 2) Welding wire of both types is the same material with the diameter of 0.8 mm was purchased directly from the trade.
- 3) Making V grooves for welding joints with a milling machine with an angle of 30° for one side of the AH36 steel plate and 30° for the stainless steel plate.
- 4) Preparation of welding by adjusting the distance between two-parent metals with different types of materials, a certain distance (2.5 mm) remains along the weld seam groove with locking.
- 5) Welding of 2 base metals using a combined filler rod of ER50-60 and ER304. Welding wire has been twisted into a filler rod at currents of 60A, 70A, and 80A for one layer and two layers, respectively.
- 6) Cleaning the welds to be cut into five pieces of tensile test specimens according to ASTM E8/E8M-90 standards.
- 7) Tensile test.
- 8) Analysis of tensile test results.

The chemical compositions of the AH 36 and J-4 stainless steel plates are shown in Table 1.

Table 1. The composition of AH36 steel and J4 stainless steel [17], [18]

| Material            | C (%)     | Mn (%)     | Si (%)     | P (%)      | S (%)       | N (%)      | Al (%) | Nb (%)       | V (%)      | Ti (%) | Cu (%)   | Cr (%)   | Ni (%)   | Mo (%) |
|---------------------|-----------|------------|------------|------------|-------------|------------|--------|--------------|------------|--------|----------|----------|----------|--------|
| AH 36 Steel         | 0.18      | 0.9 to 1.6 | 0.1 to 0.5 | 0.035      | 0.035       | -          | 0.15   | 0.02 to 0.05 | 0.5 to 0.1 | 0.02   | 0.35     | 0.2      | 0.4      | 0.08   |
| J-4 Stainless steel | 0.1 (max) | 8.5 to 10  | 0.75 (max) | 0.08 (max) | 0.015 (max) | 0.1 to 0.2 | -      | -            | -          | -      | 1.5 to 2 | 15 to 17 | 1 to 1.5 |        |

AH36 steel has a yield strength of 355 MPa and tensile strength of 490 to 620 MPa with a strain of 19% [17] and J4 stainless steel has a yield strength of 300 MPa and tensile strength of 650 MPa with a strain of 40% [18].

The composition of the filler rod was determined using a spectrometer to determine the chemical elements of the metal contained in it from 2 different types of electrode wires of ER50-60 and ER304 which are shown in Table 2.

Table 2. The composition of combined filler rod of AH36 steel and J4 stainless steel [19]

| Material              | C (%)  | Si (%) | Mn (%) | P (%)  | S (%)  | Cr (%) | Mo (%) | Ni (%) | Cu (%) |
|-----------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Combine filler rod of | 0.064  | 0.591  | 5.797  | 0.129  | 0.063  | 7.189  | 0.03   | 1.094  | 0.0746 |
| AH36 steel and        | Al (%) | Co (%) | Mg (%) | Nb (%) | Ti (%) | V (%)  | W (%)  | Fe (%) |        |
| J4 stainless steel    | <0.005 | 0.054  | <0.005 | 0.0099 | 0.0044 | 0.052  | 0.152  | 84.02  |        |

The independent variables consisted of welding current (60 A, 70 A, and 80 A) and layers (1 layer and two layers). In contrast, the dependent variable was tensile strength. The controlled variable was 60° seam grooves, the thickness of the main plate from the two different materials is 5 mm, constant welding speed and angle, and a filler rod J4-AH36 twist.

Tensile strength data is obtained directly from the test results using the Tarno Grocky Universal Testing Machine, equipped with an electronic circuit that can produce a plot of the stress versus strain curve. The plate shape and dimensions of the tensile test specimen according to ASTM E8/E8M-90 are shown in Figure 1.

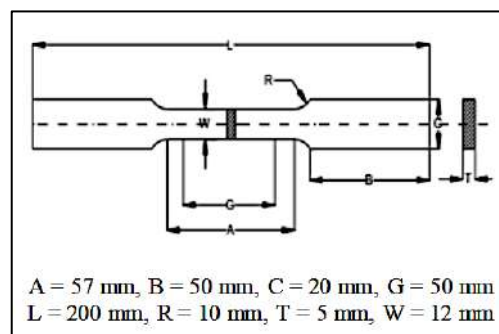


Figure 1. The plate shape and dimensions of the tensile test specimen [17]

Preparation of welded plate material consists of AH36 steel and J4 stainless steel. V-grooves of 30° angle of each specimen are made using a milling machine (a). Bonded with welds determines the distance between the bimetallic before welding (b). Welding using TIG Welding equipment is implemented (c). Cutting and shaping into a standard tensile test specimen size (d). Tensile testing is applied to obtain force and elongation data with a universal Testing Machine (e). Finally, the fracture surface of the broken specimen (f) is shown in Figure 2.

The calculations of the tensile strength,  $\sigma$  is used formula (1), cross-sectional area, A is used Formula (2), and strain,  $\epsilon$  is used Formula (3).

$$\sigma = F/A \quad (1)$$

$$\epsilon = (\Delta L/L_0) \times 100\% \quad (2)$$

$$A = w \times b \quad (3)$$

where:  $\sigma$ : tensile strength (MPa), F: force (N), A: cross-sectional area (mm<sup>2</sup>),  $\epsilon$ : strain (%),  $\Delta L$ : elongation (mm), and  $L_0$ : gauge length (mm).

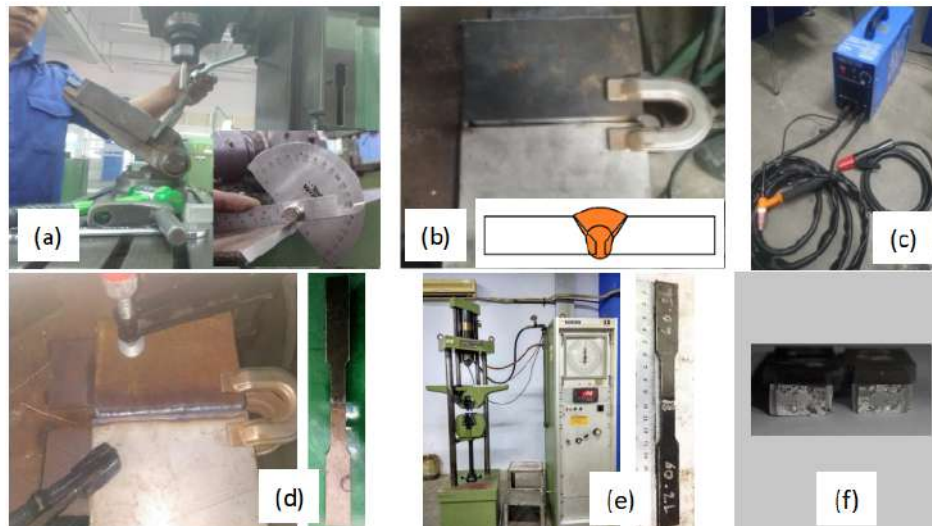


Figure 2. (a) Preparation of welded plate material by making side grooves at a 30° angle with a milling machine, (b) bonded with welds for setting the distance between the bimetallic, (c) welding with TIG Welding equipment, (d) cutting and shaping into a standard tensile test specimen size, (e) tensile testing with a Universal Testing Machine, and (f) the fracture surface of the broken specimen

### 3. RESULTS AND DISCUSSION

The tensile test results on the welded specimens of bimetallic AH36 steel and J4 stainless steel obtained force and elongation data. Force data is used to obtain tensile strength by dividing the force by the original cross-sectional area of the specimen in the gauge length area and for the strain obtained from elongation divided by the gauge length as the actual length of the sample multiplied by 100 % to obtain units in %. The serial data shows that tensile strength and strain can be plotted into stress versus strain curves. An example of stress- strain curve for a specimen welded with a current of 60A with one layer is shown in Figure 3.

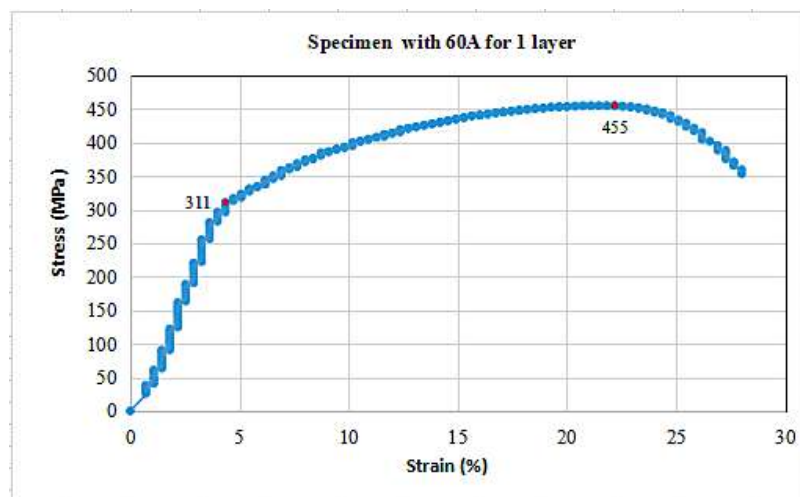


Figure 3. Stress versus strain curve for specimen welded with a current of 60 A with 1 layer

Each welding was repeated five times, which resulted in 5 tensile test data to determine the character of the data to ensure the results so that 30 serial tensile strength and strain data were obtained for three current welding treatments at 60 A, 70 A, and 80 A and the number of layers of 1 layer and two layers. Tensile test results data in the form of tensile strength and strain for current treatments at 60 A, 70 A, and 80 A and the number of layers of one layer and two layers are shown in Table 3.

Table 3. The tensile strength,  $\sigma$  and strain,  $\epsilon$  results data for 60 A, 70 A, and 80 A and 1 layer and 2 layers

| No. | I (A) | Layer | n- | F (kg) | W (mm) | T (mm) | F (N) | $\sigma$ (MPa) | $\Delta L$ (mm) | $L_0$ (mm) | $\epsilon$ (%) |
|-----|-------|-------|----|--------|--------|--------|-------|----------------|-----------------|------------|----------------|
| 1   | 60    | 1     | 1  | 2783   | 12     | 5      | 27294 | 455            | 13              | 50         | 26             |
| 2   |       |       | 2  | 2487   | 12     | 5      | 24393 | 407            | 14              | 50         | 28             |
| 3   |       |       | 3  | 2800   | 12     | 5      | 27455 | 458            | 14              | 50         | 28             |
| 4   |       |       | 4  | 2735   | 12     | 5      | 26819 | 447            | 14              | 50         | 28             |
| 5   |       |       | 5  | 2699   | 12     | 5      | 26464 | 441            | 14              | 50         | 28             |
| 6   |       | 2     | 1  | 1133   | 12     | 5      | 11111 | 185            | 13              | 50         | 26             |
| 7   |       |       | 2  | 1145   | 12     | 5      | 11225 | 187            | 2               | 50         | 4              |
| 8   |       |       | 3  | 1176   | 12     | 5      | 11535 | 192            | 2               | 50         | 4              |
| 9   |       |       | 4  | 1157   | 12     | 5      | 11344 | 189            | 2               | 50         | 4              |
| 10  |       |       | 5  | 1208   | 12     | 5      | 11848 | 197            | 2               | 50         | 4              |
| 11  | 70    | 1     | 1  | 2762   | 12     | 5      | 27084 | 451            | 13              | 50         | 26             |
| 12  |       |       | 2  | 2794   | 12     | 5      | 27404 | 457            | 14              | 50         | 28             |
| 13  |       |       | 3  | 2645   | 12     | 5      | 25941 | 432            | 14              | 50         | 28             |
| 14  |       |       | 4  | 2720   | 12     | 5      | 26678 | 445            | 14              | 50         | 28             |
| 15  |       |       | 5  | 2695   | 12     | 5      | 26425 | 440            | 14              | 50         | 28             |
| 16  |       | 2     | 1  | 2582   | 12     | 5      | 25321 | 422            | 11              | 50         | 22             |
| 17  |       |       | 2  | 2463   | 12     | 5      | 24152 | 403            | 11              | 50         | 22             |
| 18  |       |       | 3  | 2593   | 12     | 5      | 25431 | 424            | 11              | 50         | 22             |
| 19  |       |       | 4  | 2579   | 12     | 5      | 25287 | 421            | 11              | 50         | 22             |
| 20  |       |       | 5  | 2594   | 12     | 5      | 25442 | 424            | 11              | 50         | 22             |
| 21  | 80    | 1     | 1  | 2667   | 12     | 5      | 26156 | 436            | 12              | 50         | 24             |
| 22  |       |       | 2  | 2522   | 12     | 5      | 24732 | 412            | 12              | 50         | 24             |
| 23  |       |       | 3  | 2574   | 12     | 5      | 25240 | 421            | 12              | 50         | 24             |
| 24  |       |       | 4  | 2597   | 12     | 5      | 25466 | 424            | 12              | 50         | 24             |
| 25  |       |       | 5  | 2612   | 12     | 5      | 25617 | 427            | 12              | 50         | 24             |
| 26  |       | 2     | 1  | 2265   | 12     | 5      | 22212 | 370            | 6               | 50         | 12             |
| 27  |       |       | 2  | 2251   | 12     | 5      | 22079 | 368            | 4               | 50         | 8              |
| 28  |       |       | 3  | 2328   | 12     | 5      | 22828 | 380            | 1               | 50         | 2              |
| 29  |       |       | 4  | 2263   | 12     | 5      | 22189 | 370            | 4               | 50         | 8              |
| 30  |       |       | 5  | 2254   | 12     | 5      | 22106 | 368            | 4               | 50         | 8              |

Table 3, compared to the current 60 A, 70 A, and 80 A used in TIG welding for one layer and two layers, shows the tensile strength and replication are shown in Figure 4 to Figure 6. The results of tensile strength and repeat for the current 60 A used in TIG welding for one layer and two layers are shown in Figure 4.

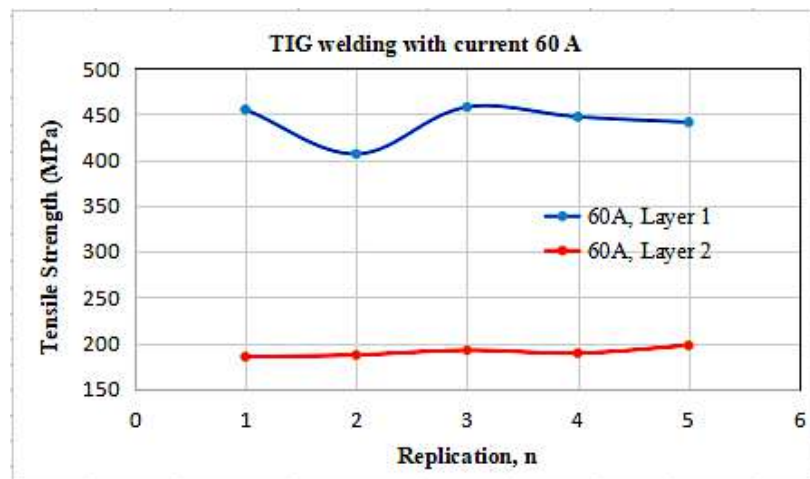


Figure 4. The tensile strength and replication for 60 A used in TIG welding for 1 layer and 2 layers

Figure 4 shows that the tensile strength is at a minimum value of 400 MPa and a maximum of 460 MPa, and the lowest is in the 2nd replication at a welding current of 60 A and one layer. Still, for two layers, it shows a typical tensile strength value of around 195 MPa. This is possible because the current used in TIG welding is too low for a plate thickness of 5 mm in welding bimetallic AH36 steel and J4 stainless steel.

The results of tensile strength and replication for the current 70A used in TIG welding for one layer and two layers are shown in Figure 5.

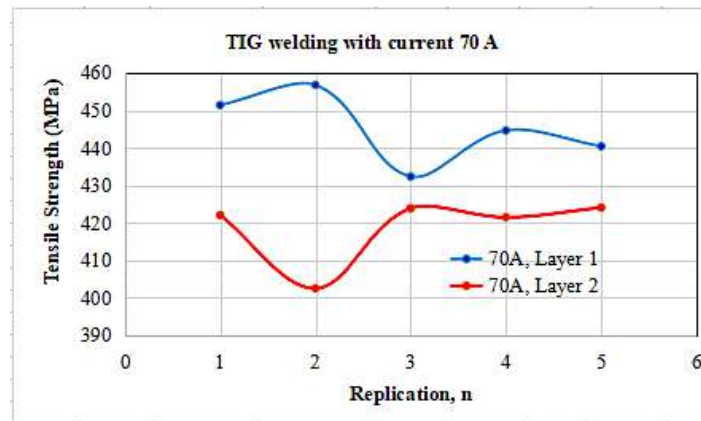


Figure 5. The tensile strength and replication for 70A used in TIG welding for 1 layer and 2 layers

Figure 5 shows that the tensile strength is at a minimum value of 432 MPa and a maximum of 458 MPa, and the lowest is in the 3<sup>rd</sup> replication at a welding current of 70 A and one layer. Still, for two layers, the tensile strength value is a minimum of 402 MPa and a maximum of 424 MPa. This shows that the results are close to the tensile strength results in one layer and two layers, which means that between 1 layer and two layers, the tensile strength results are good with a current of 70 in TIG welding bimetallic welding AH36 steel and J4 stainless steel.

The effects of tensile strength and replication for the current 80A used in TIG welding for one layer and two layers is shown in Figure 6.

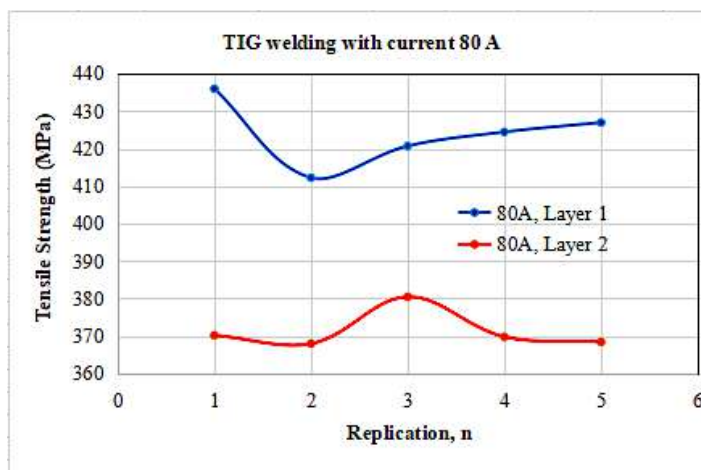


Figure 6. The tensile strength and replication for 80A used in TIG welding for 1 layer and 2 layers

Figure 6 shows that the tensile strength is at a minimum value of 412 MPa and a maximum of 437 MPa, and the lowest is in the 2<sup>nd</sup> replication at a welding current of 80 A and one layer. Still, the minimum tensile strength value for two layers is 369 MPa and a maximum of 380 MPa. This shows that the results are pretty different and lower between the tensile strength results in one layer and two layers, which means that between 1 layer and two layers, the tensile strength results are pretty good with current 80 A in TIG welding bimetallic welding of AH36 steel and J4 stainless steel.

The tensile strength of the parent metal of AH36 steel with a value of 490 MPa is lower than the tensile strength of J4 stainless steel with a weight of 650 MPa. Therefore the tensile strength of the weld with a bimetallic filler rod is compared with a lower value, namely the tensile strength of AH36 steel. Tensile strength is good in one layer and two layers, which results close together. Both of which reach a reasonably high value, namely in welding current 70 A, the highest is 458 MPa, and the lowest is 402 MPa, when compared to the tensile strength of AH36 steel, which is worth 490 MPa, meaning that it has reached tensile strength is about 82%. In contrast, at the current 60 A, it only reaches the lowest of 40 % at the current of 80 A. It resembles a relatively high of 75%.

The welding results using a current of 60 A with one layer showed a tensile strength of 402 MPa. In two layers, the value decreased to 200 MPa with a difference of 50 %. It means there is a significant enough difference. For a current of 70 A with one layer, the tensile strength is 433 MPa, but with two layers, the value decreases very little at 426 MPa with a difference of 2%, which means there is a minimal difference, and for current 80 A with

one layer produces tensile strength of 412 MPa. Still, with two layers, the value decreases slightly to 380 MPa with a difference of 8 %, which means there is a relatively small difference. Selection of the best current of the three TIG welding is at 70 A with a difference in tensile strength for one layer 433 MPa close to two layers 426 MPa or about 2%.

#### 4. CONCLUSION

The conclusions that can be drawn from the study of dissimilar welding of materials from AH36 steel and J4 stainless steel using a combined filler rod of ER304 electrode for J4 stainless steel electrode and ER50-60 electrode for AH36 steel include as follow:

- 1) Welding using a current of 60 A with one layer showed a tensile strength of 402 MPa. Still, with two layers, the value decreased to 200 MPa with a difference of 50 %, which means that there is a significant enough difference.
- 2) Welding using a current of 70 A with one layer, the tensile strength is 433 MPa, but with two layers, the value decreases very little at 426 MPa with a difference of 2 %, which means there is a tiny difference.
- 3) Welding using a current 80 A with one layer produces tensile strength of 412 MPa, but with two layers, the value decreases slightly to 380 MPa with a difference of 8 %, which means a relatively small difference.
- 4) The best current of the three TIG welding is at 70 A with a difference in tensile strength for one layer 433 MPa close to two layers 426 MPa or about 2%.

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# EFFECT SIZE OF MATHEMATICS BLENDED LEARNING DESIGN ON INCREASING MATHEMATICAL PROBLEM-SOLVING ABILITY OF POLYTECHNIC STUDENTS IN THE COVID-19 PANDEMIC PERIOD

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**Abstract.** The purpose of this study was to determine the magnitude of the effect of blended learning design on increasing Mathematics Problem Solving which is the ability of polytechnic education students during the covid 19 pandemic. The study was carried out at the Bali State Polytechnic, using a mastery-experimental approach, using a pre-test post-test design. non-equivalent controls. design group. The subjects of this research are students of mechanical engineering in the year 2020/2021. Sampling was carried out purposively as many as 10 classes and divided into two groups, namely experimental and control. The data were obtained by using a mathematical ability test developed by the researcher himself. Data were analyzed using inferential statistics, namely t-test and N-Gain scores. Problem solving ability data was measured using a validated test, then analyzed using the average difference test and normalized gain. The results of the analysis show that there is a significant difference in effectiveness between the blended learning and full e-learning models. The blended learning model can be stated to be more effective in improving mathematical problem solving abilities compared to full e-learning or online models. The magnitude of the effect is very large on increasing mathematical solving abilities in learning using blended learning. The implication of this research is that the application of an optimal blended learning design in polytechnic education during the covid 19 pandemic makes the learning process more effective and succeeds in improving students' mathematical problem solving abilities.

*Keywords : effect size, blended learning, mathematical problem-solving ability, polytechnics, covid 19.*

## 1. INTRODUCTION

Vocational education is education that prepares students to be able to work using a competency-based approach [1]. In general, the aim is to prepare and produce graduates who have the skills to be able to enter the world of industry, business, and work as well as to continue higher education levels. However, it is preferable to be ready to work, equipped with various knowledge and skills. Vocational education has a very strategic role in handling the workforce and educating them to become skilled, professional, and highly competitive personnel in accordance with 21<sup>st</sup>-century skills. Vocational education must prepare and implement 21<sup>st</sup>-century learning by forming 4C skills, namely: Critical thinking, Communication, Collaboration, and Creativity.

Polytechnic is part of higher vocational education that produces graduates who are competent and able to carry out tasks in the industry well and professionally. Graduates must be able to master the necessary knowledge and skills. For example, a technician or analyst for Maintenance-Repair of Automotive and Industrial Machinery.

In addition, polytechnic graduates are required to be able to work with accuracy, that is, on time, in the right size, and with the right rules. Learning at polytechnic educations must be able to develop students' competence skills so that they are ready to solve various problems in society and at work, so they are ready to enter the world of work in the 21st century. Learning in polytechnic vocational education needs to be packaged in accordance with the development of the learning paradigm in the 21st century and beyond so that it can guarantee job readiness, ability, and career development in accordance with the demands of stakeholders.

Corona Virus Disease 2019 (COVID-19) suddenly appeared in early 2020, causing changes in various aspects of life including education in polytechnics [2], [3]. The polytechnic education system uses a package system with a learning process designed so that graduates are ready to work. The learning process in the field of hard skills is achieved through the application of the concept of learning by doing with the proportion of theoretical material 40% and practice 60%. The learning process should not be stopped and must be sustainable both in theory and practice. The learning has to be held online through e-learning [4]. Lecturers are required to be able to make various innovations in their learning patterns so that the 4C skill development process can continue without being hampered by the COVID-19 pandemic.

At the beginning of 2020, the pandemic of Covid 19 suddenly appeared and had an impact on various aspects of life, including vocational education [2], [3]. The learning process at polytechnics should be able to take place continuously without being limited by space and time, namely by learning through e-learning [3]. Lecturers are required to be able to innovate in preparing learning tools and change the face-to-face learning pattern in the classroom into a fully online learning pattern through e-learning.

E-learning is an educational system that utilizes information technology in the teaching and learning process. Through e-learning, learning can be more flexible with respect to time, place and speed of the process, so that individual students have the opportunity to control their own learning. E-learning, has a minimum level of effectiveness equivalent to face-to-face learning [5]. On the other hand, full online learning is considered less able to accommodate all learning needs [6]. One of them is the difference in the learning styles of each student. Besides that, the interaction between lecturers and students is still limited even between students [7]. This lack of interaction can slow down the formation of values in the learning and teaching process. The communication process between lecturers and students occurs in one direction. On the other hand, learning requires a two-way communication process. or there is feedback between the two parties. Joyce stated that e learning only increases insight and knowledge, if you want to get an increase in skills and attitudes, real face-to-face activities are needed [8]. Bates and Sangra emphasize that the e-learning model really needs direct face-to-face learning to provide feedback from students to instructors/lecturers and vice versa [9]. The combination of online and offline learning or between e-learning and face-to-face can produce effective and efficient learning. Furthermore, Hameed, Badii, & Cullen stated that the e-learning or online model would be more efficient if it was combined with face-to-face or offline learning [10]. To support and complement each other between e-learning and face-to-face learning, a blended learning model can be used.

Blended learning is learning that combines the advantages of face-to-face learning and online learning. This learning model combines the advantages of face-to-face learning in classroom learning and online learning that can be done anywhere and anytime without distance or time limits. Direct face-to-face learning between lecturers and students was a common lesson in our education before the covid 19 pandemic. Students could discuss, exchange opinions or ideas about certain materials, but time constraints resulted in the face-to-face learning process being not optimal. Through e-learning that can be done anywhere and anytime, the previous learning done face-to-face can be resumed in online learning. The learning process can be more optimal.

Blended learning is very in line with the learning style of the millennial generation, and provides opportunities for students to use ICT to search for information based on big data [11]. The application of blended learning for students will encourage an increase in digital literacy and technological literacy. Blended learning is very relevant to 21st century learning [12], can be a solution in overcoming the weaknesses or shortcomings of e-learning [13], [14]. Combining the advantages of the face-to-face learning model (offline) and the e-learning model (online) will have a good influence and are more suitable for the learning process. [15], [16]. The blended learning has proven to be effective in improving the quality of student learning outcomes and has a positive impact on student academic achievement, including improving students' problem solving abilities [17], have positive impacts on student learning outcomes, skills, and everyday attitudes [18], and so can improve students' understanding and thinking skills [19].

Problem solving ability is one of the highest skills and is called higher order thinking, because the results of the solution contain thinking skills, collaboration, communication, and others [20]. This ability is a skill in students, so they are able to use mathematical activities to solve problems in mathematics, problems in other

sciences and problems in everyday life [21]. Problem solving ability has received great attention from researchers in the field of education and is even referred to as a skill that must be mastered in the 21st century [22].

Mathematics is one of the basic science courses that need to be taught at the Polytechnic and is one of the keys in the development of science and technology. Mathematical knowledge and skills are very important in daily life activities and as the basis for the development of science and technology in the world [23]. Mathematics as one of the supporting tools prepares polytechnic students to be able to solve problems in the world of work or everyday life [24]. Mathematics is one of the media in developing student attitudes and skills in polytechnics in the 21st century and beyond.

The problem solving ability faced is an inseparable part of learning mathematics. Skills and abilities in problem solving become an integral part of learning mathematics courses [25], even this method is central in the teaching of mathematics [26]. It should be emphasized that the importance of having mathematical problem solving abilities and skills in students is that they are the goal of teaching mathematics and as the heart of mathematics. [27]. A learning model that is in accordance with the 21st century mathematics learning paradigm is needed, to make it easier for students to achieve these skills. One of the models is schoology-based blended learning.

The implementation of e-learning requires an application, namely a learning management system (LMS). LMS is an application or software used to manage online learning, covering several aspects, namely material, placement, management, and assessment [28]. One of the conditions, educators and students must be connected to an adequate internet network. The features of the LMS to support the online learning process are: discussion forums, learning resource curriculum, quizzes, assignments, types of academic information, and student data management. LMS that can be used in the learning process, including: Schoology, Learnboos, Edmodo, Moodle and others. Schoology in the form of a social web can be used easily by students and lecturers, as well as other social media such as Facebook, Twitter and others. Schoology is an interesting and fun e-learning platform that can be used as a medium for social interaction as well as learning. The advantages of Schoology compared to other LMS include using terms that we usually use on social networks such as Facebook, Moodle, and Edmodo such as recent activity, message, course, resource, groups, assignment, and attendance [29]. Schoology has facilities that Edmodo and Moodle don't have. Another advantage is that attendance figures are available by choosing to be present, permitted, late, or not entering. Every student activity will also be monitored through analytical facilities on course features, assessments, discussions and other activities provided for students. Schoology is also equipped with symbols, equations, and latex. all types of questions that contain pictures, symbols, and equations can be written easily in schoology. Sicit shows that Schoology is effectively used to implement blended learning [30]. Furthermore, Sijinjak, shows that students who are taught using the help of schoology have high learning outcomes compared to conventional learning. Students with visual learning styles who are taught using the help of schoology have the highest learning results compared to other learning styles [31].

Blended learning can be applied in the learning process where the use of online learning resources without leaving teaching and learning activities in the classroom. Online-based technology-supported learning with the help of digital technology. This digital technology assistance will make learning more effective. Through blended learning blended learning students can be trained to master technology and use technology wisely and problem solving skills can be improved. This study aims to determine the effectiveness of the schoology-based blended learning model in improving mathematical problem solving abilities in polytechnic students.

## 2. METHODS

This research is quantitative, aiming to determine the effect of a blended learning model on mathematical problem-solving ability. The study used a quasi-experimental approach, with a pre-test-post-test nonequivalent control group design [32].

Table 1.  
Pre-test-post-test Nonequivalent Control Group Design

| Class      | Pretest        | Treatment      | Posttest       |
|------------|----------------|----------------|----------------|
| Experiment | O <sub>1</sub> | A <sub>1</sub> | O <sub>2</sub> |
| Control    | O <sub>1</sub> | A <sub>2</sub> | O <sub>2</sub> |

Explanation:

O<sub>1</sub> = Pre-test for experimental and control groups

- O<sub>2</sub> = Posttest for the experimental and control groups  
 A<sub>1</sub> = Learning treatment with the blended learning model  
 A<sub>2</sub> = Learning treatment with a full e-learning model

The research was conducted in the field of Engineering at BSP. The population is Engineering students who received applied for mathematics courses in 2020/2021 in as many as 18 classes spread over 6 majors and 15 study programs. Samples were taken purposively in as many as 10 classes and divided into experimental and control groups. The number of members of each group is 130 people. The experimental group was taught using the blended learning model, while the control group was taught using the full e-learning model and both were assisted by the LMS Schoology application media.

The problem-solving ability test has been developed by the researcher himself. The data obtained from this test have been tested for the level of validity and reliability. The level of validity is at 0.31-0.89. The reliability of the instrument is 0.97 and can be said to be reliable. The difficulty level is at 0.41 with a discriminating power index of 0.25-0.75. Before further testing, the normality of the data was tested using the Kolmogorov Smirnov test.

Learning effectiveness is predicted based on the percentage of N-Gain score. The level of learning effectiveness using the categories from [33] in Table 2

Table 2.

Category Effectiveness of N-Gain Score Interpretation

| Percent (%) | Interpretation  |
|-------------|-----------------|
| < 40        | ineffective     |
| 40 < g < 55 | less effective  |
| 56 < g < 75 | quite effective |
| > 76        | effective       |

Source: [33]

Meanwhile, the effect size of design blended learning increasing problem-solving abilities is seen from the results of the effect size test with the formula developed by Cohen d in [34] as follows.

$$d = \frac{M_2 - M_1}{\sqrt{\frac{SD_1^2 + SD_2^2}{2}}} \quad (1)$$

Information:

- d = effect size  
 M<sub>1</sub> = Average pretest score  
 M<sub>2</sub> = Average posttest score  
 SD<sub>1</sub> = pretest standard deviation  
 SD<sub>2</sub> = posttest standard deviation

The results of the effect size calculation are interpreted according to the classification developed by Cohen in Table 3 below.

Table 3.  
 Cohen's Benchmarks for Interpreting Effect-Size Estimates

| Mean difference effect sizes ( d ) | Benchmarks    |
|------------------------------------|---------------|
| 0.00 – 0.19                        | Insignificant |
| 0.20 – 0.49                        | Small         |
| 0.50 – 0.79                        | Medium        |
| > 0.8                              | Large         |

Source: Cohen ' s in [34]

### 3. RESULTS AND DISCUSSION

Descriptive analysis showed that the average pretest of the mathematical problem-solving ability of the two groups was 43.9 and 43.5, both categorized as low. Both groups had the same initial ability. The post-average mathematical problem-solving ability in the group taught using the blended learning model was 79.8, while in the

group taught using the e-learning model it was 74.6 both categorized as high. The average student achievement in the blended learning group was higher than in the e-learning group.

The results of the normality test of the experimental group's pretest and post-test data showed the Kolmogorov-Smirnov statistical value showed 0.059 and 0.051 both with sig.  $0.200 > 0.05$ . The control group showed 0.052 and 0.043 both with sig.  $0.200 > 0.05$ . The pretest and posttest data in both groups were normally distributed.

Paired t-test results showed that the correlation between pretest and post-test in the experimental group was 0.73 which was categorized as positive, very strong, and significant. This means that the correlation between abilities before and after the learning process is positive and very strong and real. While in the control group the correlation between pretest and posttest was 0.43 with positive, strong, and significant categories.

The results of the t-test in the experimental group get at-value of -267.1 with sig. Two-tailed 0.00 is less than 0.05. The ability before and after the learning process is significantly different. Meanwhile, for the control group, t is -176.9 with sig. Two-tailed 0.00 is less than 0.05. Problem-solving ability before and after the learning process is significantly different.

Significantly the blended learning model can improve mathematical problem-solving skills. Furthermore, the percentage of the pretest and posttest N-gain scores in the experimental group was at least 46.1% and a maximum of 75.4%. The average N-Gain score between the pretest and posttest was 63.6%, categorized as quite effective. Meanwhile, in the control group, the n-gain pretest score with a minimum posttest of 41.5%, a maximum of 68.3%, and an average of 54.89% were categorized as less effective. The blended learning model with the Schoology application is quite effective in improving mathematical problem-solving abilities. The results of the average difference test of N-Gain score (%) show a t-value of 13.67 with a probability (sig.2-tailed) of 0.000, meaning that the t-value is significant. The average achievement of the N-Gain score in the control group (54.89%) was lower than the achievement in the experimental class (63.6%). There is a significant effectiveness difference between the use of the blended learning model and the full e-learning model in improving the mathematical problem-solving abilities of polytechnic students. The learning process using the full e-learning model can significantly improve mathematical problem-solving abilities, but its effectiveness is lower than the blended learning model, as evidenced by the pretest and posttest that are categorized as positive and significant but the correlation is weak. The blended learning model is more effective in improving mathematical problem-solving abilities than the full e-learning model. The blended learning model is more effective in improving mathematical problem-solving abilities than the full e-learning model. The results of the effect size analysis (d) of blended learning design on increasing mathematical problem-solving abilities show the d value of  $1.7 > 0.8$  which is categorized as very large [12]. The implementation of blended learning design in learning has a very large effect on increasing mathematical problem-solving abilities.

The findings of this study support the results of previous studies: 1) research by [35], blended learning is effective in increasing the value of attitudes and responses to media variations, 2) recommendations for the results of 'Namyssova's research, increasing the effectiveness of college lectures can be improved. start by applying a blended learning model [36], 3) Adi and Fathono, blended learning is effective and efficient for use in sports schools [37], 4) Deivam, and Devaki, blended learning is more effective than conventional teaching methods [38], and 4) Paudel, e-learning can be an alternative means of face-to-face learning during Covid-19, but the application of the blended learning approach to the learning process will be more effective and successful [39].

The research findings support Stein and Graham's theory that blended learning as a solution to overcome the learning gap is currently more focused on face-to-face learning or only online learning [40]. Blended learning can encourage skills, foster creative attitudes to carry out learning activities independently, activities do not depend on teachers or lecturers, provide convenience and build creative and innovative attitudes in carrying out learning activities. Blended learning is very appropriate to be applied in the conditions of the covid-19 pandemic, especially in polytechnic education.

Blended learning is a student-centered learning process. Groups of students who are taught using Blended learning are very likely to be actively involved in learning. Students not only get a learning experience when accompanied by lecturers in class and outside the classroom but also get a wider learning experience independently. When studying in class, they get learning materials and learning experiences in the form of orientation, exercises and feedback, examples, and direct motivation from the lecturer. Furthermore, when studying online they will be able to control their own learning time, can study anywhere, anytime, and are not tied to the lecturer. They can also study independently or interact easily with lecturers and fellow students and have access to various online learning resources that can be obtained using their gadgets and applications. The variety of learning objects is more complete, which can be in the form of electronic books or electronic articles, simulations, animations, augmented reality), virtual reality, learning videos, or other multimedia that can be

accessed online [11]. Students become increasingly motivated to learn and seek information from various online and print sources. Increased motivation to learn and students become very active in looking for supporting materials from various sources, in turn, their learning outcomes also increase.

The learning process is the interaction of students, lecturers, and learning resources. The process is not only limited to providing information from lecturers to students but through reciprocal communication between the two parties. In the process of reciprocal communication, students have the opportunity to be actively involved in learning both mentally, intellectually, emotionally, and physically to be able to seek and find knowledge, attitudes, and skills. In the group of students who are taught to use the full e-learning model, there are limited interactions between lecturers and students, even between students [7]. This lack of interaction can slow down the formation of values in the learning process. The communication process between lecturers and students occurs in one direction. Learning requires a two-way communication process or there is feedback between the two parties. The learning process tends towards training rather than education. Students who do not have high learning motivation and willingness to learn independently tend to fail. The success of e-learning is highly dependent on the willingness of students to learn independently [41]. The further impact on those who are taught full e-learning is that there is an impression of loneliness which encourages boredom and boredom in the learning process, and learning motivation tends to decrease [13]. In the end, it affects the achievement of learning outcomes. Those who are taught using full e-learning get lower learning outcomes compared to those who are taught using blended learning.

Blended learning is learning that combines the best aspects of face-to-face learning with the advantages of online learning. The learning process integrates ICT, combining various methods of delivery, teaching models, learning styles, and various variations of technology-based media. The implementation begins with a learning orientation to prepare face-to-face and online scheduling through clear instructions such as learning materials and assignments that must be done every week and is also equipped with online and face-to-face learning directions. Online using the Schoology model LMS application. The task content in learning includes the making of a structured and systematic project, namely the order of the topics is hierarchically related to the topic of the previous project, there is an increase in the scope of material that must be understood by students, to encourage students to think at a higher level. There is enrichment in each project task that combines online and face-to-face learning, and online and face-to-face group discussions with critical thinking elements such as making assumptions and drawing conclusions. Group discussions can be held virtually via video conference using the Zoom cloud meeting application or discussion forum on the group's menu at Schoology. Group discussion activities can encourage increased ability to collaborate, work in teams, and communicate in the classroom and outside the classroom. In doing project assignments, students can innovate and be creative and use technology to produce a quality product. Learning resources or teaching materials are accessed online through learning links such as YouTube and other sites. While working on problem-solving-oriented project assignments, students are encouraged not only to build higher-order thinking skills, collaborate, innovate and be creative, but are also encouraged to develop communication, problem-solving, technology literacy, and data literacy skills. The application of the blended learning model in polytechnic education can help students achieve 21<sup>st</sup>-century skills. In line with Sahim, the blended learning model can improve the performance of vocational education students and produce more effective learning [42].

The application of blended learning with the Schoology application makes it possible for learning interactions to occur anywhere and anytime. Learning resources have been packaged electronically and are available to be accessed by students via the internet, so they can interact with these learning resources anytime and from anywhere. The tasks of learning activities that have been completed can be submitted to the instructor/lecturer via submission or re-submission assignment on the assignment menu. Students are not tightly bound by the time and place of learning activities as is the case with face-to-face learning. The implementation of blended learning using Schoology can provide security and comfort for students, as well as lecturers in carrying out learning activities during the covid 19 pandemic. Blended learning, can reduce mass gathering activities as one of the health protocols to avoid contracting covid-19. However, blended learning remains oriented towards achieving learning outcomes, namely increasing knowledge, skills, and attitudes. Online learning can increase insight and knowledge, and face-to-face learning can improve skills, especially in specific materials where skills are not automatically obtained from increasing knowledge. The application of the blended learning model assisted by the Schoology application in polytechnic education during the Covid-19 pandemic was quite effective in improving mathematical problem-solving abilities. The implication is that the blended learning model assisted by the application of Schoology can be used as an innovative strategy in learning mathematics for vocational education, especially polytechnics.

#### 4. CONCLUSION

There is a significant difference between the average mathematical problem solving ability of students taught using the blended learning model and being taught using the full e-learning model. The blended learning model is more effective in improving mathematical problem solving abilities than the full e learning model. The effect size is very large on increasing mathematical solving abilities in learning using blended learning based on schoology. The implication is that the optimal application of the blended learning model in polytechnic education during the covid 19 pandemic, the learning process becomes more effective and succeeds in improving students' mathematical problem solving abilities.

## 5. ACKNOWLEDGEMENT

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# IMPLEMENTATION OF INVERSE KINEMATIC AND TRAJECTORY PLANNING ON 6-DOF ROBOTIC ARM FOR STRAIGHT-FLAT WELDING MOVEMENT

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**Abstract.** Robotic arms have been used in various processes such as for moving goods, welding, assembling, and painting. In the case of welding and painting, it is necessary to move the end-effector robot accurately and smoothly to follow the specified trajectory. In robotic arm control, 2 things are important to be analyzed and implemented in controlling the motion of the robotic arm, namely inverse kinematic and trajectory planning. In this study, the inverse kinematic and trajectory planning algorithms are implemented to the robotic arm controller in the form of an Arduino Mega 2560 microcontroller. The inverse kinematic solution uses geometric and algebraic analytical methods. while the trajectory planning method is using LSPB (Linear Segment Parabolic Blend) Trajectory in Cartesian Space. Data retrieval is done by giving 2 input coordinates of the desired position and orientation, then the data in the form of the joint angle value will be measured using a rotary encoder as an angle sensor. Furthermore, the joint angle measurement value is converted in cartesian coordinates to get the end-effector position. Data analysis is done by comparing the data value of each joint angle with the calculated value so that the error value appears. The results showed that the inverse kinematic and trajectory planning algorithms were successfully applied to the 6-DOF robotic arm to perform straight-flat welding movements. Inverse kinematic testing on both input coordinates, the average error value for joints 2, 3, and 5 is 1.82°, 1.26°, and 2.08°. Meanwhile, the average error of the end-effector position at the x and z coordinates is 2.08 mm and 12.9 mm, respectively. Then for the trajectory planning test, the error value for the end-effector position in the x and z coordinates is 2.25 mm and 10.7 mm.

*Keywords : inverse kinematic, trajectory planning, robotic arm, DOF, welding movement.*

## 1. INTRODUCTION

In the era of the industrial revolution 4.0, many manufacturing industries have implemented several cutting-edge technologies. One technology that is gaining popularity in the manufacturing industry is a robotic arm manipulator. The use of this technology is because today's industry wants to further increase effectiveness and productivity. The increase in effectiveness and productivity is because the robotic arm can increase speed and accuracy [1]. In addition, a robot can replace jobs that were previously difficult and dangerous to become easier and safer [2]. This technology in the form of robotic arms has been used in various industrial processes, such as moving goods, cutting, casting, welding, painting, assembling, and others.

In the case of applying robots for certain purposes such as welding, and painting, it is necessary to move the end-effector robot accurately and smoothly to follow the specified trajectory [3]. In this study, a robot motion control will be discussed to perform a simple straight welding movement in the flat position. 2 things are

important to be analyzed and implemented in controlling the motion of the Robotic Arm. The two things are inverse kinematic and trajectory planning. From the design process to the experiment it is important to analyze the kinematic solution and plan the trajectory of the robot [4]. In robotics, inverse kinematic is an equation to find joint parameters with known the desired position and orientation of the end-effector [5]. While the trajectory is a specification of the position of the robot in a function of time and the trajectory should be quite smooth in a function of time [6]. By applying a combination of the inverse kinematic and trajectory planning algorithm, it can produce an accurate and smooth of the robotic arm movement.

There are previous studies that have been used as literature studies, such as the inverse kinematic solution on the 6 Degrees of Freedom (DOF) robotic arm analytically using algebraic and geometric methods [7-9]. Then some studies discuss trajectory planning methods such as the LSPB trajectory method [10], [11], and polynomial trajectory [12], [13]. Several studies have also implemented inverse kinematic and trajectory planning methods on robotic arms. Such as research on the application of inverse kinematic and fuzzy logic on a 4-DOF robotic arm for pick and place purposes [14], the application of inverse kinematic on a 3-DOF robotic arm [15], research on the application of inverse kinematic and trajectory planning on a 5 DOF Scorbot robotic arm based on simulation using Matlab software [16], and research on controlling 4 DOF robots uses Cartesian-space trajectory planning [17]. However, some of the above application studies are still applied to small-scale robots and for purposes other than welding.

By looking at previous studies, in this study, the inverse kinematic and trajectory planning algorithms are applied in a 6 DOF robotic arm motion control to perform simple welding movements in the form of a straight line.

## 2. METHODS

This research is experimental and applied research by implementing the inverse kinematic algorithm and trajectory planning to the 6-DOF robotic arm controller as a control for straight-flat welding motion. The Robotic Arm controller in this study is the Arduino Mega 2560.

### 2.1 System Implementation

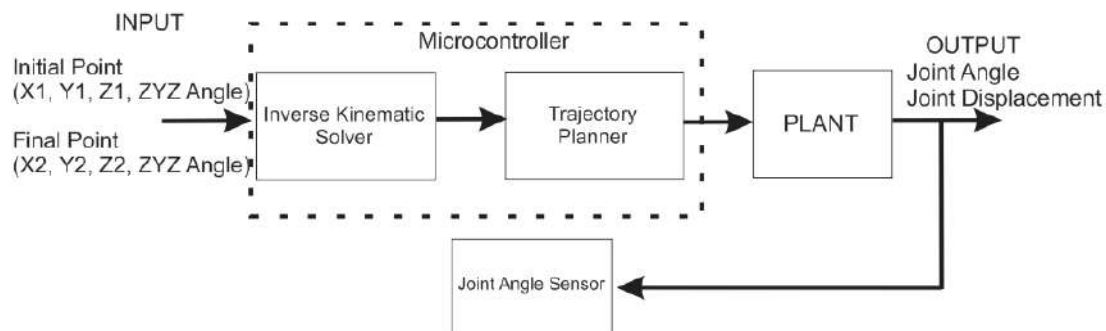


Figure 1. Implementation System Diagram

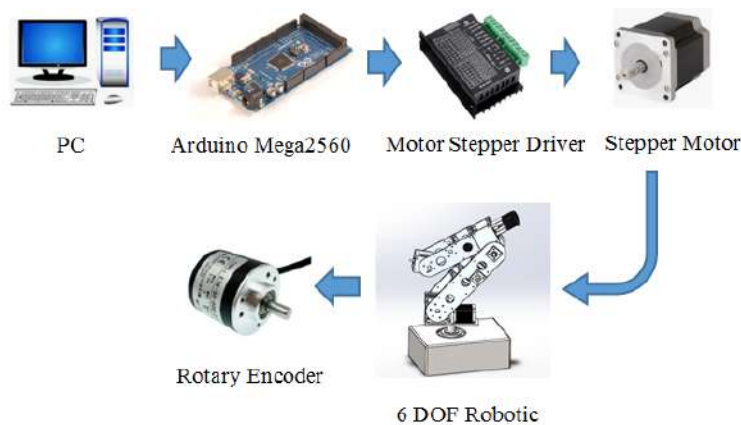


Figure 2. Hardware Implementation

The implemented system in Figure 1 is an open-loop system without any feedback from sensors. The way this implementation system works is that initially 2 input coordinate points are given along with the desired

orientation,  $(x_1, y_1, z_1, \text{zyz angle } 1)$  and  $(x_2, y_2, z_2, \text{zyz angle } 1)$ . Then with the inverse kinematic algorithm, the microcontroller will calculate the angle value at each joint for the two positions. Then the trajectory planning algorithm will calculate how much the joint angle changes each time it changes. Then the calculation is converted by the microcontroller into a digital control voltage signal sent by the stepper motor driver. Furthermore, the motor driver will send voltage to the stepper motor. Finally, the stepper motor converts the voltage signal into rotation which can finally rotate the joint robot mechanism. To monitor the joint angle of the robotic arm, a rotary encoder has been installed on each robot joint as an angle sensor. The movement of the end-effector robot is expected to gently traverse a straight line between the 2 input coordinates to perform straight welding. Full Hardware Implementation diagram is shown in Figure 2.

## 2.2 Robot Specification

In this study, a robotic arm that has 6 DOF has been designed using a stepper motor as the actuator. Each stepper motor is connected to a worm gear mechanism and a timing belt as shown in Figure 3b. The kinematic structure model of the robotic arm is shown in Figure 3a.

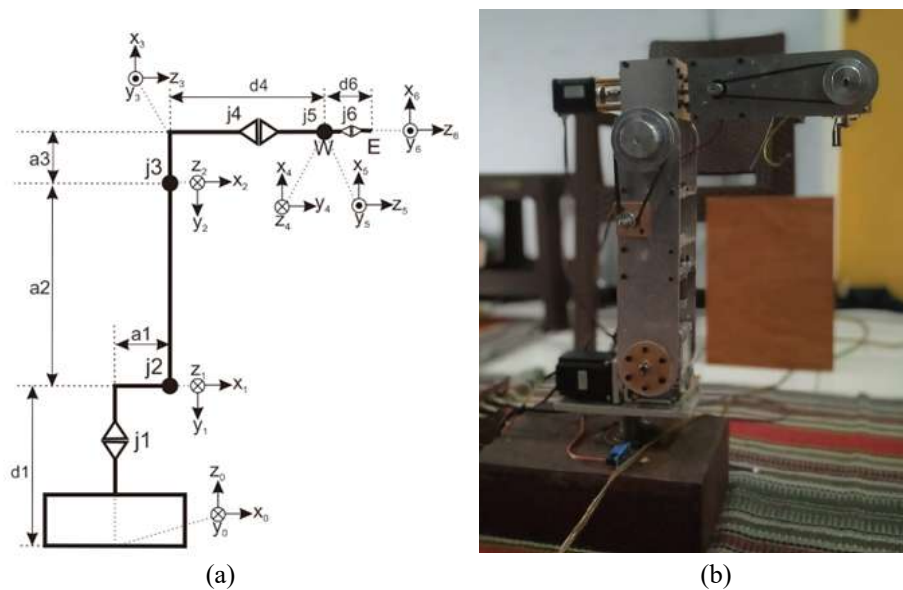


Figure 3. Kinematic Model (a) and Real Robotic Arm (b)

The letters W and E in the Figure 3a are wrist points and end-effector points, respectively. The end-effector in this research robot arm is a Mig welding torch. Table 1 is the kinematics specification of the robot which is indicated by the Denavit Hartenberg (DH) Parameters.

Table 1. DH) Parameter of 6-DOF Robotic Arm

| Joint | Alpha<br>( $\alpha_{i-1}$ ) | Arm Length<br>( $a_{i-1}$ ) | Offset Joint<br>( $d_i$ ) | Theta<br>( $\theta_i$ ) |
|-------|-----------------------------|-----------------------------|---------------------------|-------------------------|
| 1     | -90°                        | $a_1=55 \text{ mm}$         | $d_1=200$                 | $\theta_1$              |
| 2     | 0°                          | $a_2=280 \text{ mm}$        | 0                         | $\theta_2$              |
| 3     | -90°                        | $a_3=60 \text{ mm}$         | 0                         | $\theta_3$              |
| 4     | 90°                         | 0                           | $d_4=220 \text{ mm}$      | $\theta_4$              |
| 5     | -90°                        | 0                           | 0                         | $\theta_5$              |
| 6     | 0°                          | 0                           | $d_6=40 \text{ mm}$       | $\theta_6$              |

## 2.3 Inverse Analysis Method

In this study, the inverse kinematic algorithm implemented on the robotic arm controller uses analytical methods, namely geometric and algebraic methods. Although there are many inverse kinematic solution methods such as analytic, numeric, or soft computing in some literature, if the structure of the robot has a closed-form solution, analytical methods will be the fastest calculation [10]. A geometrical method is used to calculate joint

1, joint 2, and joint 3. While the algebraic method is used to calculate joints 4, 5, and 6. The following is the solution for joints 1, 2, and 3.

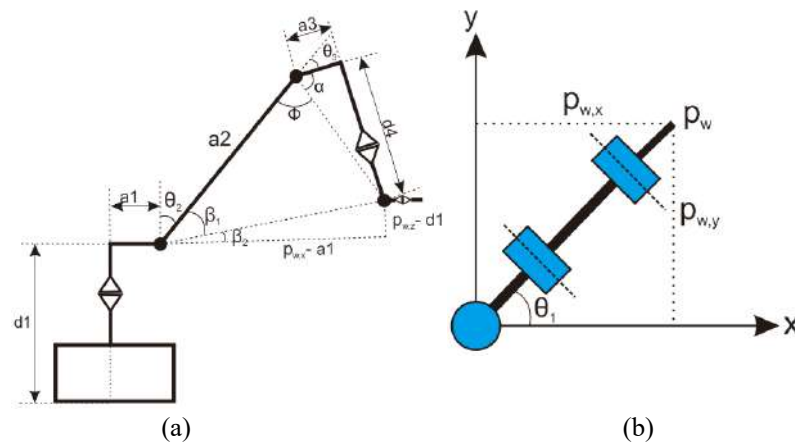


Figure 4. Kinematic Structure (a) Side view (b) Top View

### Joint 1

$$\theta_1 = \text{Atan} \left( \frac{p_{w,y}}{p_{w,x}} \right) \quad (1)$$

### Joint 3

$$\theta_3 = \pi - \phi - \alpha \quad (2)$$

As for finding the values of and the tone is as follows:

$$\alpha = \text{Atan} \left( \frac{d_4}{a_3} \right) \quad (3)$$

$$\phi = \text{Acos} \left( \frac{(a_2^2 + (d_4^2 + a_3^2) - ((P_{w,z} - d_1)^2 + (P_{w,x} - a_1)^2))}{2a_2(d_4^2 + a_3^2)} \right) \quad (4)$$

### Joint 2

$$\theta_2 = 90 - \beta_1 - \beta_2 \quad (5)$$

The values of 1 and 2 can be found with the following equation.

$$\beta_2 = \text{Atan} \left( \frac{P_{w,z} - d_1}{P_{w,x} - a_1} \right) \quad (6)$$

$$\beta_1 = \text{Acos} \left( \frac{a_2^2 + ((P_{w,z} - d_1)^2 + (P_{w,x} - a_1)^2) - (d_4^2 + a_3^2)}{2a_2 \sqrt{(P_{w,x} - a_1)^2 + (P_{w,z} - d_1)^2}} \right) \quad (7)$$

Here are the solutions for joints 4, 5, and 6 using the algebraic method. To get  $\theta_4$ ,  $\theta_5$ ,  $\theta_6$ , value is needed calculations to find the rotation matrix from frames 3 to 6.

$$R_6^3 = (R_3^0)^{-1} R_6^0 \quad (8)$$

$$R_6^3 = \begin{bmatrix} R_{611}^3 & R_{612}^3 & R_{613}^3 \\ R_{621}^3 & R_{622}^3 & R_{623}^3 \\ R_{631}^3 & R_{632}^3 & R_{633}^3 \end{bmatrix} \quad (9)$$

$$\theta_4 = \text{Atan} (-R_{623}^3, -R_{613}^3) \quad (10)$$

$$\theta_5 = \text{Acos}(R_{633}^3) \quad (11)$$

$$\theta_6 = \text{Atan}(-R_{632}^3, -R_{631}^3) \quad (12)$$

Table 2 is the result of analytical calculation of the joint angle value of the 2 input coordinates that will be used in this study.

Table 2. Inverse Kinematic calculation Using Analytical Method

| Input Coordinate<br>(Px, Py, Pz, ZYZ Angle) | Joint Angle Calculation (°) |         |         |         |         |         |
|---------------------------------------------|-----------------------------|---------|---------|---------|---------|---------|
|                                             | Joint 1                     | Joint 2 | Joint 3 | Joint 4 | Joint 5 | Joint 6 |
| 400, 0, 300, -90, 180, 90                   | 0                           | -59.578 | 17.639  | 0       | 41.918  | 0       |
| 300, 0, 300, -90, 180, 90                   | 0                           | -76.377 | 43.880  | 0       | 32.477  | 0       |

Through calculations using analytical methods (geometrical and algebraic method) at the two input coordinates that will be used for this research, there are 3 moving joints. The moving joints are joint 2, joint 3, and joint 5. Validation of the joint solution values for the 2 coordinate positions has also been carried out with an inverse kinematic solution using a numerical method. Table 3 is the result of calculating the joint value solution using the numerical method with the help of the Matlab Robotic Toolbox software.

Table 3. Inverse Kinematic calculation Using Numerical Method (Matlab)

| Koordinat Input<br>(Px, Py, Pz, ZYZ Angle) | Joint Angle Calculation (°) |         |         |         |         |         |
|--------------------------------------------|-----------------------------|---------|---------|---------|---------|---------|
|                                            | Joint 1                     | Joint 2 | Joint 3 | Joint 4 | Joint 5 | Joint 6 |
| 400, 0, 300, -90, 180, 90                  | 0                           | -59.577 | 17.730  | 0       | 41.847  | 0       |
| 300, 0, 300, -90, 180, 90                  | 0                           | -76.379 | 43.974  | 0       | 32.406  | 0       |

In table 2 and table 3, It can be seen that the difference in the value of the inverse kinematic solution with the value of the geometric solution is very small. These results prove that the analytical method inverse kinematic algorithm can be implemented into the 6 DOF Robotic Arm controller.

## 2.4 Trajectory Planning Method

The trajectory used in this robotic arm is LSPB (Linear Segment Parabolic Blend) trajectory in Cartesian-space. The Robotic Arm is expected to be able to move from the initial coordinate point to the final coordinate point smoothly. The trajectory time is planned for 27 seconds with a maximum end-effector speed of 4.5 m/s. With the help of the Matlab Robotics Toolbox software, the robot movement plan can be described in graphical form as shown in Figure 5. The circle line is the end-effector movement plan at the x-coordinate (Px), while the triangle line is the end-effector trajectory plan at the z-coordinate (Pz).

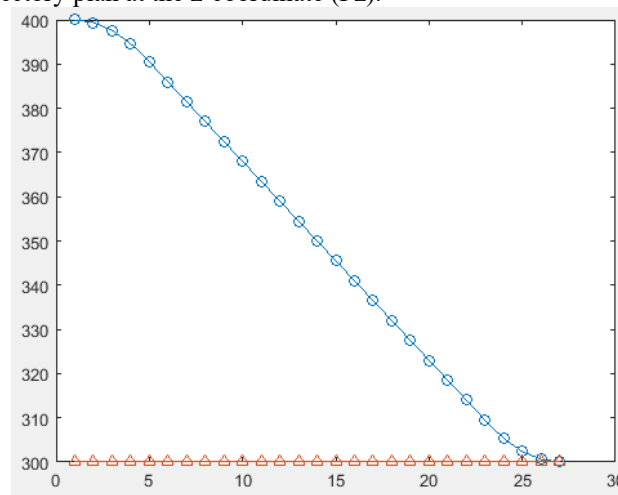


Figure 5. Trajectory Planning

## 2.5 Data Collection

Data collection is divided into 2 stages. The first stage of data collection is to test the inverse kinematic algorithm when the position coordinates are input. The data to be measured is in the form of the joint angle of the Robotic Arm. Then to find the position of the end-effector, forward kinematic calculations are carried out with the measurement value of the joint angle. Meanwhile, for the second stage, trajectory planning data was collected by measuring changes in joint angles per unit time. The angle value can also be converted into a

change in the position of the end-effector in Cartesian coordinates using forward kinematics so that the end-effector trajectory can be known. The value of the end-effector trajectory is then compared with the value of the trajectory planning, using the matlab robotics toolbox

### 3. RESULTS AND DISCUSSION

Here is the real movement of the 6-DOF Robotic Arm in carrying out straight welding movements in a flat position.

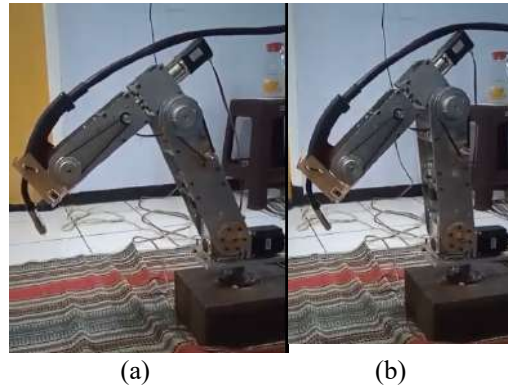


Figure 6. Robot Movement Testing (a) Position 1 (b) Position 2

In Figure 6, the robot arm moves from position 1, which is the coordinate point 400, 0, 300, to position 2, which is the coordinate point 300, 0, 300 by maintaining the orientation of the robot arm, namely  $-90^\circ$ ,  $180^\circ$ ,  $90^\circ$  in Euler angle or zyz angle. In Figure 6, the MIG Welding Torch has also been installed as the end-effector of the robotic arm.

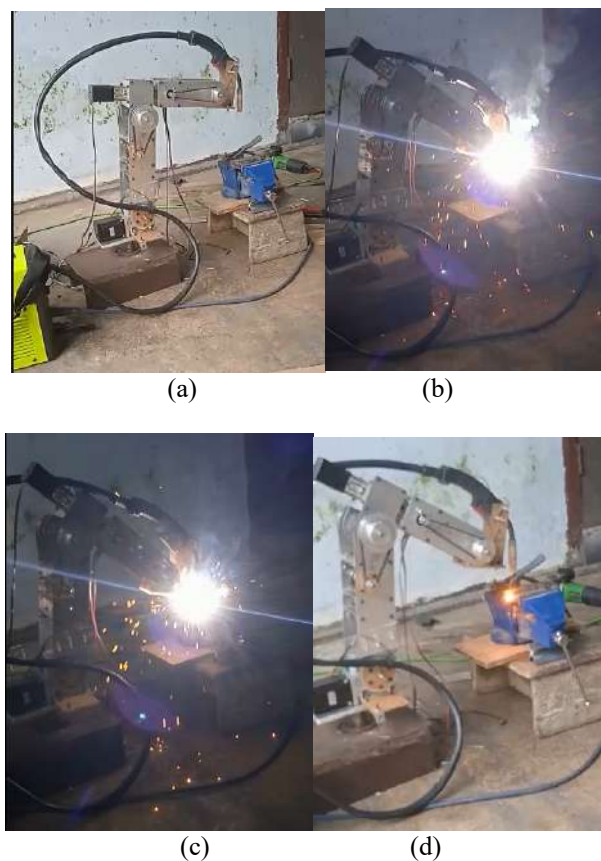


Figure 7. Straight Welding Task Using Robotic Arm (a) Home Position, (b) Start Welding Process, (c) Final Welding process, (d) Back to Home Position.

After testing the movement of the robot, in Figure 7 the robot arm is also used in a real environment, namely to perform straight welding tasks in a flat position. The movement of the robot starts from the home position, then

to position 1 to start welding process, then to position 2 as the end point of welding process, and returns to the home position by maintaining the orientation of the end-effector.

### 3.1 Inverse Kinematic Testing

Inverse kinematic testing is carried out by inputting 2 coordinate positions along with their orientation. The coordinates of 1 or initial position are (400mm, 0mm, 300mm, -90°, -180°, 90°) while coordinates 2 or the final position are (300mm, 0mm, 300mm, -90°, -180°, 90°). Real data in the form of the angle value of each joint will be measured using a rotary encoder sensor for joint angle readings. Then the angle data can be used to calculate the position of the end-effector using forward kinematic. The sensor reading data is compared with the calculated value. While the position of the end-effector will be compared with the desired input coordinates. From the test results, 3 joints play a role to form the two end-effector positions. Table 4 and Table 5 are observation data for joints 2, 3, and 5 as well as the position of the end-effector at x and z coordinat.

Table 4. Input Coordinate (400mm, 0mm, 300mm, -90°, -180°, 90°)

| Sample | Joint Angle Measurement (°) |         |         | Joint Angle Error (°) |         |         | End-Effector Position (mm) |        | End-Effector Position Error (mm) |       |
|--------|-----------------------------|---------|---------|-----------------------|---------|---------|----------------------------|--------|----------------------------------|-------|
|        | Joint 2                     | Joint 3 | Joint 5 | Joint 2               | Joint 3 | Joint 5 | Px                         | Pz     | Px                               | Pz    |
| 1      | -57.15                      | 18.68   | 40.28   | 2.63                  | 0.96    | 1.57    | 400.7                      | 282.5  | 0.7                              | 17.5  |
| 2      | -56.93                      | 18.13   | 40.88   | 2.86                  | 0.40    | 0.97    | 402.2                      | 283    | 2.2                              | 17    |
| 3      | -57.83                      | 18.68   | 40.73   | 1.95                  | 0.96    | 1.12    | 399.7                      | 286.5  | 0.3                              | 13.5  |
| 4      | -57.38                      | 18.38   | 39.6    | 2.40                  | 0.66    | 2.24    | 401.9                      | 284.8  | 1.9                              | 15.2  |
| 5      | -57.15                      | 18.17   | 40.05   | 2.63                  | 0.45    | 1.79    | 402.7                      | 284.1  | 2.7                              | 15.9  |
| 6      | -56.93                      | 19.63   | 41.4    | 2.85                  | 1.91    | 0.44    | 397                        | 278.1  | 3                                | 21.9  |
| 7      | -57.15                      | 19.07   | 39.83   | 2.63                  | 1.35    | 2.02    | 399.7                      | 281.2  | 0.3                              | 18.8  |
| 8      | -57.15                      | 18.56   | 40.05   | 2.63                  | 0.85    | 1.79    | 401.2                      | 282.8  | 1.2                              | 17.2  |
| 9      | -57.38                      | 19.35   | 40.05   | 2.40                  | 1.63    | 1.79    | 401                        | 281.66 | 1                                | 18.34 |
| 10     | -57.60                      | 18.45   | 40.73   | 2.18                  | 0.73    | 1.12    | 400.6                      | 285.9  | 0.6                              | 14.1  |

In Table 4, it can be observed that from 10 attempts at input coordinates (400mm, 0mm, 300mm, -90°, -180°, 90°) the highest t error occurred at joint 2, which was 2.86°. While the smallest error occurs at joint 3 which is 0.4°.

Table 5. Input Koordinat (300mm, 0mm, 300mm, -90°, -180°, 90°)

| Sample | Joint Angle Measurement (°) |         |         | Joint Angle Error (°) |         |         | End-Effector Position (mm) |       | End-Effector Position Error (mm) |      |
|--------|-----------------------------|---------|---------|-----------------------|---------|---------|----------------------------|-------|----------------------------------|------|
|        | Joint 2                     | Joint 3 | Joint 5 | Joint 2               | Joint 3 | Joint 5 | Px                         | Pz    | Px                               | Pz   |
| 1      | -74.93                      | 18.68   | 40.28   | 1.23                  | 1.42    | 2.7     | 297.1                      | 290.8 | 2.9                              | 9.2  |
| 2      | -74.93                      | 18.13   | 40.88   | 1.45                  | 0.42    | 1.43    | 301                        | 292.7 | 1                                | 7.3  |
| 3      | -75.83                      | 18.68   | 40.73   | 0.55                  | 1.69    | 2.93    | 296.5                      | 292.8 | 3.5                              | 7.2  |
| 4      | -75.38                      | 18.38   | 39.6    | 1.00                  | 1.476   | 3.60    | 298.2                      | 291.5 | 1.8                              | 8.5  |
| 5      | -75.15                      | 18.17   | 40.05   | 1.23                  | 1.476   | 2.93    | 298.2                      | 291.5 | 1.8                              | 8.5  |
| 6      | -74.93                      | 19.63   | 41.4    | 1.45                  | 2.376   | 2.26    | 294.4                      | 287   | 5.6                              | 13   |
| 7      | -75.15                      | 19.07   | 39.83   | 1.23                  | 1.814   | 3.38    | 297                        | 289.6 | 3                                | 10.4 |
| 8      | -75.15                      | 18.56   | 40.05   | 1.23                  | 1.139   | 1.58    | 298.2                      | 291.5 | 1.8                              | 8.5  |
| 9      | -75.38                      | 19.35   | 40.05   | 1.00                  | 2.094   | 3.16    | 295.6                      | 289.7 | 4.4                              | 10.3 |
| 10     | -75.60                      | 18.45   | 40.73   | 0.78                  | 1.307   | 2.93    | 298.1                      | 293   | 1.9                              | 7    |

In table 5, it can be observed that out of 10 attempts at the input coordinates (300mm, 0mm, 300mm, -90°, -180°, 90°) the highest error occurred at joint 5, which was 3.6°. While the smallest error occurs at joint 3 which is equal to 0.42°.

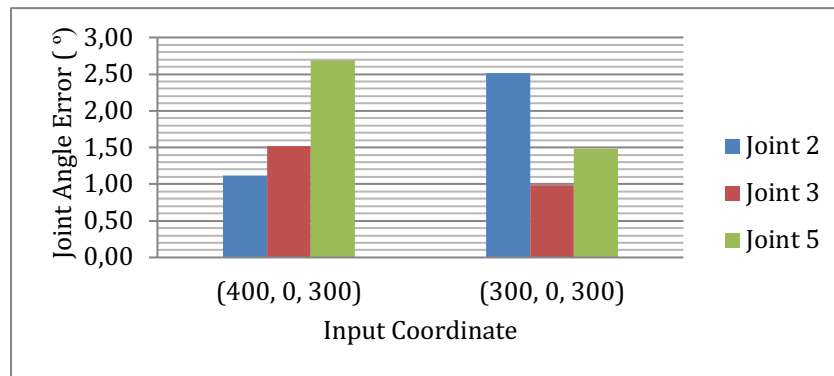


Figure 8. Joint Angle Mean Error

In Figure 8, it can be seen that the average error values for joint 2, joint 3, joint 5 at the input coordinates of 400, 0, 300 with Euler angles of -90, 180, 90 are 1.12°, 1.52°, and 2.69°, respectively. While the average error values for joint 2, joint 3, and joint 5 at the input coordinates of 300, 0, 300 are 2.51°, 0.99°, and 1.48°, respectively. The average error for both positions is 1.82° for joint 2, 1.26° for joint 3 and 2.08° for joint 5.

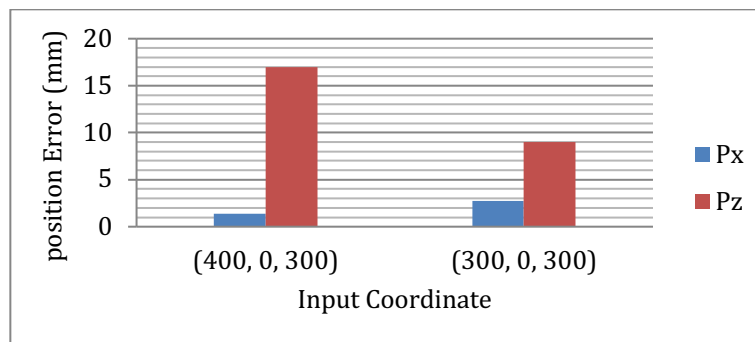


Figure 9. End-Effector Position Mean Error

By performing forward kinematic calculations, the measurement data can be converted into the end-effector position. It can be seen in Figure 9, that the average error value at the end effector position at the input coordinates (400, 0, 300). By comparing the position of the end-effector with the input coordinates, the average error value is obtained at the x and y coordinates. while the average error value for the end-effector position (400, 0, 300) in the x and y coordinates is 1.39 mm and 16.94 mm, respectively. Meanwhile, the average error value for the position of the end-effector (300, 0, 300) in the x and y coordinates is 2.77 mm and 8.99 mm, respectively. The average error for the two coordinate positions when compared with the input coordinates we want is for Px, and Pz is 2.08 mm and 12.9 mm.

### 3.2 Trajectory Planning Testing

The trajectory planning test was carried out by monitoring changes in the angles of joints 2, 3, and 5 of the Robotic Arm every second for 27 seconds. To obtain the displacement of end-effector data, the joint value measurement data is converted into Cartesian coordinates using forward kinematic calculations. Table 6 is data on changes in joint angle and end-effector position for 27 seconds with sampling every second.

Table 6. Experimental data of robotic arm trajectory

| Time (s) | Joint Angle (°) |         |         | End-Effector Position (mm) |    |       |
|----------|-----------------|---------|---------|----------------------------|----|-------|
|          | Joint 2         | Joint 3 | Joint 5 | Px                         | Py | Pz    |
| 0        | -57.15          | 18.68   | 40.28   | 400.7                      | 0  | 282.5 |
| 1        | -57.15          | 18.80   | 40.05   | 400.1                      | 0  | 282   |
| 2        | -57.38          | 19.24   | 40.05   | 398.8                      | 0  | 282   |
| 3        | -58.05          | 20.03   | 39.60   | 396                        | 0  | 283.3 |
| 4        | -58.73          | 21.09   | 39.38   | 392                        | 0  | 283.8 |
| 5        | -59.40          | 22.05   | 38.70   | 388.8                      | 0  | 284.6 |

| Time<br>(s) | Joint Angle (°) |         |         | End-Effector Position (mm) |    |       |
|-------------|-----------------|---------|---------|----------------------------|----|-------|
|             | Joint 2         | Joint 3 | Joint 5 | Px                         | Py | Pz    |
| 6           | -60.30          | 22.78   | 38.25   | 385.8                      | 0  | 286.3 |
| 7           | -60.75          | 23.79   | 37.58   | 382                        | 0  | 286.5 |
| 8           | -61.65          | 24.64   | 36.90   | 379.3                      | 0  | 288.8 |
| 9           | -62.55          | 25.71   | 36.68   | 375.1                      | 0  | 290.3 |
| 10          | -63.45          | 27.00   | 35.78   | 370.5                      | 0  | 291.1 |
| 11          | -64.13          | 28.13   | 35.55   | 366.2                      | 0  | 291.1 |
| 12          | -64.80          | 29.59   | 35.10   | 360                        | 0  | 290   |
| 13          | -65.48          | 30.60   | 34.65   | 357                        | 0  | 290.4 |
| 14          | -66.38          | 31.95   | 34.20   | 351.9                      | 0  | 290.8 |
| 15          | -67.28          | 33.19   | 33.98   | 346.8                      | 0  | 291.4 |
| 16          | -67.95          | 34.43   | 33.75   | 341.9                      | 0  | 290.9 |
| 17          | -68.85          | 35.55   | 33.30   | 337.5                      | 0  | 291.8 |
| 18          | -69.75          | 36.73   | 33.08   | 332.5                      | 0  | 292.5 |
| 19          | -70.65          | 37.91   | 32.63   | 327                        | 0  | 293.1 |
| 20          | -71.55          | 39.09   | 32.18   | 322.8                      | 0  | 293.8 |
| 21          | -72.23          | 40.33   | 31.50   | 318                        | 0  | 293   |
| 22          | -72.90          | 41.46   | 31.28   | 313.6                      | 0  | 292.7 |
| 23          | -73.58          | 42.64   | 30.60   | 309.1                      | 0  | 292.1 |
| 24          | -74.25          | 43.43   | 30.38   | 305                        | 0  | 292.7 |
| 25          | -74.70          | 44.21   | 30.15   | 302.5                      | 0  | 292.2 |
| 26          | -74.93          | 44.78   | 29.93   | 300                        | 0  | 292.5 |
| 27          | -74.93          | 45.11   | 29.93   | 299.9                      | 0  | 290.7 |

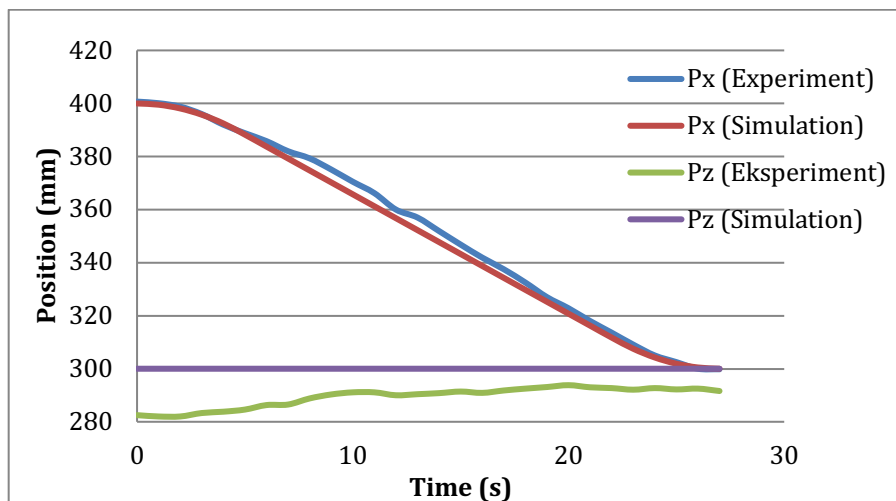


Figure 10. End-effector trajectory Eksperimen vs Simulation

Figure 10 is a comparison of the trajectory end-effector in Cartesian coordinates. The red and gray lines represent the trajectory of the robotic arm on the x and z axes in the simulation using the Matlab Robotics toolbox, or in other words, an illustration of the trajectory planning. While the red and orange lines are the actual end-effector trajectories from the calculation results on the x and z axes with the joint robot measurement values obtained. If we observe the movement of the end-effector on the x-axis from the coordinates  $P_x=400\text{mm}$  to  $P_x=300\text{mm}$  it looks quite smooth, this is evidenced by the presence of a parabolic curve at the beginning and end of each robot's movement. However, when compared to the trajectory planning chart, it can be seen that there are still error values. Because not all parts of the end-effector movement graph coincide with the desired trajectory graph, or in other words, there is an error value in the movement of the Robotic Arm. Then on the z-axis, there is a fairly large error value. It can be seen that the movement of the end-effector has not been able to fully maintain the position of the end-effector at a height of 300 mm on the z-axis. In addition, it can be seen that the movement of the end-effector in the z-axis changes which tends to increase, in the sense that the movement of the end-effector tends to increase. The following is a graph of the error value of the end-effector position when moving

from the coordinate point (400, 0, 300)mm to the coordinate point (400, 0, 300) while maintaining the Euler angle orientation value (-90°, 180°, 90°).

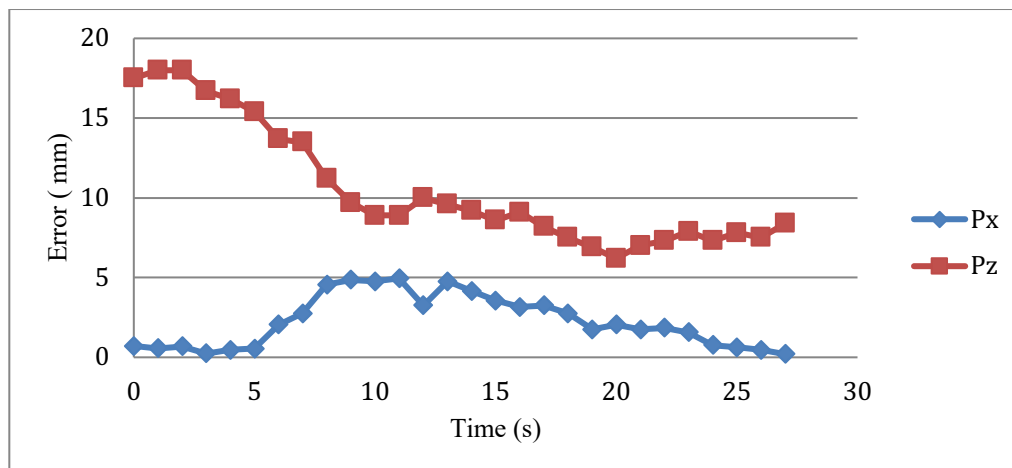


Figure 11. End-Effector Absolute Error Trajectory

The graph in Figure 11 above is a comparison of the trajectory end-effector in Cartesian coordinates. It can be seen at the end-effector position that at the end-effector position in the x-coordinate, the largest absolute error value that occurs is 4.95 mm, while the largest error that occurs in the y-coordinate is 18 mm. The average x-coordinate error value is 2.25 mm and the z-coordinate average error is 10.7 mm.

#### 4. CONCLUSION

The inverse kinematic algorithm with analytical method (geometrical and algebraic) and LSPB trajectory planning method in cartesian space has been successfully applied to the 6-DOF robotic arm to perform straight flat welding movements. Inverse Kinematic testing on both input coordinates, the average error value for joints 2, 3, and 5 is 1.82°, 1.26°, and 2.08°. Meanwhile, the average error of the end-effector position at the x and z coordinates is 2.08 mm and 12.9 mm, respectively. Then for the trajectory planning test, the average error value for the end-effector position in the x and z coordinates is 2.25 mm and 10.7 mm.

#### 5. ACKNOWLEDGMENT

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# FREEZE DRYER MACHINE DESIGN FOR MANGO FRUIT STORAGE

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**Abstract.** The purpose of the research on the design of this tool is to determine the cooling load on the freeze dryer and to determine the time it takes to reach a temperature of -20°C. This tool uses a vapor compression cooling system and a vacuum process means that this tool cools the storage space with air in the dry cabin. The research method is to determine the volume of the cabin to determine the capacity of the freeze dryer and determine the cooling load by calculating the product load and then calculating the heat load through the walls and other loads that generate heat. for a freeze dryer machine with a capacity of 1.8 PK. From testing the tool for 10 minutes once for 6 hours, the results of the system performance at the evaporator temperature -24.64°C and product temperature -16.2°C, COP<sub>Carnot</sub> performance of 3.77, and COP<sub>Actual</sub> of 2.87 with an efficiency of 76%, This is in line with the performance values in the COP<sub>Carnot</sub> design of 3.8 and COP<sub>Actual</sub> of 3.30 with an efficiency of 87%.

*Keywords : Mango, Freeze dryer, Cooling load, Engine performance*

## 1. INTRODUCTION

Mango is a food ingredient commonly consumed by the people of Indonesia. Mangoes have a very high water content and are only harvested twice a year. From this problem, it is necessary to store mangoes with a drying process. The best process is freeze-drying because the freeze-drying process will not damage the mangoes, will not reduce the nutritional content of the mangoes, will not rot quickly and remain fresh. In contrast to other drying processes, it is necessary to design a freeze drying machine for this. The purpose of this research is to design a freeze-drying machine for mango storage

Indonesia is a tropical country that has a variety of fruits in the lowlands or highlands. Mango is one of the fruit products in the tropics which contains compounds to maintain body health such as carotenoids, vitamin C, and phenolic compounds that are useful for the prevention of cardiovascular disease and cancer [1], The water content in mangoes is very high, namely 84%, so freeze-drying is one of the best drying methods for drying fruit because it can maintain the distinctive characteristics of the fruit such as color, taste, and aroma as well as for the preservation of horticultural products limited.

In contrast to other drying methods which generally require a temperature that is hotter than the ambient temperature, in the freeze-drying method, most of the drying process takes place at temperatures below the ambient temperature. So in the freeze dryer, the temperature must be below 0°C. In the conventional drying process, the water content in the product is released due to the evaporation process, or the process of changing the liquid phase to gas. Meanwhile, in the freeze-drying method, the process that occurs is a sublimation process, which changes the solid phase (water content in the product) into gas.

Based on the description above, the author makes a journal with the title "Design of a Freeze Dryer Machine for Storage of 20 kg Mangoes". The expected cabin temperature is -20°C. With this tool, it is hoped that it will be useful, especially for the development of better refrigeration research.

The purpose of this journal is to determine the cooling load on the freeze dryer, to find out the time it takes to reach a temperature of -20°C, to find out the performance of the resulting freeze dryer.

According to [2], states that the vacuum freeze dryer with condenser heating with a working pressure of -1

to 3 millibars, chamber temperature to minus or below 0°C, condenser temperature to 35°C. In the drying process that does not use condenser heating until the sublimation process is completed for 13 hours and the detection limit value (LOD) is  $\pm 98.6\%$ , on the other hand, in the drying process that uses condenser heating, the time becomes 6.5 to 7 hours, and the obtained value is detection limit (LOD) of  $\pm 95.6\%$ .

According to Martin [3] and Ichsan [4], stated that 1 kg of dried yam products where the freezing system uses an R134a vapor compression system as a refrigerant. Freezing time is 20 minutes with temperatures and pressures below the triple point in the air phase diagram. The planned drying chamber is a cylinder with a diameter of 30 cm and a length of 30 cm. The final temperature of the material in the drying chamber is expected to be -18°C with a planned vacuum pressure of 10 Pa or 0.1 bar. In the design, an evaporator design with a total pipe length of 4.22 meters and a condenser design with a total pipe length of 15.09 meters is produced. Cooling the condenser using a fan motor whose capacity is adjusted to the airspeed of 0.08 m<sup>3</sup>/s. From the calculation results, the compressor used is a compressor with an energy of 0.5 HP.

The results of the test performance prove that the final pressure of the drying chamber achieved is constant at 0.000667 bar or 66.7 Pa. Vacuum freeze-drying is used below the triple point of the air, under 6.1 bar or 610 Pa. The final pressure achieved is lower than 610 Pa, so this vacuum freeze dryer can be used as needed even if the final pressure reached is not following the design state of 10 Pa. Experimental testing of vacuum freeze-drying on yam can only remove 62% water content, and from the results of testing, drying, observation and analysis of vacuum freeze-drying characteristics of yam bean drying, it can be concluded that the drying procedure that can remove the mass and maximum water content is the freezing method manually. fast, but the drying method which shows the sublimation process (phase change of materials in the phase diagram) is very good, namely the method in which the temperature of the material in the drying chamber is kept constant at -5°C [5].

Ilyas [6], in her research entitled "Changes in the characteristics of food ingredients in fruit chips using the freeze-drying method" that freeze-drying is one of the non-thermal processing techniques to increase the shelf life of the product. Fruit chips produced from freeze-drying look better from a sensory, chemical, and physical point of view compared to thermal processing, but thermal processing has not been able to remove microbiological spores in the fruit so this technology is rarely used because it has high investment and operational costs.

According to Anna [7], states that freeze dryers are used to dry radiopharmaceuticals by manual or automatic methods for approximately 31 hours based on the drying procedure. From the observation, it is proved that the freeze-drying machine functions very well according to its specifications, namely the manual method in the freezing process reaches -40°C and -34°C on automatic, the drying process at a temperature of 15°C and a pressure of 0.050 bar produces a dry product in the form of powder at each – each method.

According to Kumar [8], states that freeze-drying is used for food products to determine the appropriate concentration of skimmed milk and maltodextrin binder combinations to produce the best viability and characteristics of *Lactobacillus Plantarum* microcapsules by the freeze-drying method. In Microencapsulation technology, an experiment with *Lactobacillus Plantarum* bacteria with the addition of a binder combination concentration of 20% Maltodextrin resulted in the best viability and characteristics of 10% skimmed milk, namely 3.93% moisture content, 19.79% yield, and 97.76% cell viability nutritional content.

The research of Yulfianti [9], entitled "Utilization of coconut dregs as raw material for high-fiber coconut flour using the freeze-drying method" states that the drying process of coconut dregs using the freeze-drying method is influenced by drying time, which results in differences in nutritional quality including protein, fat, crude fiber, and water content. Efficient drying time is carried out for 1 day (24 hours), which results in higher fiber content than protein content. The freeze-drying process for 24 hours produced 37.1% crude fiber, 4.12% protein, 0.33% water content, and 12% fat. The decrease in crude fiber content is caused by the breakdown of hemicellulose in the material.

Pujihastuti [10] in his research entitled "Tomato Fruit Preservation Technology With Freeze Drying Method" that when freeze-drying at low temperatures has a minimum level of damage because the speed of the dryer depends on the intensity of the flow of water vapor passing through the dry suction layer. Dehydration and chemical interactions prevent damage to dead cells very effectively required at a rate to obtain a quality product. The effectiveness of the freeze dryer depends on the sample temperature and thickness after processing. At either 40°C or 80°C, a higher rate of rehydration occurs initially to prevent damage to dead cells resulting from freeze-drying.

According to Shamseieh [11], freeze-drying is a method for removing water using ice crystal sublimation. If this process goes well, it will produce products with the best quality compared to products with traditional

methods. In the food industry and pharmaceutical field, powder products have become an important subject for ongoing development and expansion. The powdered product used in this project is not common in the Middle East, so a prototype will be built to produce a high-quality product during the freeze-drying process. So based on the results of the study that powder or powder products are an effective way to produce good quality with the freeze-drying method compared to traditional methods. The performance results obtained from the mass of the product decreased to 83% with a color change, vacuum pressure reached 10-kPa, the temperature reached  $-21^{\circ}\text{C}$ , freezing time for 2 hours.

According to Solomon [12], stated that tomatoes and pepper were tested in a freeze dryer at temperatures of  $-1.4^{\circ}\text{C}$ ,  $-1.5^{\circ}\text{C}$  and  $-2^{\circ}\text{C}$ , and vacuum pressures of -22 inHg, -24 inHg, and -29 inHg, freeze-drying time is 10 hours and 20 hours, each data collection time is 10 hours. 0% moisture content is achieved with the help of a vacuum because moisture is not present in the vacuum chamber. Freeze-dried products can regain their freshness when dissolved in water. It was recommended among other things that farmers be encouraged to use freeze dryers to dry tomatoes and peppers. The results of the freeze-drying machine performance during the freezing process carried out for 10 hours obtained the freezing temperature of tomato and pepper products, namely  $-2^{\circ}\text{C}$  and vacuum pressure of -29 inHg.

Freeze-drying is a process in which water is removed from the product after freezing and the air in the cabin is removed by the vacuum process, allowing the ice to change from solid to vapor without passing through the liquid phase. Freeze drying is one method that has advantages in maintaining the quality of drying results, especially for products that are sensitive to heat [13] [14].

The freeze-drying process is described using the water phase diagram in Figure 1 [15] [16].

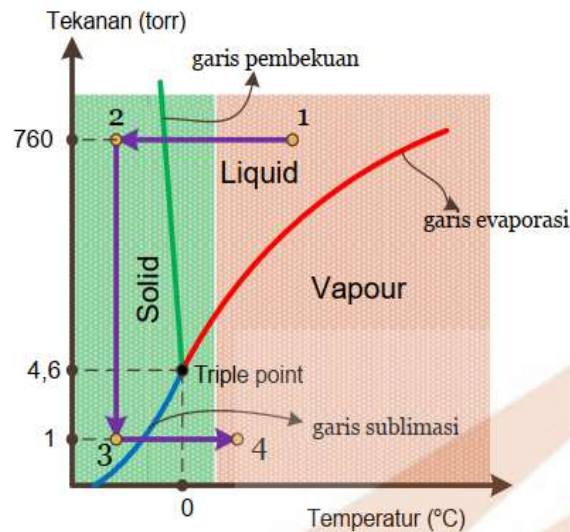


Figure 1. Freeze-drying process on the liquid phase diagram [12]

In Figure 1. 3 (three) main processes. The first process is the freezing process, which is the process from point 1 to point 2. This process is generally carried out in a separate frozen machine with a freeze dryer, with a product temperature of around  $-20^{\circ}\text{C}$ . The second process is the vacuum process, namely the process from point 2 to point 3. This process takes place in a freeze dryer machine, and the vacuum is carried out with a vacuum pump. The third process is the drying process, which is from point 3 to point 4. Similar to the second process, this third process also takes place in the freeze dryer. In this drying process (point 3 to point 4), the addition of heat (heat) should not be too high, or in other words, the product temperature should not be too hot. In this third process, it can be seen that the drying process does not pass through the evaporation line, but passes through the sublimation line [15] [17] [18].

The stages in the freeze-drying machine are first freezing the product, followed by drying the product. Both vacuums mean that after freezing, the air in the cabin will come out. This allows the frozen solvent to evaporate without going through the liquid phase or sublimation. The third heating will be carried out on the product so that the sublimation process takes place quickly. Fourth, low-temperature condensation will remove the solvent that evaporates in the vacuum which turns into a solid [4] [19].

Cooling load is the total heat that moves from the air conditioning system at any time [20]. The cooling load consists of room heat and additional heat from lighting and living things that affect the performance of the air

conditioning machine. The influence of the cooling load with the Coefficient of Performance (COP) is important because a refrigeration machine that has a high COP value means it has a large cooling capacity but uses a small compressor power.

## 2. METHODS

This type of research uses the design method, which is carried out to obtain data on the design, manufacture of the machine, and the performance of the freeze dryer. The flow of this research can be seen in Figure 2.

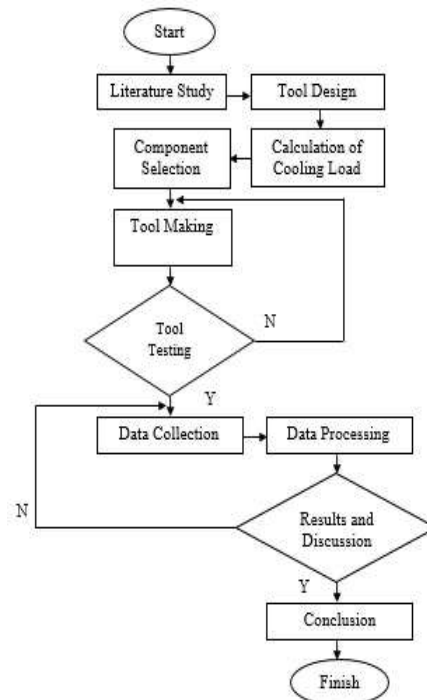


Figure 2. Implementation Flow Chart

The design used in this study was started from the manufacture of a custom cylindrical cabin with a height of 0.5 m and a diameter of 0.35 m for storage of 20 kg mangoes. The component unit uses a 1 unit 1.8 HP compressor. The evaporator as much as 1 unit used is a custom evaporator, the evaporator adjusts to the diameter of the suction pipe and is then wrapped around the cylindrical cabin with solid coils. The condenser used is an air-cooled condenser with an additional fan with a capacity equal to the capacity of the compressor, while the expansion device uses a capillary tube made of copper pipe with a diameter and length adjusted to the compressor capacity.

Of the four components, the assembly process was carried out with the equipment and materials that had been provided with colleagues to form a unit according to design, the unit used for research was designed and built in such a way that it could be used as research for colleagues with different titles. The design of the assembled unit is with the cabin design temperature for the freeze dryer, which is  $-20^{\circ}\text{C}$ , the refrigeration system that we designed uses 404A refrigerant, while the capillary pipe calculation is based on the capillary pipe conversion table reference.

The cooling load is divided into several parts, namely the calculation of the cooling load on the wall and the cooling load on the product.

To calculate the cooling load on the wall, namely :

$$Q = U \times A \times \Delta T$$

Where :

$Q$  = The heat generated (watts)

$U$  = Heat transfer coefficient on the wall ( $\text{watt}/\text{m}^2.\text{K}$ )

$A$  = The surface area of wall space ( $\text{m}^2$ )

$\Delta T$  = Difference between ambient and room temperature (K)

To get the value of  $U$ , a formula is needed, namely :

$$U = \frac{1}{\frac{1}{f_0} + \frac{x_1}{k_1} + \frac{x_2}{k_2} + \frac{x_3}{k_3} + \frac{1}{f_i}}$$

Where :

$f_0$  = Coefficient of convection in the environment (Watt/m<sup>2</sup>.K)

$k_n$  = Thermal conductivity of the nth wall layer (Watt/m .K)

$x_n$  = The thickness of the nth wall (meter)

$f_i$  = Coefficient of convection in space (Watt/m<sup>2</sup>.K)

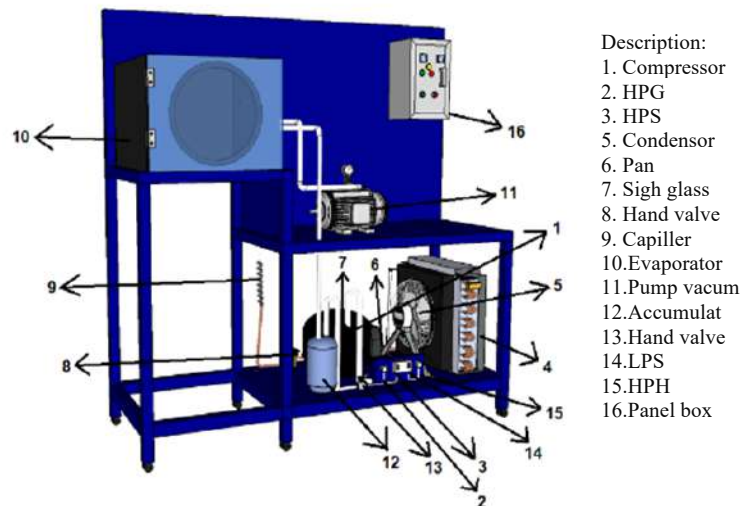


Figure 3. Freeze Dryer Tool Design

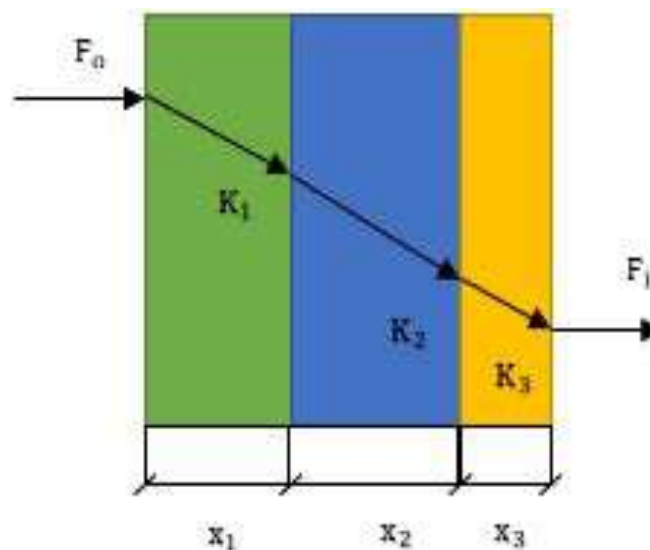


Figure 4. Cabin Material

Table 1. Wall Material

| Ingredients               | Thickness | Unit (m) | Thermal Conductivity<br>W/mK |
|---------------------------|-----------|----------|------------------------------|
| Steel Plate ( $K_1$ )     | 1,4 mm    | 0,0014   | 14                           |
| Polyurethane ( $K_2$ )    | 30 mm     | 0,03     | 0,023                        |
| Stainless Steel ( $K_3$ ) | 0,8 mm    | 0,0008   | 19                           |
| Still air ( $F_{in}$ )    | -         | -        | 9,37                         |
| Moving Air ( $F_{out}$ )  | -         | -        | 22,70                        |

Calculation of the cooling load on the wall, namely:

$$\begin{aligned}
 U &= \frac{1}{\frac{1}{f_i} + \frac{x_1}{k_1} + \frac{x_2}{k_2} + \frac{x_3}{k_3} + \frac{1}{f_o}} = \frac{1}{\frac{1}{9,37} + \frac{0,0014}{14} + \frac{0,03}{0,023} + \frac{0,0008}{19} + \frac{1}{22,70}} \\
 &= \frac{1}{0,11 + 0,0001 + 1,30 + 0,000042 + 0,04} \\
 &= \frac{1}{0,11 + 0,0001 + 1,30 + 0,000042 + 0,04} \\
 &= \frac{1}{1,45} \\
 &= 0,69 \text{ W/m}^2\text{K}
 \end{aligned}$$

Calculation of the heat load generated by the wall, namely:

$$\begin{aligned}
 Q &= U \times A \times \Delta T \\
 &= 0,69 \text{ W/m}^2\text{K} \times 0,82 \text{ m}^2 \times 52^\circ\text{K} \\
 &= 29,42 \text{ W}
 \end{aligned}$$

### 3. RESULTS AND DISCUSSION

Mango is a food ingredient commonly consumed by the people of Indonesia. Mangoes have a very high-water content and are only harvested twice a year. From this problem, it is necessary to store mangoes with a drying process. The best process is freeze-drying because the freeze-drying process will not damage the mangoes, will not reduce the nutritional content of the mangoes, will not rot quickly, and remain fresh. In contrast to other drying processes, it is necessary to design a freeze-drying machine for this. The comparison of system performance between the design and the test results is shown in the table below:

Table 2. System Performance Comparison

| System Performance                | Design  | Test Result |
|-----------------------------------|---------|-------------|
| Compression Process (kJ/kg)       | 29,2    | 34,5        |
| Condensation Process (kJ/kg)      | 125,6   | 133,43      |
| Evaporation Process (kJ/kg)       | 96,4    | 98,93       |
| Refrigerant Mass Flow Rate (kg/s) | 0,04    | 0,04        |
| Condenser Capacity (kJ/s)         | 5,02    | 5,34        |
| Evaporation Capacity (kJ/s)       | 3,86    | 3,96        |
| Compression Capacity (kJ/s)       | 1,8     | 1,8         |
| COP <sub>Actual</sub>             | 3,30    | 2,87        |
| COP <sub>Carnot</sub>             | 3,8     | 3,77        |
| Efficiency (%)                    | 87      | 76          |
| Compression Ratio                 | 12,67   | 15          |
| Electric Power (Watt)             | 201.177 | 223.891     |

The results from the table 2 above show that the design with the test results is not much different in value, so that the design of the freeze dryer machine can run well. From the results of electric power consumption for one month it is more efficient than other freeze dryer designs. The results of this study can be distributed to the community or community service because the consumption of electric power is very efficient and this design is very easy to use for the community in general and has used very sophisticated technology to regulate the freeze dryer.



Figure 5. Freeze Dryer Design Result

#### 4. CONCLUSION

From the results of this journal research, it can be concluded that the cooling load obtained is 1,352.36 watt so that the compressor used for the freeze dryer is 1.8 HP. Data retrieval was carried out for 8 hours, the freeze-drying machine with cabin design temperature  $-20^{\circ}\text{C}$ , while for the results obtained cabin temperature  $-13.1^{\circ}\text{C}$ . The cabin temperature was not reached because the cabin experienced condensation so that the temperature in the cabin was not maximal or not reached. The  $\text{COP}_{\text{Carnot}}$  value for the design data is 3.8 while the  $\text{COP}_{\text{Carnot}}$  value for the test results is 3.77. The  $\text{COP}_{\text{Aktual}}$  value for the design data is 3.30 while the  $\text{COP}_{\text{Aktual}}$  value for the test results is 2.87. The efficiency value for the design data is 87% while the efficiency of the test results is 76%. The consumption of electrical power for the design data is 880 watt while for the test results it is 990 Watt.

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## IMPLEMENTING KANSEI ENGINEERING AND QUALITY FUNCTION DEPLOYMENT METHOD IN DESIGNING SHOES : CASE STUDY AT REJOWINANGUN ORIGINAL LEATHER

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**Abstrak.** Small Medium Enterprise (SME) played an important role in the economic growth in Indonesia, as Yogyakarta one of it's promising province with relied so much on tourism and art and creative business, SME has become one of the main source of income for Yogyakarta. Rejowinangun Original Leather is one of SME in Yogyakarta that creates and produces its own hand made shoes. Not only producing themselves, this SME also buy several shoes product from another province, which ironically sells better than their own. One of the main concern of the failure in sale is the poor design of the self-made shoes. If the SME cared about their own design, it could be their selling point in order to survive and even played as an one of the big player in shoes industry. This research implementing both Kansei and Quality Function Deployment (QFD) on the design of the shoes, thus collecting what the customer needs and creating the best design for the SME. The outcome of this research is the newly designed shoes based on what the customer needs, the proposed design basically make the product looks more aesthetics compared to the last one.

*Keywords : Shoes, Kansei Engineering, Quality Function Deployment, Brand Image*

### 1. INTRODUCTION

Shoes, has become one of the main point of fashion [1], at the moment wearing a shoes has becoming more of an fashion icon and fashion item, rather than a regular foot protector. It has also transformed into a new communication item where the wearers would like to confer the message into the public or as a statement or stance [2]. Choosing to buy a new product or a new fashion item, in this case a pair of shoes, needs several considerations from the customers, ranging from price and even small details such as color, design and so on [3], sometimes a good product is the one that could capture what the customers actually needed. Another consideration in buying a shoes, is how fit and comfortable in the wearer's feet and also giving a satisfaction upon buying it. [3] [4]. As shoes has evolved and grown into several types and design, so does the complication of creating and designing a good and satisfying shoes. Several problems such as monotonous design and the high cost of the material [5], the needs to implementing new technologies in order to create a better footwear [6], and even lacks of strategies that consist of the usage of data and technologies in both market analysis and information technology [7] has become a great barrier in this industry, moreover in a SME. As it mentioned in the previous sentences, monotonous design, is one of the problems in shoes business, design could defined as the aesthetic part of the shoes, that could impact user's satisfaction using or buying the product [8], another research stated that design, somehow also giving and impact and intervene on both customer's satisfaction and loyalty towards the product [9]. On the other hand, shoemaker sometime still using the old-fashioned method in creating and designing shoes like the old time, although the usage of technologies have slowly been implied in the process [10] and it could hinder the growth of the business especially in shoe making.

Customers are the vital point for SMEs, as they are the "bloodline" that help SME to grow and survive. Building a good communication, is one of the key points for SME to grow and survive [11]. On a side note, as SME does not have a huge capital to help them grow, customer's satisfaction is needed in order to help the survive

against bigger player [12]. Having a quality product, is one of the way to ensure customer's satisfaction both directly or indirectly [13], several others variable should also be considered by company in order to improve customer's satisfaction such as : Serviceability, Durability, Aesthetics and Perceived Quality [12], furthermore, the image of the brand also plays an important role in this [12] [14].

Fashions, leads to the needs of an aesthetic feels or even a vibe, to fully grasps what the customers wants. Kansei Engineering (KE), is one of the tools in product design and development that relies on that. KE basically a consumer's oriented method that was developed in Japan, that can be utilized in product development [15]. KE comes from the terms Kansei, a Japanese word that can be used to express impression towards several things such situation, surrounding or anything else [16]. As shoes is a fashion product, Kansei could be used to capture what actually the customer's need. It is also possible, to implement Kansei in several other item, not fashion related, such as in : food packaging [17] [18] [19] [20], electric motorcycle [21], kitchen appliance [22], or even an intangible product and services [23] [24] [25].

Another tools, that mostly used in product design and development, is the Quality Function and Deployment (QFD). QFD, is a method that could make every step in product design and development become transparent by finding and understanding what the customer's need [26], thus one of the step in this method is creating the House of Quality (HoQ) which represent the customer's needs and the specification of the product. Implementing QFD will most likely having several impact such as : a) Finding and could prioritizing both spoken and unspoken customer needs. b) Translating theirs needs into technical characteristics via HoQ. c) Building and delivering a quality product (or services) by focusing on customer's satisfaction. [27].

Based on the research background, this paper will mostly covering on the redesigning process of the shoes in Rejowinangun Original Leather SME, as the mentioned SME are mostly having its product's design quite outdated compared to the other shoes-making SME. Rejowinangun Original Leather mostly relies on another distributor to supplies their catalog, as the consequences of it's poorly design shoes. Both Kansei and QFD method are implemented in this research in order to create a more aesthetic shoes that could help to boost the sales of Rejowinangun Original Leather, as it is now most of their best selling products are the one that the SME does not create by itself. KE, has the approach in aesthetic sides, some products, such as fashion, should be having an aesthetic approach in order to help to enhance the current design, whereas QFD will mostly be used to establish the specifications of the wanted product, thus author could decide what color, size, shape or any design related things that could help boosting the sales of the shoes in Rejowinangun Leather.

## 2. METHODS

This research is can be dividied into two (2) big steps. The first part of this research is conducted using Kansei Engineering, while the latter, is done in QFD Method.

The KE method, is used to find the customer's needs, hidden in their feelings, words or action that being represented in Kansei Words. The Kansei words, in this research, are found in online forum in several platform or application that mostly talking and commenting about shoes. The Kansei words that been collected than being used to create the questionnaires that will be spreaded into the customers.

QFD is then used on the next step. Using the customers need that been found by the KE method, authors could build up a HoQ model that could fit and answer's all of the needs that been found in the previous step. This step will provide several parameters result that could be used to create a final design. This final design, will be returned back to the respondent of the research in order to be validated by them. The validation given by the respondents will be in a form of comments on the final design whether it is finally relevant to their needs or not. The validation process, will be conducted through a questionnaire along with the newly designed shoes. The questionnaire used in this validation process basically a simple question .

The validated design most likely become the final design of the shoes that could be used by Original Leather Rejowinangun SME to boost their sale.

## 3. RESULTS AND DISCUSSION

### 3.1. Kansei Words Mining

KE solely relies on the impression and feels that customers felt when seeing, hearing or even wearing the products. The first step in this research is done by collecting the *Kansei Words* that will be used in KE method. Kansei words were mined from 30 students of Universitas Ahmad Dahlan (UAD) Industrial Engineering's students that become the main respondents in this research. The words were solicited using *Google Form* because it is unable to collect the words using regular method such as interview due to Covid-19. The results of the solicitation process of the Kansei words, is shown in Table 1 below

Tabel 1 Potential Mined Kansei Words

| Number | Mined Text (in Indonesian)                                    |
|--------|---------------------------------------------------------------|
| 1      | <i>Indahnya</i>                                               |
| 2      | <i>Keren Hitam Polos</i>                                      |
| 3      | <i>Motif Camo Realtree Bagus</i>                              |
| 4      | <i>Warna Putih Bagus</i>                                      |
| 5      | <i>Keren Banget</i>                                           |
| 6      | <i>Keren Pisan Euy</i>                                        |
| 7      | <i>Warna Tan Bagus</i>                                        |
| 8      | <i>Soft Sekali Warnanya Tan</i>                               |
| 9      | <i>Ganteng</i>                                                |
| 10     | <i>Manis</i>                                                  |
| 11     | <i>Cakep Banget</i>                                           |
| 12     | <i>Ganteng Banget</i>                                         |
| 13     | <i>Halus Dan Rapih</i>                                        |
| 14     | <i>Materialnya Benar-Benar Bagus</i>                          |
| 15     | <i>Sol Dan Kulitnya Tebal</i>                                 |
| 16     | <i>Good Price Good Quality</i>                                |
| 17     | <i>Model Lama Bagus</i>                                       |
| 18     | <i>Desain Rapi Dan Terlihat Casual</i>                        |
| 19     | <i>Bagus Ya Warnanya Pastel</i>                               |
| 20     | <i>Warnanya Manis Karena Pastel</i>                           |
| 21     | <i>Warna Kulit Mengkilap</i>                                  |
| 22     | <i>Kelihatan Formal</i>                                       |
| 23     | <i>Desainnya Simple Bagus</i>                                 |
| 24     | <i>Jangan Pakai Logo Yang Itu, Jadi Kelihatan Kurang Unik</i> |

Mined text that have been collected mostly can be grouped into several groups, it is because several mined text somehow have similarity. Using the grouped mined text, we could extract the final Kansei Words that being shown in Table 2

Table 2 Kansei Words

| Number | Kansei Words (in Indonesian) |
|--------|------------------------------|
| 1      | <i>Indah</i>                 |
| 2      | <i>Berwarna Hitam</i>        |
| 3      | <i>Bermotif Camo</i>         |
| 4      | <i>Berwarna Putih</i>        |
| 5      | <i>Elegan</i>                |
| 6      | <i>Berwarna Tan</i>          |
| 7      | <i>Desain Menarik</i>        |
| 8      | <i>Bertekstur Halus</i>      |
| 9      | <i>Material Berkualitas</i>  |
| 10     | <i>Kulit Tebal</i>           |
| 11     | <i>Sol Rapih</i>             |
| 12     | <i>Harga Bagus</i>           |
| 13     | <i>Old School</i>            |
| 14     | <i>Desain Menarik</i>        |
| 15     | <i>Kasual</i>                |
| 16     | <i>Berwarna Pastel</i>       |
| 17     | <i>Mengkilap</i>             |
| 18     | <i>Formal</i>                |
| 19     | <i>Simple</i>                |
| 20     | <i>Tidak Unik</i>            |

Using the 20 Kansei Words, we could proceed to create the Semantic Differential Questionnaire/ Kansei Questionnaire that will be used to find the customers need. The Semantic Differential Questionnaire is shown in Table 3 below.

Table 3 Kansei Semantic Differential

| Kansei (in Indonesian)  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Kansei (in Indonesian)  |
|-------------------------|---|---|---|---|---|---|---|-------------------------|
| <i>Tidak Indah</i>      |   |   |   |   |   |   |   | <i>Indah</i>            |
| <i>Berwarna Putih</i>   |   |   |   |   |   |   |   | <i>Berwarna Hitam</i>   |
| <i>Polos</i>            |   |   |   |   |   |   |   | <i>Bermotif Camo</i>    |
| <i>Tidak Elegan</i>     |   |   |   |   |   |   |   | <i>Elegan</i>           |
| <i>Berwarna Pastel</i>  |   |   |   |   |   |   |   | <i>Berwarna Tan</i>     |
| <i>Mewah</i>            |   |   |   |   |   |   |   | <i>Kasual</i>           |
| <i>Bertekstur Kasar</i> |   |   |   |   |   |   |   | <i>Bertekstur Halus</i> |
| <i>Kulit tipis</i>      |   |   |   |   |   |   |   | <i>Kulit Tebal</i>      |
| <i>Sol Tidak Rapih</i>  |   |   |   |   |   |   |   | <i>Sol Rapih</i>        |
| <i>Harga Murah</i>      |   |   |   |   |   |   |   | <i>Harga Bagus</i>      |
| <i>Membosankan</i>      |   |   |   |   |   |   |   | <i>Desain Menarik</i>   |
| <i>Model Modern</i>     |   |   |   |   |   |   |   | <i>Model Klasik</i>     |
| <i>Pucat</i>            |   |   |   |   |   |   |   | <i>Mengkilap</i>        |
| <i>Umum</i>             |   |   |   |   |   |   |   | <i>Unik</i>             |
| <i>Desain In-Formal</i> |   |   |   |   |   |   |   | <i>Desain Formal</i>    |
| <i>Kompleks</i>         |   |   |   |   |   |   |   | <i>Simple</i>           |

The Kansei Questionnaire shown above, will be spread into 30 respondents, whom are the students of Industrial Engineering of UAD, the result is shown below.

Table 4 Kansei Questionnaire Recap

|            |    | Kansei Words |    |    |    |    |    |    |    |    |     |     |     |     |     |     |     |
|------------|----|--------------|----|----|----|----|----|----|----|----|-----|-----|-----|-----|-----|-----|-----|
|            |    | K1           | K2 | K3 | K4 | K5 | K6 | K7 | K8 | K9 | K10 | K11 | K12 | K13 | K14 | K15 | K16 |
| Respondent | 1  | 3            | 3  | 3  | 3  | 2  | 2  | 2  | 1  | 3  | 2   | 3   | 1   | 3   | 3   | 3   | 3   |
|            | 2  | 6            | 7  | 1  | 7  | 6  | 7  | 7  | 2  | 6  | 5   | 6   | 7   | 6   | 2   | 4   | 6   |
|            | 3  | 3            | 3  | 2  | 2  | 2  | 4  | 4  | 4  | 4  | 3   | 3   | 3   | 4   | 4   | 3   | 3   |
|            | 4  | 4            | 3  | 2  | 3  | 2  | 3  | 2  | 4  | 4  | 2   | 3   | 2   | 3   | 3   | 3   | 3   |
|            | 5  | 2            | 1  | 3  | 3  | 1  | 1  | 1  | 3  | 4  | 3   | 2   | 3   | 3   | 1   | 3   | 2   |
|            | 6  | 6            | 6  | 3  | 5  | 6  | 5  | 6  | 6  | 3  | 3   | 5   | 6   | 5   | 6   | 2   | 6   |
|            | 7  | 6            | 6  | 5  | 5  | 6  | 3  | 3  | 5  | 7  | 6   | 5   | 7   | 6   | 3   | 4   | 5   |
|            | 8  | 3            | 3  | 5  | 6  | 5  | 6  | 5  | 7  | 6  | 6   | 3   | 5   | 5   | 7   | 6   | 6   |
|            | 9  | 2            | 3  | 1  | 3  | 3  | 3  | 3  | 3  | 6  | 1   | 3   | 3   | 3   | 3   | 1   | 3   |
|            | 10 | 2            | 2  | 1  | 2  | 2  | 2  | 1  | 2  | 3  | 2   | 2   | 2   | 1   | 2   | 1   | 2   |
|            | 11 | 1            | 3  | 1  | 1  | 3  | 3  | 3  | 3  | 3  | 2   | 3   | 1   | 3   | 2   | 2   | 3   |
|            | 12 | 2            | 2  | 1  | 2  | 2  | 2  | 3  | 3  | 3  | 3   | 3   | 3   | 4   | 3   | 3   | 3   |
|            | 13 | 2            | 3  | 3  | 2  | 1  | 3  | 1  | 3  | 1  | 1   | 3   | 3   | 1   | 2   | 2   | 3   |
|            | 14 | 1            | 7  | 4  | 1  | 4  | 7  | 7  | 4  | 7  | 1   | 4   | 6   | 5   | 3   | 2   | 7   |
|            | 15 | 3            | 3  | 3  | 3  | 2  | 3  | 3  | 3  | 3  | 2   | 3   | 3   | 3   | 2   | 3   | 3   |
|            | 16 | 3            | 1  | 1  | 3  | 3  | 2  | 3  | 3  | 3  | 1   | 3   | 3   | 1   | 1   | 1   | 3   |
|            | 17 | 3            | 6  | 6  | 7  | 5  | 7  | 6  | 2  | 6  | 1   | 4   | 4   | 2   | 5   | 2   | 6   |
|            | 18 | 2            | 3  | 1  | 2  | 3  | 3  | 3  | 1  | 3  | 1   | 3   | 3   | 1   | 1   | 1   | 3   |
|            | 19 | 5            | 7  | 1  | 7  | 5  | 7  | 7  | 4  | 7  | 4   | 4   | 7   | 4   | 7   | 1   | 7   |

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Figure 1 House of Quality

### 3.3 Quality Function Deployment

The next step in QFD method, is generating the concept of- soon to be- the final product. The concept generation in this research is based on the current product of Rejowinangun Original Leather, and being used as a reference to improve their current product.



Figure 2 Referenced Product

It is shown in the Figure 2, that the referenced shoes or the original product of the SME, is a formal shoes with leather as its main material and it has a gum rubber out-sole. Based on the current product, authors are generating two concept that related with the customer's need and it is shown in Figure 3 and 4 below



Figure 3 Alternate Concept



Figure 4 Alternate Concept

The first concept is the closest design with the current product, this design is the improved design of the previous product that based on several customer's needs, on the other hand, concept 2 is another improved design from the current product too. The second improved design, is based on the customer's need that wanting an in-formal shoes, even though this research focusing more on the formal shoes. It is possible that customer saw the current product of Original Leather is not appealing to their sense, thus it is an insight for the authors as it is become one of the generated concepts in this research.

Benchmarking, in product design and development, is an essential step as it is giving an insight for the developer to compare their own generated concept with the existing product in the market. In this research, authors do a benchmark with several existing product which are closely resembles the current product/referenced product and also the second concept. These two benchmarked shoes, will be used as comparison in the concept screening and scoring process. Both benchmarked shoes is shown in Figure 5 and 6 below.



Figure 5 Benchmarked Product 1



Figure 6 Benchmarked Product 2

Both benchmarked shoes come from the existing product. The first shoes is from *Nappa Milano Edmond Derby*, and it is closely resembles with current product as it is made from leather, gum rubber outsole and a formal shoes. Second one, is from *Exodos57 model Gennaios Green*, and it will be used as a comparison for the second concept as the latter come up from the in-formal shoes needs.

### 3.3 Quality Function Deployment (Concept Screening and Scoring)

Both screening and scoring process, is a way to eliminate unwanted concept and to ensure that the proposed design should go further in the product development or not. The concept that being screened and scored is the first alternative (Figure 3), because of the current product is the formal type shoes, while second alternative is the in-formal type and it will create another different need.

Table 6 Concept Screening

| Screening                                        | Concept         |       |             |             |
|--------------------------------------------------|-----------------|-------|-------------|-------------|
|                                                  | Current Product | Alt I | Benchmark 1 | Benchmark 2 |
| Safe and secure toe tip                          | 0               | +     | +           | +           |
| Having a good material both strength and quality | 0               | +     | +           | 0           |
| Color and motive combination                     | 0               | +     | -           | -           |
| Comfortable counter shoes design                 | 0               | +     | +           | 0           |
| Unique design                                    | 0               | +     | -           | +           |
| Informal casual shoes design                     | 0               | -     | -           | +           |
| Perforation vents Design                         | 0               | +     | +           | -           |
| Comfortable Shoelace design                      | 0               | +     | +           | +           |
| Comfortable outsole design                       | 0               | +     | +           | 0           |
| Strong midsole                                   | 0               | 0     | -           | 0           |
| Elastic collar shoes type                        | 0               | -     | 0           | 0           |
| Safe yet slick shoe tongue design                | 0               | +     | +           | +           |
| Pluses                                           |                 | 10    | 8           | 5           |
| Sames                                            |                 | 1     | 1           | 5           |
| Minuses                                          |                 | 1     | 4           | 2           |
| NET                                              |                 | 9     | 4           | 3           |
| Rank                                             |                 | 1     | 2           | 3           |
| Continue?                                        |                 | Yes   | Yes         | No          |

From Table 6, we could inferred that both Alt 1 (the generated concept) and benchmark 1 is going through the scoring process, the reference product is not getting any ranking but it will go to the next step, it is because the referenced product will become the main comparison for both the alternative and the benchmark. The second benchmark is out of the screening process, because of its irrelevant type and looks compared to the other two.

Table 7 Concept Scoring

|                                                  |        | Concepts  |                |        |                |             |                |
|--------------------------------------------------|--------|-----------|----------------|--------|----------------|-------------|----------------|
|                                                  |        | Reference |                | Alt1   |                | Benchmark 1 |                |
| Selection Criteria                               | Weight | Rating    | Weighted Score | Rating | Weighted Score | Rating      | Weighted Score |
| Safe and Secure Toe Tip                          | 54     | 3         | 162            | 4      | 216            | 4           | 216            |
| Having a Good Material Both Strength and Quality | 60     | 3         | 180            | 4      | 240            | 4           | 240            |
| Color and Motive Combination                     | 142    | 3         | 426            | 5      | 710            | 2           | 284            |
| Comfortable Counter Shoe                         | 18     | 3         | 54             | 4      | 72             | 2           | 36             |
| Unique Design                                    | 129    | 3         | 387            | 5      | 645            | 3           | 387            |
| Informal Casual Shoes Design                     | 69     | 3         | 207            | 5      | 345            | 3           | 207            |
| Perforation Vents Design                         | 98     | 3         | 294            | 5      | 490            | 4           | 392            |
| Comfortable Shoelace Design                      | 93     | 3         | 279            | 4      | 372            | 3           | 279            |
| Comfortable Outsole Design                       | 18     | 3         | 54             | 4      | 72             | 3           | 54             |
| Strong Midsole                                   | 27     | 3         | 81             | 3      | 81             | 3           | 81             |
| Elastic Collar Shoes Type                        | 24     | 3         | 72             | 2      | 48             | 2           | 48             |
| Safe Yet Slick Shoe Tongue                       | 51     | 3         | 153            | 4      | 204            | 4           | 204            |
| Total Score                                      |        | 36        | 2349           | 49     | 3495           | 37          | 2428           |
| Rank                                             |        |           | 3              |        | 1              |             | 2              |
| Continue?                                        |        |           | NO             |        | YES            |             | NO             |

### 3.4 Final Design and Validation Process

Based on both screening and scoring process, it could be concluded that Alternative 1 or the generated concept will be the winning concept for the redesigning process, the following steps would be creating the final design and validated the proposed design back to the respondent

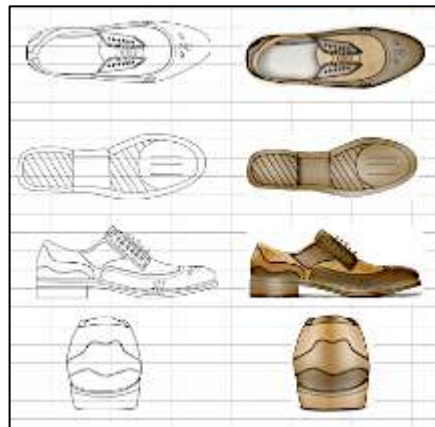


Figure 7 Proposed Final Design

Figure 7 is the proposed final design although it is still need to be validated, the next step is validating Figure 7, by returning back the proposed design to the respondents. Validation is the process which will become an input for the researcher to grasp “unseen” needs by the customers. Validation also acted as a tool to improve further the current design and also possible for researcher to add or even remove several features of the current proposed design.

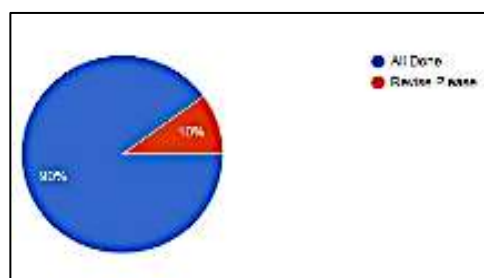


Figure 8 Validation Process

The validation process, shown in Figure 8, provides an information that the current design is good enough for the respondent, although 10% of the respondents still demanded an improvement on the proposed design, mainly talking about a distinctive feature on the back part of the shoes, thus, authors provide an improved design based on the suggestion that is shown in Figure 9 and 10 below.



Figure 9 Final Design of the Shoes



Figure 10 Change of Design

On the previous step, authors could generate 2 designs based on the customer's need, although authors only focusing on redesigning on the current product as an improvement. The second design, as it is also part of the customer's need, would be better to help the SMEs grow better in the future. Having another type of shoes, most likely help the SME to gain another segment of market, namely the youngsters. The proposed design, is also undergo the same steps as the previous design, which will also having a validated process by the respondent. Both the proposed design and the validated design by the respondent (Final Design) are shown in both Figure 11, 12 and 13 below

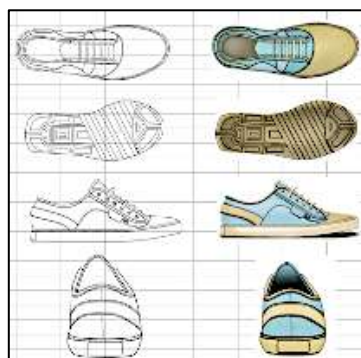


Figure 11 Proposed Design

Figure 11 is the proposed design, that expected could help the sales for Original Leather, this proposed design is then validated to the same respondent for the first design



Figure 12 Final Design of the Informal Shoes

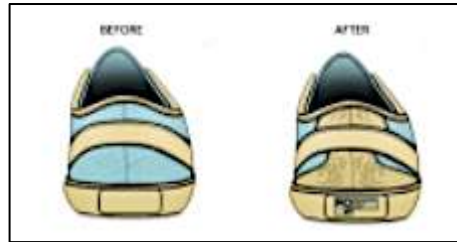


Figure 13 Change of Design

The same responses obtained for the second alternative. Respondents feel the lack of identity for the proposed design, thus authors provide the SME logo and put it in the back heel of the shoes. Based on the result, the usage of Kansei Engineering could be applied in fashion item, because of its relations with aesthetic things. It is strongly believed that fashion relates a lot with aesthetic and several other parameters such as price, quality and so on. QFD, is also a staple tool in Product Design, as it helps researcher in determining what should or should not be implied and incorporated on the product, therefore the integration of both theories should be able to be used in most of fashion products.

#### 4. CONCLUSION

Creating a brand image, in some way, will boost customer satisfaction. Customer, for an SME, somehow plays an important role in their continuity, and one of the ways to raise customer satisfaction, is by creating a good product both design and function. Original Leather, is one of an SME in Yogyakarta that somehow lacks a proper design in their product and ended up having trouble with their sales. Using KE and QFD as the tools has made an impact in changing the looks of their design, the referred shoes have significant changes as it is shown in Figure 9 and 10 after undergoing several steps and validation with the respondents. Authors also provide another design that hopefully could gain and grasp another segment, which is the youngsters. Undergoing the same steps, the newly proposed design are shown in both Figure 12 and 13. This newly made concept is expected to gain another new segment of market that could help boosting the sales level. The applied method in this research significantly helps the SME in making a better yet aesthetic product.

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