POLITEKNIK NEGERI BALI

Journal of Engineering Design and Technology

logic

Vol. 23 No. 1, Maret 2023

LOGIC

Jurnal Rancang Bangun dan Teknologi

p-ISSN. 1412-114X

e-ISSN. 2580-5649

LOGIC

Jurnal Rancang Bangun dan Teknologi

Journal of Engineering Design and Technology

Gedung P3M, lt.1 Politeknik Negeri Bali, Bukit Jimbaran
PO BOX 1064 Kuta Selatan, Badung, Bali - Indonesia
Telp. (+62)361 701981 Fax. (+62)361 701128
Email: logic@pnb.ac.id

LOGIC JOURNAL TEAM

PREFACE

Logic: Jurnal Rancang Bangun dan Teknologi (Journal of Engineering Design and Technology) is a peer-reviewed research journal aiming at promoting and publishing original high quality research in all disciplines of engineering and applied technology. All research articles submitted to Logic should be original in nature, never previously published in any journal or presented in a conference or undergoing such process across the world. All the submissions will be peer-reviewed by the panel of experts associated with particular field. Submitted papers should meet the internationally accepted criteria and manuscripts should follow the style of the journal for the purpose of both reviewing and editing.

Logic is a journal covering articles in the field of civil and mechanical engineering, design, and technology published 3 times a year in March, July, and November. Language used in this journal is English.

LOGIC. P-ISSN 1412-114X
LOGIC. E-ISSN 2580-5649
Indexing : GOOGLE SCHOLAR, DOAJ, EBSCO OPEN SCIENCE DIRECTORY, SINTA, GARUDA

Best Regard,

LOGIC Editorial Team

TABLE OF CONTENTS

LOGIC
Journal of Engineering Design and Technology
Vol.23 No.1 March 2023; p. 1 - 7

p-ISSN : 1412-114X
e-ISSN : 2580-5649
http://ojs2.pnb.ac.id/index.php/LOGIC

WATER CONDITIONING REFRIGERATION SYSTEM DESIGN AND CONSTRUCTION FOR LOBSTER CULTIVATION

Wardika [1], Yudhy K [1], Hadi Prasetyo [1], Sintya Haula H. [1]

[1] Refrigeration and Air Conditioning Engineering Department, Indramayu State Polytechnic, Street Lohbener Lama No. 08 Lohbener, Indramayu, Indonesia

Correponding email [1] :

wardika@polindra.ac.id

This research is to determine the cooling burden of the water conditioning system for lobster conditioning, where water must be conditioned to its temperature by its 21°C conditioning. This device uses steam compression systems precisely by utilizing water conditioning systems to condition water to stay awake at a temperature of 21°C. The method used in this study was to determine the volume of the water tank and its cooling capacity by calculating the cooling load calculating the heat load through the walls of the water tank and other heat generated. For lobster cultivation, an air conditioning machine with a capacity of 0.5 PK was used. Following a 3-hour test of the performance of the system, the following results were obtained: evaporation temperature of 15.2 °C and a product temperature of 21 °C obtained a Carnot COP of 7.11, an actual COP of 5.87, and an efficiency of 82.55%. This is in accordance with Design Carnot COP 8, actual COP design of 6.7, and design efficiency of 83%.

Kata kunci : Lobster, Cooling Load, COP, Efficiency, Refrigeration

1. INTRODUCTION

Freshwater lobster is a freshwater fishery commodity that has the potential to be developed as a cultivation commodity. In addition, this freshwater crayfish has a fairly high nutritional content, especially protein, and has a character that is not easily stressed and is not easily attacked by disease if the feed requirements and water quality are good. In good freshwater crayfish cultivation, the water quality is usually around 21°C to 28°C. With a degree of acidity (pH) in the range of 6–8, the maximum ammonia content in the water is 1.2 ppm, and the turbidity level is 30–40 cm [1]. In research (Hiwari 2018), it is also stated that water quality is also an important factor that must be investigated for the suitability of this lobster cultivation for the survival of the lobster to be cultivated [2]. Specifically, to maintain the quality of the water temperature between 21°C and 28°C. Research (Kurniasih 2008) states that freshwater crayfish (Cherax) habitats are shallow water flows and fresh water, such as lakes, swamps, and rivers. If the depth is less than 0.8 meters, it will cause death due to changes in temperature during the summer. The optimum growth of freshwater crayfish (Cherax) is in the temperature range of 21°C to 29°C Temperatures that are too low or too high will interfere with growth, with a tendency to immerse themselves in mud or become inactive [3]. In research (Roskiana et al. 2018), researchers conducted research on the use of a refrigeration system to cool water for hydroponic media because farmers experienced obstacles caused by the air temperature in Indonesia, which was too high so that it affected the results of hydroponic plant growth and resulted in good engine performance [4]. Therefore, this research will also utilize the air-conditioning (AC) refrigeration system for conditioning the water temperature in lobster cultivation.

Refrigeration is a process of absorbing heat in an object where each object will have a heat content whose amount depends on the temperature of the object [5]. The vapor compression refrigeration system is basically a system with an energy balance where the energy absorbed by the evaporator comes from the product discharged by the condenser through water or other cooling media in the system. This system has four main components, where each component has an important role in the running of the system. The 4 main components of the

refrigeration system are the compressor, condenser, expansion, and evaporator [9].

Pressure-enthalpy diagram for a standard vapor-compression cycle

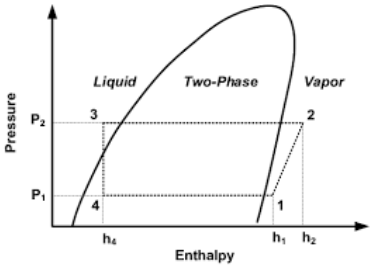


Figure 1 Vapor Compression Cycle P-h Diagram [10]

Based on Figure 1 Pressure-enthalpy diagram for a standard vapor-compression cycle, this vapor compression system also has 4 cycles where refrigerant vapor (freon) is compressed in the compressor and then condensed into a liquid in the condenser. The refrigerant liquid pressure is lowered in the expansion device (capillary pipe or expansion valve) so that the refrigerant is in liquid form and can then evaporate in the evaporator [6].

So, in this study, the air conditioning (AC) refrigeration system is no longer a food conditioning device but will be applied as a tool that will help condition water temperature in freshwater crayfish cultivation.

In this study, the authors will collect experimental data regarding system design and system performance, time, the value of COP (Coefficient of Performance), and to determine the cost of using a water conditioning system for lobster cultivation.

Thus, it is possible to determine the effectiveness of the air conditioning (AC) system in the lobster cultivation water conditioning system, as well as to determine the feasibility of system performance in terms of system performance, including the COP value, and the success of system design in lobster cultivation.

Based on research (Effendi and Setiawan 2016) entitled "Design of Refrigerated Sea Water (RSW) Dry System on 58 GT Fiber Plywood Fishing Vessel with 45 M3 Hatch Capacity" states that Refrigerated Sea Water (RSW) has several pipes that function to suck seawater to be processed into cold water and then connected to the fish storage hatch. In this study, RSW uses a capacity of 40 HP with refrigerant type R22. The results obtained from this study are that it takes 2 hours to reduce the temperature to 0°C and to reach the hold temperature of -23°C it takes 3 hours. The high pressure reaches 140 Psi while the low pressure reaches -10 Psi. and obtained a COP value of 4.5708 [7].

Based on research (Education et al., 2014), in a study entitled "Increasing COP (Coefficient of Performance) Car AC System Using Condensed Water," it states that coefficient of performance (COP) is one of the indicators in the refrigeration system that determines the work of the system. COP itself is a comparison between refrigeration capacity and compressor power. Performance (COP) can also be defined as the ratio between the refrigeration effect and the compression work required to compress the refrigerant in the compressor. Therefore, the greater the performance value (COP), the better the performance of the refrigeration system. The greater the performance value (COP), the more efficient the refrigeration machine. Factors that affect the COP value include the impact of refrigeration and changes in compression work [8].

2. METHODS

This research uses the design method. The design method was carried out to obtain design data, machine manufacture, and performance testing of the water conditioning refrigeration system for lobster cultivation. The following is a flowchart of this research, which is shown in Figure 2.

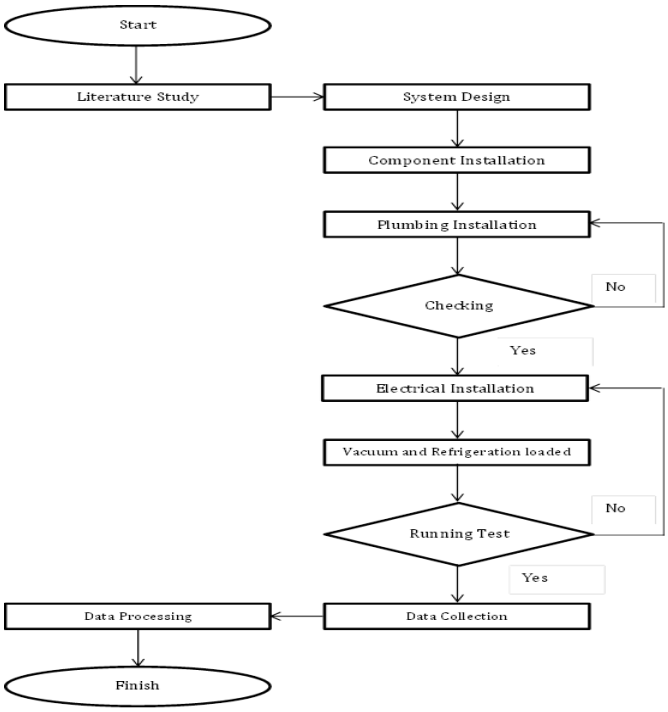


Figure 2 *Implementation Flow Chart*

The design carried out in this study started with making lobster racks with a height of 1.5 meters, a length of 83 cm, and a width of 63 cm for lobster storage of 1 package lobster/pond, then continued with the manufacture of two loser ponds made of plastic with The size is 55 cm in diameter, 87 cm in length and 27 cm in depth, so that in two ponds the number of lobsters is 20. In addition, in this study, using a compressor with a capacity of 0.5 PK and one evaporator, and adjusting the size of the evaporator to the suction pipe, the condenser used is a type of air-cooled condenser with a fan whose capacity is equal to the capacity of the compressor, while the expansion device uses a capillary tube with a length and diameter are adjusted to the compressor capacity.

Of the four components that are already available, the assembly process is carried out with the equipment and materials that have been provided to form a unit according to the design. This tool will be used for research, so it will be designed and built in such a way that it can be used as research for all of you. This unit will be designed to produce water at a temperature of 21°C, and this cooling system will use refrigerant type R32.

The calculation of the cooling load is divided into several parts, namely the calculation of the wall cooling load and the calculation of the product cooling load. Count the burden of cooling the wall, that is:

$Q_{wall} = U \times A \times \Delta t$ (Equation 1.1) [9].

Where:

Q_{wall}	= Heat Load on the Wall (Watt)
U	= Heat Transfer Coefficient on The Wall (Watt/m^2. K)
A	= Room wall surface area. (m^2)
ΔT	= The difference between the ambient temperature and the room (K)

To get the value of U, obtained by the following equation,

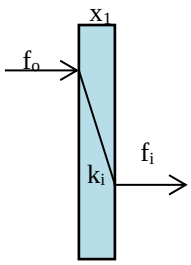


Figure 3 Cabin Material

$$U = \frac{1}{\frac{1}{f1}+\frac{x1}{k1}+\frac{1}{fo}} \quad \text{(Equation 1.2)}$$

Where:

f_o = The coefficient of convection in the environment (Watt/m^2. K)
k_1 = The thermal conductivity of the nth wall layer (Watt/m.K)
x_1 = The thickness of the nth wall layer (m)
f_1 = The coefficient of convection in space (Watt/m^2K)

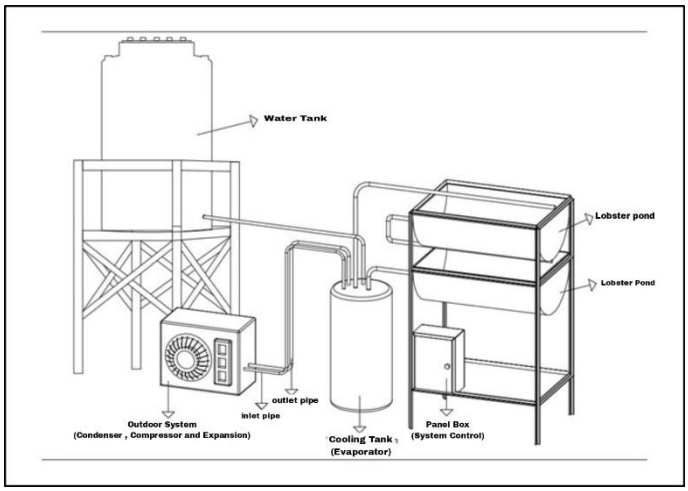


Figure 4 Lobster Cultivation Water Conditioning Device Design.

Table 1 Cooling tank wall material

Cabin Construction	Thickness (m)	Conductivity (W/m.K)	Thermal Conductance (W/m^2.K)
Inside air (f_{in})	-	-	9.37
Plastic	0.002	0.15	-
Outside air (f_{out})	-	-	22.7

By using equation 1.2,

$$U = \frac{1}{\frac{1}{f1}+\frac{x1}{k1}+\frac{1}{fo}} \quad \text{(Equation 1.2)}$$

Then the resulting wall load of 6,12 W/m^2K.
To calculate the heat load generated by the walls in the cabin, namely:

Q = U x A x ΔT
= 6.12 W/m^2. K x 1.25m^2 x 11 K
= 84.15 watt

3. RESULTS AND DISCUSSION

Table 2 System Performance Comparison

Variable	System Test	System Design
The Cooling Tank Temperature (°C)	21	21
Evaporation Temperature (°C)	15.2	10
Condensing Temperature (°C)	55.7	40
Discharge Pressure (bar)	36	30
Suction Pressure (bar)	13,5	11
qw (kJ/kg)	40	35
qc (kJ/kg)	275	270
qe (kJ/kg)	235	235
Rate of Refrigerant Mass Flow ṁ (kg/s)	0.0093	0.0108
Qw (kW)	0.34	0.378
Qc (kW)	2.37	2.9
Qe (kW)	2.03	2.5
COP actual	5.87	6.7
COP carnot	7.11	8
Efficiency (%)	82.55	83
Current (A)	1.2	1.7
Real Power (watt)	244.64	299.2

The results from the data above show that the design with the test results is not much different in value, so that the design of the water conditioning system for lobster cultivation can run well. From the results of electricity consumption for one month, it is more efficient than other freeze dryer designs. The results of this study can be distributed to public services because electricity consumption is very efficient and this design is very easy to use for the general public and has used very sophisticated technology to regulate water temperature conditions for lobster cultivation.

The following is a data graph of the performance of the air conditioning system for water conditioning in lobster cultivation.

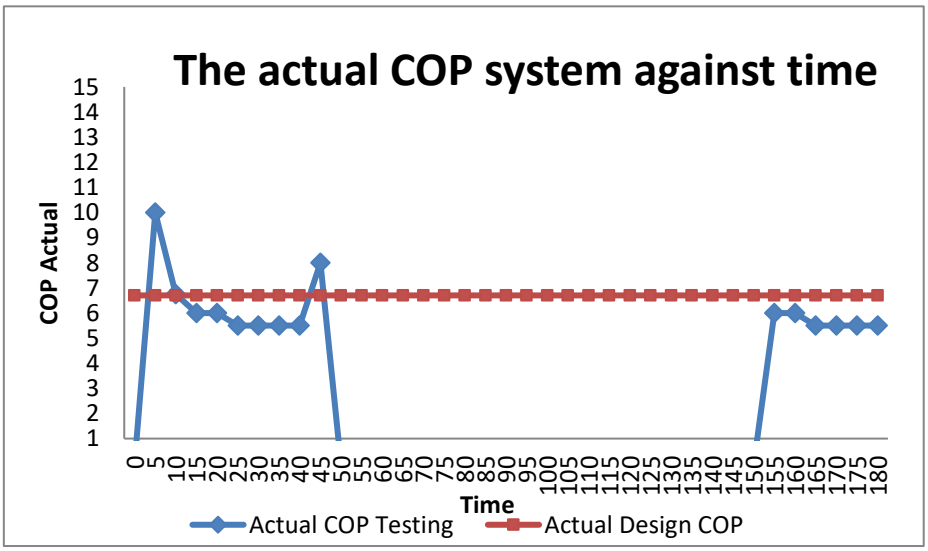


Figure 5 Actual COP of the system

Figure 5 above explains that the actual COP of the test results has an actual COP value of 5.87 while the actual COP of the design results has a value of 6.7. This happens due to the influence of the value of the refrigeration effect and compression work at the time of testing but does not have a very large difference so that the system can run properly according to the design.

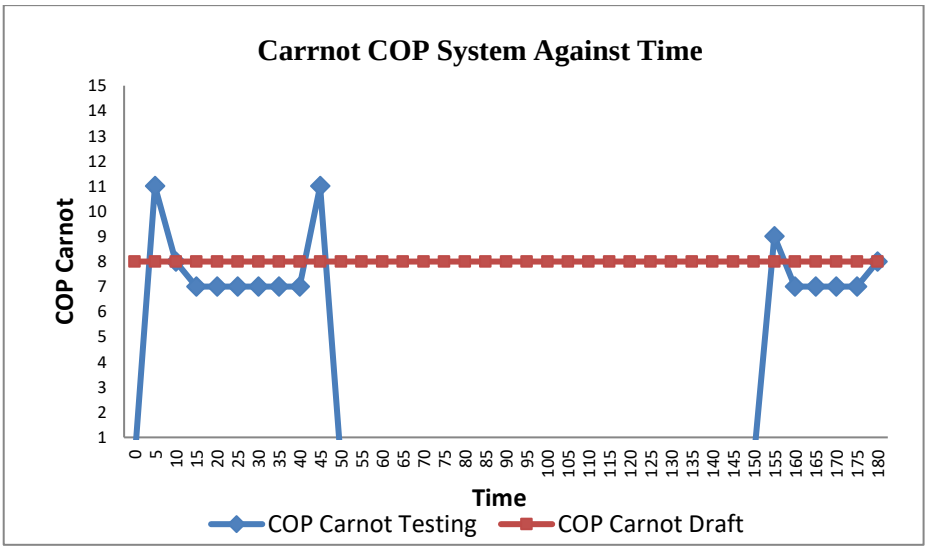


Figure 6 COP Carnot System

Figure 6 above explains that the Carnot COP from the test and design has a different COP Carnot value, namely the Carnot COP in the design is 8, while the Carnot COP from the test is 7.11. This proves that the design that has been made has a good performance value because at working temperatures, or saturation temperatures, both condensation and evaporation occur, the maximum COP that can be obtained for the system is COP Carnot. So it can be said that the larger the coefficient value, the more efficiently the system will work.

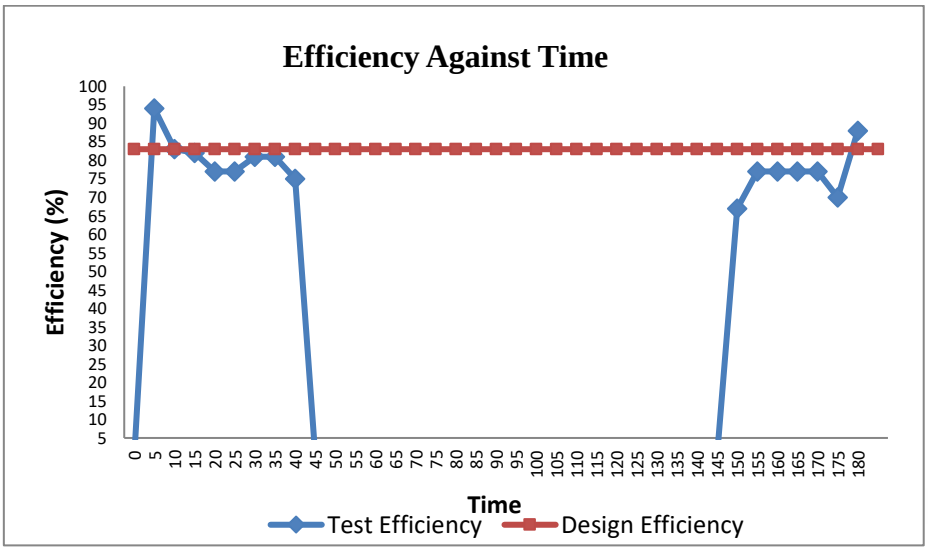


Figure 7 System Efficiency

In charts, the performance value of test systems has a smaller average of 82.55% than the design system's average of 83%. his can happen because it is influenced by several factors, ranging from ambient temperature to the mass of the refrigerant used. Based on the data in table 2, it is also shown that the refrigerant mass flow rate at the time of testing is lower than the refrigerant mass flow rate in the design, which affects the performance value of the air conditioning system for water conditioning in lobster cultivation. However, the overall performance value of this system at the time of testing did not experience a very large difference from the design performance value, so that the system continued to run well.

4. CONCLUSION

After all the processes are completed, starting from the design, the system installation process, the testing process, and the data retrieval process, So it can be concluded:

1. System cooling load or cooling load based on calculation results of 381.7 watts: in this system, the compressor we use is 0.5 PK.
2. The engine cooling time can be said to be successful because when the temperature reaches 21°C after 45 minute, and within 3 hours, the system can reach 21°C twice, while the design data takes 3 hours, or 180 minutes. So it can be said that this system works well because it experiments with the time it takes to cool the water faster than the time to cool the water in the design.
3. The performance of the water conditioning system in lobster cultivation resulted in the actual COP value at the time of testing at 5.87 and the actual COP at the design being 6.7. The Carnot COP value at the time of testing obtained a value of 7.11 and the Carnot COP in the design of 8. While the efficiency value at the time of testing was obtained, the average value was 82.55%, and the design efficiency was 83%. So it can be said that this cooling system works well because the efficiency values at the time of the experiment and the efficiency values of the design do not have a significant difference in average values.
4. From the results of testing tools, it can be concluded that the application of the refrigeration system for conditioning lobster culture water is feasible to use because the system that works on it has good performance.

5. REFERENCES

[1] S. S. Tumembouw, "Kualitas Air Pada Kolam Lobster Air Tawar (Cherax Quadricarinatus) Di Bbat Tatelu," *J. Perikan. Dan Kelaut. Trop.*, vol. 7, no. 3, p. 128, 2011, doi: 10.35800/jpkt.7.3.2011.190.

[2] H. Hiwari, "Estimasi Pemanfaatan Lahan Perairan Sekitar Pulau Batu Nusamanuk Di Kabupaten Tasikmalaya Sebagai Daerah Budidaya Lobster (Panulirus spp)," *Semin. Nas. Geomatika*, vol. 2, p. 47, 2018, doi: 10.24895/sng.2017.2-0.396.

[3] T. Kurniasih, "Lobster Air Tawar (Parastacidae: Cherax), Aspek Biologi, Habitat, Penyebaran, Dan Potensi Pengembangannya," *Media Akuakultur*, vol. 8, no. 1, p. 31, 2008, doi: 10.15578/ma.8.1.2013.31-35.

[4] E. Roskiana, E. T. Berman, D. Mutaufiq, and N. Diterima, "Uji Performa Prototipe Mesin Pendingin Air Kapasitas 500 Liter Untuk Media Hidroponik Informasi Artikel Abstrak," 2018. [Online]. Available: http://jurnal.untirta.ac.id/index.php/jwl.

[5] E. Erita, S. E. Darza, A. P. Kurniawan, and N. Nofrizal, "The Main Refrigeration Compressor di KM. Sabuk Nusantara 37 pada PT. Pelni," *Maj. Ilm. Bahari Jogja*, vol. 19, no. 2, pp. 20–34, 2021, doi: 10.33489/mibj.v19i2.271.

[6] H. S. K. Kupang, K. Oktober, C. Storage, M. Perangkat, and L. Coolpack, "Seminar Nasional Sains Dan Teknik Fst Undana (Sainstek)," no. 2017, pp. 433–439, 2019.

[7] R. Effendi and I. Setiawan, "Perancangan Refrigerated Sea Water (RSW) Sistem Kering Pada Kapal Ikan Kayu Lapis Fiber 58 GT Dengan Kapasitas Palka 45 m3," *SINTEK J. J. Ilm. Tek. Mesin*, pp. 56–66, 2016, [Online]. Available: https://jurnal.umj.ac.id/index.php/sintek/article/view/1442.

[8] S. Pendidikan, T. Mesin, F. Teknik, U. N. Surabaya, and A. W. Grummy, "Peningkatan Cop (Coefficient Of Performance) Sistem Ac Mobil Dengan Menggunakan Air Kondensasi," vol. 02, 2014.

[9] Dossat Roy J. 1981. Principles Of Refrigeration, S1 Version, Houtson Texas : Jhon Wiley & Sons.

[10] W. Wardika, A. Setiawan, and T. W. Fitriyani, "Pengaruh Perubahan Temperatur Kabin Terhadap Kinerja Pada Sistem Refrigerasi Freeze Drying", *politeknologi*, vol. 20, no. 3, pp. 231–237, Sep. 2021.

LOGIC
Journal of Engineering Design and Technology
Vol. 23 No.1 Maret 2023 ; p. 8 - 15

p-ISSN : 1412-114X
e-ISSN : 2580-5649
http://ojs2.pnb.ac.id/index.php/LOGIC

SIMULATION DESIGN OF ANIMAL WASTE TREATMENT INSTALLATION SYSTEM USING WATER LEVEL CONTROL SYSTEM

I Nyoman Gunung[1], I Nengah Ludra Antara[1*], I Nyoman Sutarna[1], Kadek Agus Mahabojana D.P[2], Made Dika Nugraha[2]

1) Mechanical Engineering Department, Politeknik Negeri Bali, Badung Indonesia
2) Warmadewa University, Denpasar, Indonesia

Correponding email [1)] : nengahludraantara@pnb.ac.id

Abstract. The simulation design of this animal waste treatment plant is a design that applies the sewage treatment plant system which is made to cope with environmental pollution, especially rivers due to indiscriminate disposal of animal waste. Making this animal waste treatment plant provides information to readers or the public about how to design an animal waste treatment plant system and the performance of the sewage treatment system so that people know how to deal with environmental pollution caused by the livestock themselves. The manufacture of this installation system uses data collection methods from direct farmers and theories obtained from books, journals, articles related to sewage treatment plant theory, plumbing, electricity, and others. Finally, the data was collected by testing the animal dung waste treatment system where the test data was taken from the pH content of the water used for processing the animal dung waste treatment system. The test results on the sewage treatment plant system concluded that in order to obtain optimal results or water pH content, namely the pH content of 6, it is necessary to deposit animal manure between two to three days, while the maximum processing of this system is the pH content of 6.5. and processing of animal manure, which is on the fourth day to get the maximum pH content.

Keywords: simulation design, animal waste, and level control.

1. INTRODUCTION

Along with the progress of the times and modernization, developments both in the economic field as well as in the field of science and technology are developing very rapidly, coupled with the increasingly rapid flow of information both from within and outside the country, so that the busyness of mankind is increasing. It encourages us as human beings to tend to a practical and efficient lifestyle in all matters of behavior in all fields. For example, in the daily life of residents in rural areas, carrying out activities to maintain several four-legged and two-legged livestock, in maintenance of course the farmers want to raise livestock in a practical way, for example in terms of cage cleanliness, animal waste released by livestock can certainly cause various things. negative, therefore the breeder thinks about how to overcome the negative things caused by the animal waste that is kept by the breeder himself which is commonly called waste [1][2][3].

Waste is organic or inorganic material that is no longer used, so it can cause serious problems for the environment if not handled properly [4][5]. This waste can be in the form of solid, liquid and gas waste which if

not handled properly will have a bad impact on the environment [6]-[8]. Waste originating from the farm will have high economic value if it is treated with the right treatment. There are many ways that can be done to process livestock waste, one of which is processing manure into manure, this method is the simplest way that we often encounter, namely livestock manure is left to dry, by processing the manure it cannot be said to be environmentally friendly, because manure is not environmentally friendly. Livestock processed by drying will cause pollution in the form of gas or odor [9]-[13]. Intervention is needed so as not to damage the environment and work to be more productive [14]-[15].

Research conducted on the processing of livestock manure which is currently an issue as one of the causes of global warming, therefore it is necessary to introduce livestock waste processing technology to the wider community. This prompted the intention to learn about animal waste treatment using existing technology, by means of an automatic system for cleaning animal waste in cages.

The limitations of the problems in the design of the pig manure waste treatment installation system are as follows: (a) Design of an automation system for treating pig manure, (b) In designing an animal dung waste treatment installation system in the manufacture of a miniature simulation of its installation using a water level control system that drives an electric motor, and a submersible pump, blower or aerator turns on automatically through a water level control switch, (c)The calculation uses real data from farmers in the design of this system, while the simulation of the design of the installation system is a mock-up or a small-scale imitation of the original system, (d) The tests carried out are only testing the pH of the water removed from the system treatment process.

The objectives of our research are as (a) to find out how to design a simulation of an animal dung sewage treatment plant system using a water level control system, (b) to find out how the animal waste treatment plant system works using a water level control system. Based on these objectives, the expected benefits of the research results are: (a) reducing disturbances that can occur during the distribution of animal waste disposal channels so as to prevent damage to the surrounding environment, (b) from a scientific point of view, the results of this study are expected to be useful and contribute to the development of knowledge, especially in the problem of animal waste treatment systems, which are related to environmental influences on farmers.

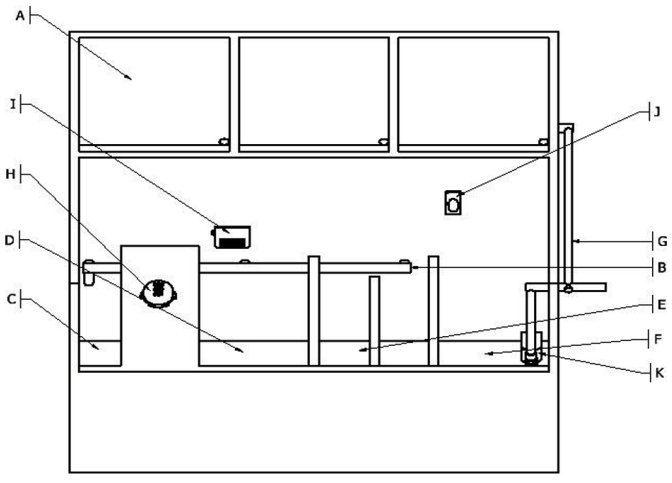
2. METHODS

2.1 Research Procedure

In this type of research, it is divided into two options, namely study or case analysis and testing, and also design. From the choices above, the author chooses the design method because the author will design a sewage treatment system using a water level control system assisted by an electric motor, a blower and a submersible pump. The size of the simulation to be made is 100 cm long, 50 cm wide and 50 cm high overall (Figure 1).

2.2 Design Model

The design model is as follows.



Descriptions:

A. Cage	H. Dynamo
B. Cage Drain	I. Aerator
C. Extractor Tub	J. Water level control
D. Aerator Tub	K. submersible Pump
E. Filter Tub	
F. Chopsticks Tub	

Figure 1. Animal waste treatment system simulation

2.3 Research Instrument

In this design, instruments or tools are needed that support the data collection process from material preparation to obtaining data. The instruments needed are: meter, animal dung, and measuring pH.

2.4 Research Procedure

The stages that will be carried out by the author to get the results of the targeted design are as follows:

1. Conducting literature studies and field surveys, interviews with residents around the river and direct farmers so that they get the data needed in this design.
2. Processing the data obtained so that we get the data that will be used in the design of the animal dung treatment plant system.
3. After that we design in terms of tools or materials, design and layout of the installation needed in designing the system.
4. After that we began to collect the materials needed and started assembling according to the design that has been made.
5. After the mock-up is completed, we start the calculation starting from determining the use of an electric motor that matches the size to be used, as well as blowers and submersible pumps.
6. Then we test the treated water so that it can be said to be clean using the elements obtained

3. RESULTS AND DISCUSSION

3.1 Design Results

This simulation design is designed and made to overcome the problem of river environmental pollution by processing it using the sewage treatment plant method. This simulation design has dimensions of 50 cm high, 50 cm wide and 100 cm long, using a water level control system, electric motor and submersible pump (Figure 2.).

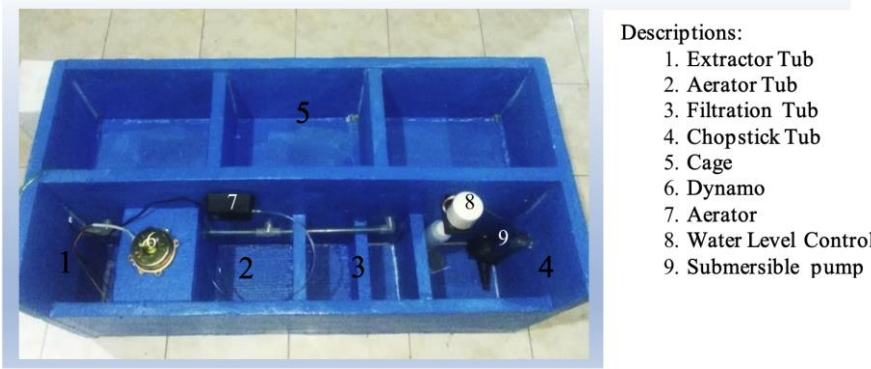


Figure 2. Animal waste treatment system simulation

1. Design Working Principle

The simulation of this animal waste treatment system uses a water level control system that plays a role in the process of processing manure and water. In the design process of the simulation of the animal waste treatment system, the operation is determined by the water level control which is based on the volume of water installed in the chopstick tub, if the tub has reached the full point, the water level control which is an automatic switch will automatically turn on the system then after the volume of water in the sump is reduced, the system will automatically turn off, only the aerator continues to be turned on. This aims to control or can be said to be a safety cost if this simulation is implemented in real time (Figure 2).

2. Design Specification.

a. High total	: 50 cm	f. Cage Length	: 30 cm
b. Width	: 50 cm	g.Tub Height	: 26 cm
c. Length	: 100 cm	h.Tub Width	: 19 cm
d. Cage Height: 23 cm	i. Tub Length	: 23 cm	
e. Cage Width	: 22 cm		

Volume : 30 x 22 x 23 = 15,18 cm^3, 15,18 x 3 Cage = 45,54 cm^3, 45,54 cm^3 : 4 = 11,380 cm^3

So the volume of each tub = 11,380 cm^3

3.2 Discussions

Making a simulation design for processing animal dung is obtained by performing various calculations and tests in accordance with the existing formula.

1. Selection of Materials for Making Simulation Cages and Tubs

The material used in making the simulation of the cage and the tub in the simulation design of the animal waste treatment system is styrofoam with 2 meters length, 1 meter width and 5 cm thickness per styrofoam, the purpose of choosing styrofoam for the simulation of the cage and the tub is to save energy. cost and easy to use in the sense that it is easy to shape according to the series of cages and tubs that we have designed and also styrofoam is water resistant if used correctly. Making this simulation using 3 sheets of Styrofoam.

2. Calculation of Electric Motors, Blowers and Submersible Pumps

The calculation of the minimum power of the dynamo or electric motor to be used is calculated through the volume of the tub used. The tub used has a length of 23 cm, a width of 19 cm, and a height of 26 cm using the formula W x W x H and these numbers have been converted to meters to get a volume of 11.362 liters per tub.

a. Calculation of the power of electric motors, blowers, and submersible pumps
   Q = V/t
b. Power supply calculation
   P = V . I . Cos Ø
c. MCB Current Limiter Determination
   l am = $\frac{Pth}{cos\emptyset}$

3. Plumbing Design

The plumbing design in the simulation of the animal waste treatment plant system uses a water level control system and uses a pipe with a pipe diameter of 16 mm. The plumbing installation in this simulation is divided into three, namely the inlet pipe for sewage into the extractor tank, then the pipe from the submersible pump out branches into two, one is the return channel to the cage, the other is the drainage channel which can later be used again or disposed of.

4. Electrical Installation Design

The design of the electrical installation in this simulation of the animal waste treatment system uses water level control as a switch to turn on the electric motor and submersible pump, for the aerator will continue to run because it does not go through water level control, it only passes through the MCB. The cable used in the simulation of the animal dung waste treatment system installation is an NYY cable with a cable cross-section of 0.75 mm2 with a current carrying capacity of 12 amperes (Figure 2).

5. Material Preparation

Descriptions:
1. MCB
2. Water level control
3. Submersible pump
4. Electric Motor

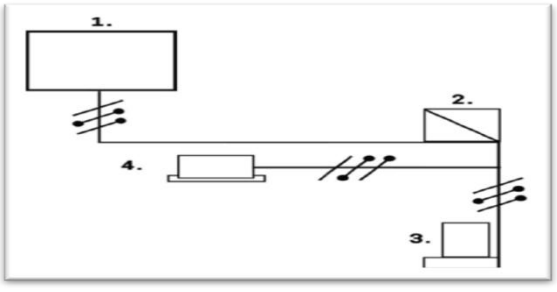


Figure 2. Water level control installation

To expedite the process of making a simulation design for this animal dung waste treatment installation system, it is necessary to prepare the materials to be used that have gone through previous calculations. The following are the materials that are prepared to make a design such as Table 1:

Table 1. Materials

No	Materials	Total
1	Styrofoam 5 cm thick, 2 m length, 1 m width	3 piece
2	Transparent pipe diameter 16 mm, length 2 m	2 piece
3	Dynamo 220V Frequency 50Hz	1 piece
4	Aerator 220 – 240V, Rate 3 L/Min	1 piece
5	Water level control	1 piece
6	submersible pump *output 1*500 L/H	1 piece
7	MCB and MCB boxes 1 ampere	1 piece
8	NYY Cable Cross Section 0,75 mm^2	4 meter
9	Stop valve/faucet	1 piece
10	Electrical Insulation	1 piece
11	Styrofoam and pipe glue	1 piece
12	Waterproof paint	1 kg
13	sealants	1 piece
14	T pipe connection	5 piece
15	L pipe connection	4 piece

6. Cage Simulation Making

[1] Prepare tools, namely: hacksaw, tape measure, marker, brush

[2] Prepare the materials as follows:

a. Styrofoam c. sealants

b. Styrofoam glued. Waterproof paint

[3] Making process

a. Make 1 piece of Styrofoam with 90 cm length and 50 cm width for the back.
b. Make 2 pieces of Styrofoam with a length of 50 cm and a width of 50 cm for the sides.
c. Then unite it using Styrofoam glue.
d. Make the cage by cutting 2 pieces of Styrofoam measuring 23 cm long, 22 cm wide for the sides, and 3pieces of Styrofoam measuring 30 cm long, 22 cm wide for the bottom of the cage.
e. Then make the front of the cage with a length of 90 cm and a width of 50 cm 1 piece.
f. After that unite using Styrofoam glue.
g. Cut the Styrofoam with a length of 26 cm and a width of 19 cm as many as 3 pieces for the tub and 1 piecemeasuring 20 cm long and 19 cm wide for the filter tub.
h. Unite using Styrofoam glue to the front of the Styrofoam cage.
i. Then make 1 piece of Styrofoam with a length of 90 cm and a width of 30 cm for the very front and thenstick it to the front of the tub.
j. After everything is put together, then sealant every corner to avoid leakage and provide holes in each tub for pipelines and holes for electrical cable lines. After that, then paint all parts using waterproof paint.

7. Installation of Plumbing and Main Components

1. Prepare materials and tools such as pipes and their connections, pipe glue, saws, meters, electric motors, aerators or blowers, water level control, submersible pumps, cables and electrical insulation, and MCB and MCB boxes, screws, and screwdrivers.

2. Making Process

a. Cut the pipe as many as 3 pieces with a length of 20 cm, then install it on the simulation tub with 2 L connections and 3 T connections to the extractor tub.

b. Then install the components starting from the electric motor or dynamo, aerator, water level control, and submersible pump as shown in Figure 3.

Figure 3. Main Components

c. After the main components are installed, install the pipe on the submersible pump as a two-pronged outlet, one return channel to the cage and one channel to exit through the faucet later.
d. Then install the MCB and MCB boxes on the left side of the cage, then assemble the electricity starting from assembling the power cable through the MCB and then connecting to the water level control which will be forwarded to the dynamo and pump.
e. Then the aerator will get a direct power supply without going through the water level control. For the neutral cable on each component is connected and mounted on the MCB box.
f. Put the plug on the power cable from the MCB which will be used to get AC from PLN.

8. Finishing Process
   1. Preparing materials for the finishing process, namely electrical insulation, sealants, cable ties, and waterproof paint.
   2. Finishing process
      a. Tidy up the cables using electrical insulation and cable ties.
      b. Sealant on the corners once again to avoid leakage in the system.
      c. Paint the inside of the system once again using waterproof paint.
9. Testing Process
   Testing the simulation design of the animal dung sewage treatment plant system is carried out by measuring the pH content of the treated water and testing is carried out based on time, alum pouring, water volume, and pH content. The test was carried out for 5 days to get the maximum water pH test results in this animal waste treatment system. The testing process is based on time, starting from the pouring of alum, the volume of water, and the deposition of dirt to the processing in which the water coming out of the filtration tank is measured for its pH content.
10. Test Result Data
    Testing the simulation design of the animal dung waste treatment installation system was carried out in the Ubung Kaja area, North Denpasar, Denpasar. In this testing process, data were collected 5 times in 5 days for the results of measuring the pH content of the water (Table 3.2)

Table 3.2 Testing the pH of the water

Deposition Time	Process Time	Water and Waste Volume	Alum Level	pH Content
1 day	10 mins	45.49 liter	45 gram	5.78
2 days	10 mins	45.49 liter	45 gram	5.93
3 days	10 mins	45.49 liter	45 gram	6.20
4 days	10 menit	45.49 liter	45 gram	6.41
5 days	10 menit	45.49 liter	45 gram	6.68

11. Desired pH content in the range of 5.5 to 6.5

From the test results data in table 3.2, the simulation design of the animal waste treatment system where the pH content curve of the water shows that the duration of deposition of the sewage effluent affects the pH content of the water in the treated sewage treatment. The following statistics illustrate the effect of the duration of deposition on the pH content of the treated water as shown in Figure 4.

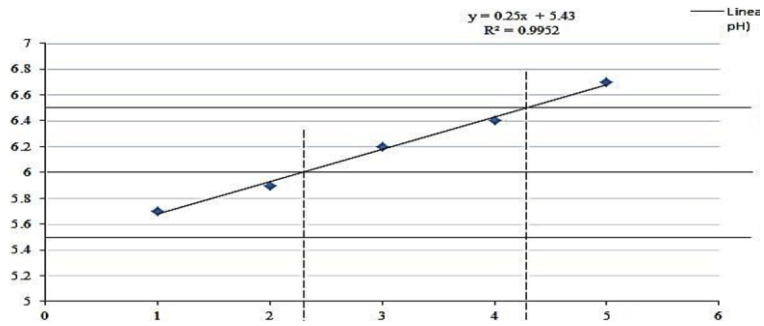


Figure 4. Linear statistics of water pH content

From the statistical picture above, it can be seen that the duration of deposition of animal dung waste affects the increase in the pH content of the water significantly, as seen in the statistics of the optimal value or the optimal pH content of the targeted water, which is at pH 6, where the optimal value point is between the second and third days. it shows that between the second and third days, the duration of deposition is the right day to get optimal water pH results while for the maximum value or maximum pH content, it is on the fourth and fifth day which indicates the maximum duration of dirt deposition in the range of four days to get the optimal pH content. desired is between 5.5 to 6.5.

4. CONCLUSION

Based on the results of the simulation design of the animal dung treatment plant system, it can be concluded:

a. Design and build a simulation of the Animal Manure Waste Treatment System using styrofoam with a thickness of 5 cm as the main material in making the simulation. This design has specifications, namely a total height of 50 cm, a width of 50 cm, and a length of 100 cm. Then for the height of cage 23, the width of the cage is 22 cm, and the length of the cage is 30 cm per tub. The tub has a height of 26 cm, a width of 19 cm, and a length of 23 cm per tub. This design in the processing process is based on the volume of water that will connect the switch to the water level control which will turn on the system and use a filter in the form of wood charcoal and alum as a filter and water purifier.
b. In the test results, it was found that in the simulation design of the animal dung waste treatment system, the duration of the deposition of waste is a factor that affects the pH content of the treated water, obtained for the optimal value or optimal pH content, namely pH 6 is in the deposition between the second and third days, while for the maximum value is on the fourth day to get the pH according to the target.

With the development of the era and technology in the world of mechanical engineering, more knowledge about technology in education is developed, especially in the field of mechanical engineering. In the design of the simulation system for the animal waste treatment plant, there are still many shortcomings, we hope that in the future someone will analyze and develop more deeply this system, and it is recommended that when processing waste, cleaning the filter is always done.

5. REFERENCES

[1] Adrian, K.2020. Ketahui Klorin. Avaliable on: https://www.alodokter.com/ketahui-fungsi-dan-bahaya-klorin. Accesed on November 25, 2022
[2] Amsari, I. 2019. Analisa Unjuk Kerja Pompa Submersibel. Skripsi. Universitas Sumatra Utara
[3] Builder Indonesia. 2018. Dinamo listrik dan bagian-bagiannya. Avaliable on: https://www.builder.id/dinamo-listrik- dan-bagiannya. Accesed on October 02, 2022
[4] Church, Austin HC, Z. Harahap. 1998. Pompa dan Blower Centrifugal. Erlangga. Jakarta
[5] Edahwati, Luluk. 2014. Kombinasi Proses Aerasi, Adsorpsi, dan Filtrasi pada Pengolahan Air Limbah Industri Perikanan. Scientific Journal of Environmental Chemical Engineering Study Program Faculty of Industrial Technology UPN Veteran East Jawa
[6] Frengky, Suryani, Reni. 2015. Pengaruh Perbedaan pH Terhadap Pertumbuhan dan Hasil Tanaman Kailan. Scientific Journal Respati Pertanian Vol. 7.
[7] Gumilar, G. 2011. Perencanaan Plumbing Air Bersih Dan Air Kotor. Yudhistira. Surakarta
[8] Hidayat Nur. 2011. Autodesk Inventor. Mastering 3D Mechanical Design. Bandung: Informatika
[9] Hadiyono, Yatin, 2015. “Gambar Teknik”. Learning Module Inventor Autodesk. 4.
[10].Hidayat, F.2019. Mengenal Submersible Pump. Avaliable on: https://www.fachrulhyd.com/2019/09/mengenal- submersible-pump- html. Accesed on December 01, 2022
[11] Qasim, S. R. 1990. Wastewater Treatment Plant. Sage publication. New York Suhartana. 2006. Pemanfaatan Tempurung Kelapa sebagai Bahan Baku Arang Aktif dan Aplikasinya untuk Penjernihan Air Sumur. Physics Periodic Journal . Vol 9:3
[12].Taharica Group. 2020. Pengertian Dasar Water Level Control. Avaliable on: https://www.loggerindo.com/pengertian dasar-water-level-control-dan- kelebihannya-351. Accesed on Januari 03, 2022
[13] Santosa, I. G., & Yusuf, M. (2017). The application of a dryer solar energy hybrid to decrease workload and increase dodol production in Bali. International Research Journal of Engineering, IT & Scientific Research, 3(6), 99–106.

[14] Rajendra, I. M. ., Yusuf, M. ., & Sugiartha , N. . (2020). Effect of substrate size and stirring on the effectiveness of fermentation of organic waste using composter cash. International Research Journal of Engineering, IT & Scientific Research, 6(6), 10–20.

[15] Yusuf, M. 2014. Design of Jewel Stone Sharpener to Increase Jewel Worker Work Productivity in Bali. Proceedings of the International Conference on Engineering Technology and Industrial Application. Surakarta. ISSN 2407-4330.

LOGIC
Journal of Engineering Design and Technology
Vol. 23 No.1 March; p. 16 - 22

p-ISSN : 1412-114X
e-ISSN : 2580-5649
http://ojs2.pnb.ac.id/index.php/LOGIC

DESIGN OF ENERGY EDUCATION MEDIA FOR SOLAR AND WIND POWER PLANTS AT BOMO BEACH, BANYUWANGI REGENCY

Adi Pratama Putra [1)*], Gatut Rubiono [1)], Rezki Nalandari [2)], Megandhi Gusti Wardhana[3)]

1) Mechanical Engineering, PGRI University of Banyuwangi, Banyuwangi, Indonesia
2) Electrical Engineering, PGRI University of Banyuwangi, Banyuwangi, Indonesia
3) Agricultural Technology, PGRI University of Banyuwangi, Banyuwangi, Indonesia

Corresponding email *) : tama.adie@yahoo.com.ac.id

Abstract. Bomo Beach, which is managed by community groups to become a tourist attraction, has the potential for renewable energy in the form of solar and wind energy. This potential can be harnessed and converted into electrical energy. This study aims to design energy education media for solar power plants and wind power plants at Bomo beach, Banyuwangi regency. The design is carried out by the natural management of the tourist beach. The power plant designed is the integration of the solar power plant system (PLTS) and the wind power plant system (PLTB). Solar power plants use solar panels while PLTB uses horizontal shaft wind turbines and vertical shafts. The energy housing is made as a power store with a 12 volts battery. The design results show that the integration design of solar power plants and PLTB can be applied as an energy education media.

Keywords: PLTS, PLTB, media, education, energy.

1. INTRODUCTION

Bomo Beach which is located in Rogojampi district, Banyuwangi regency is a tourist beach managed by the Fisheries Supervisory Community Group (Kelompok Masyarakat Pengawas Perikanan - Pokmaswas) namely Benteng Samudra. The atmosphere in the morning, afternoon, and evening the beach looks very good but at night this beach looks scary because there is no electric lighting, there is lighting from oil lamps. The beach is only enjoyed in the morning, afternoon, and evening. The provision of free energy that can be synchronized with Bomo Beach will result in the formation of independent energy education and beach tourism at night. Pokmaswas Benteng Samudra as a manager supported by many partners, want beach tourism that is different from the others and can always be remembered by the community, especially tourists.

The management of this tourism potential has constraints in terms of electrical energy supply because the location of the beach is quite far from settlements. The absence of a power source causes the development of beach tourism potential cannot be carried out optimally. Alternative solutions to energy supply are indispensable. Coastal areas are generally known to have alternative energy potentials including solar energy and wind energy. These two types of energy are renewable energy. This energy potential can be used to overcome problems on the Bomo tourist beach.

Solar power generation has a simple concept that is to convert sunlight into electrical energy. Solar cells can produce an unlimited amount of electrical energy directly taken from the sun, with no rotating parts and no need for fuel [1]. The intensity of solar radiation and ambient temperature has an influence on the electrical power produced, the greater the value of the intensity of solar radiation the electrical power produced is also the greater and the temperature influences the electrical power generated by solar panels [2]. According to data from the National Energy Council in 2019, the potential for solar energy in Indonesia is 207.8 GWP [3], with realization reaching 0.15 GWP [4]. The greater the intensity of light received by the solar panels, the greater the current and voltage produced [5]. As a renewable and clean energy, solar energy will not cause environmental pollution like

pollution produced by traditional energy e.g. coal, oil, and other fossil fuels [6]. Some new ideas can still be approached with the practical implementation of solar photovoltaic energy applied [7].

Research on solar power plant (PLTS) prototypes resulted in an efficiency of 16.42% [8]. The profit of electrical energy generated from solar power plants is 93,533 (3.3 %) kWh/year [9]. An array of about 10 - 20 or more solar panels will be able to produce sufficient high currents and voltages for daily needs [10]. The energy produced can be utilized as much as possible as electrical energy which in turn can reduce the cost of using electrical energy [11]. To use solar energy continuously both at night and during the day, the electrical energy generated is stored first to a battery controlled by a regulator. The output of the regulator is directly connected with the inverter from DC current AC. While the main technical obstacle of implementing slot power plants is battery damage [13].

Planning of solar power generation systems has been carried out among others for analysis and design for building needs [14], design and evaluation of solar power systems [15], design analysis of solar power generation systems with a capacity of 50 WP [16], development of research results of solar power generation tools [17], installation of information technology-based solar power plants for the formation of energy independent building [18], utilization of solar power plants as a source of electrical energy reserves for quail cultivation [19], planning solar power plants to meet the electricity needs of fishing ponds [20], design and build solar panels for simple home lighting installation [21], economic design and analysis [22], solar panels as power generation for lighting systems on fishing boats [23], pool water pump power requirement [24], designing portable solar power plant [25], implementing solar panels as a source of electrical energy for monitoring corn shift of agricultural land [26], experimental architectural design [27] and grid solar energy system [28].

Wind also includes renewable energy. The utilization of wind energy in Indonesia for the time being is still relatively low but has enormous potential. One of the reasons is that the average wind speed in Indonesia is classified as a l wind speed, which ranges from 3 m/s to 5 m/s, making it difficult to produce electrical energy on a large scale [29]. Wind energy can be harvested to convert wind energy into electrical energy by using wind turbines [30]. The construction and dimensions of hardware in wind energy conversion systems vary widely, depending on usage, capacity, and placement [31]. Generating installations are not only built in flat and windy areas but also in hi and the mountainous regions. The success story of wind energy is inextricably linked to its long history in research and development in many aspects. This includes ongoing efforts spent on improving the reliability of wind turbine designs and site assessments [33]. The design of wind power plants (PLTB) has among others been carried out for the Savonius vertical axis wind turbine type [29]-[32],[34] - [37] and horizontal axis wind turbine [31][36] - [42].

So far, independent energy facility in tourist attractions is only for a tourist area, not how the flow, installation, control systems, and processes of PLTS and PLTB produce energy. So with energy self-education, all visitors, especially elementary, middle and high school children, are expected to be able to instill insight from an early age about how easy it is to produce electrical energy, or for students, it can be used as a reference for lectures and practicums. The main urgency in this design is to provide an understanding so that the wider community can see how simple a power plant is so that it can attract them if they want to create an environmentally friendly energy system at home, place of business, or other things.

The concept of Bomo beach management is natural and educational. The natural concept is represented in the form of maintaining the beauty of the environment. The infrastructure building is made of wood and bamboo. The educational aspect is shown by the breeding of hatchlings (turtle cubs). New educational facilities are created by utilizing the potential of solar and wind energy. Small-scale solar and wind power plants are integrated and created in the concept of energy houses. On the other hand, this educational facility will also supply daily electricity needs. The merger of solar and wind systems is known as a hybrid system and has been studied for campus needs [43] and small-scale irrigation systems [44]. This study aims to design energy education media for solar power plants and wind power plants on Bomo beach, Banyuwangi regency.

2. METHODS

The design of energy education media is carried out by the stages of site surveys, discussions with partners (Pokmaswas), planning, and manufacturing. Site surveys are conducted to obtain site feasibility, especially on convertible energy potential. Discussions with partners are conducted as information and design considerations. The planning stage is part of the design of the system, the devices, and the installations. The manufacturing stage is the construction of a system that has been designed.

The design of energy houses in general is based on natural concepts according to the management of tourist beaches. Initial information and design were obtained from discussions with Pokmaswas. The design and

manufacture of energy education houses are designed with consideration and advice from Pokmaswas. This is related to the design of educational house facilities and infrastructure. Design discussions are generally carried out so that the addition of energy education house facilities does not conflict with existing conditions or tourism development plans that will be carried out in the future.

The design of solar power plant (PLTS) and wind power plant (PLTB) systems is based on the potential availability of energy on the Bomo beach. As with other coastal areas, this location has a relatively large potential for sunlight. This is the case with the potential for wind energy where winds throughout the year are relatively constant flow, both from the sea direction and the land direction. The components of the plant used are components that are easily available in the market.

3. RESULTS AND DISCUSSION

Houses at Bomo beach are made with wood base materials. The energy house is positioned next to the beach tourism office. This is done to facilitate maintenance and supervision. In addition, this location is also adjacent to the hatchling breeding site so it will add educational facilities for visitors. The selection of this location is also based on the space of a relatively open area so that sunlight can directly hit the solar panels. In addition, although the coastline is planted with spruce, the wind blows at a speed of 2 – 6 m/s. The measurement results using a digital anemometer show that the measurement results on the coastline range from 4-6 m/s. The measurement results at the energy house location produce an average speed of 2 m/s at the measurement point with a height of 1 meter above the ground and more than 3 m/s at an altitude of 2 meters and above. This is by reference [29] which states that wind speed in Indonesia is 3 – 5 m/s. The Energy House Location Plan Design can be seen in Figure 1

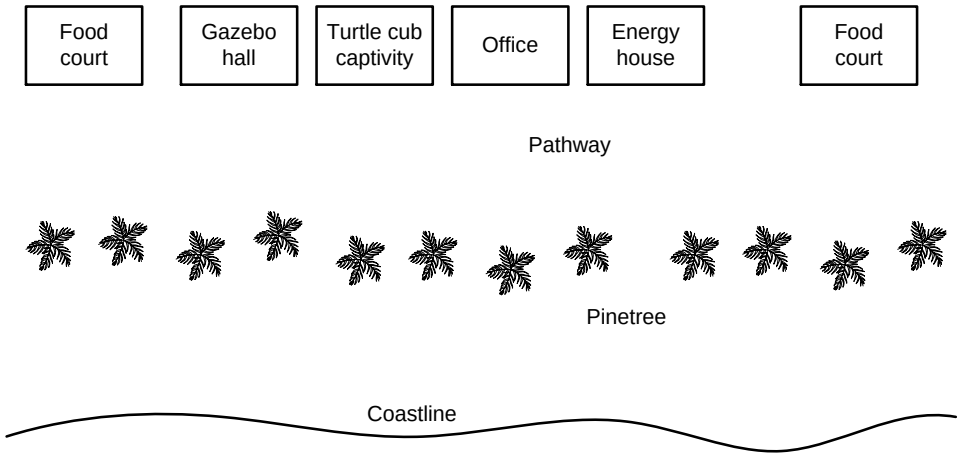


Figure 1. Energy house location plan design

The solar power plant is designed using solar panels. The wind power plant is designed using horizontal axis windmills and Savonius-type vertical axes. The selection of these two types of turbines is by the general types that are widely studied and used in the field. Solar panels are positioned as rooftop energy houses. Two types of wind turbines are installed next to the energy housing. Electrical energy storage is carried out using batteries which will then be distributed for surrounding needs.

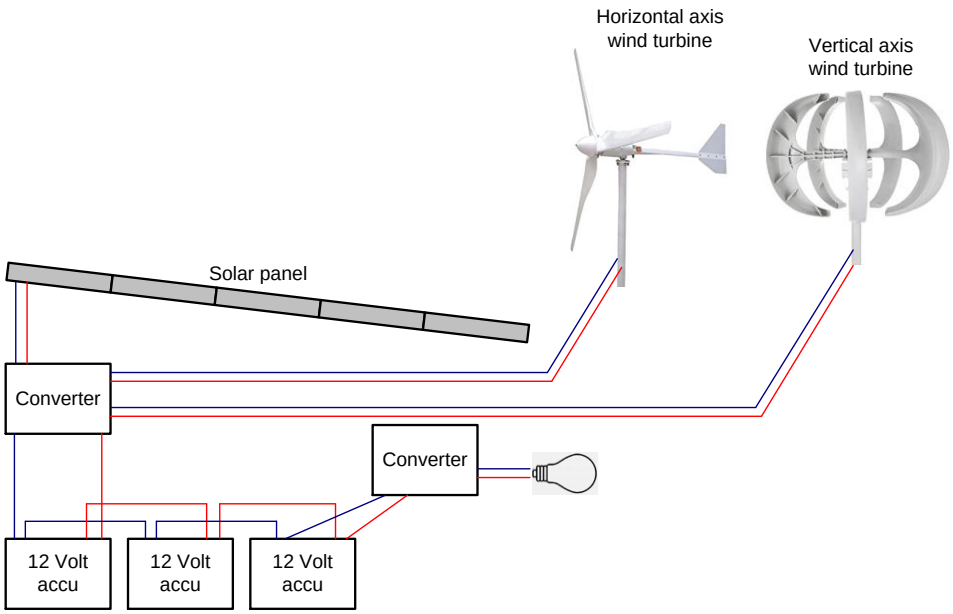


Figure 2. Basic concepts of solar and wind power plants

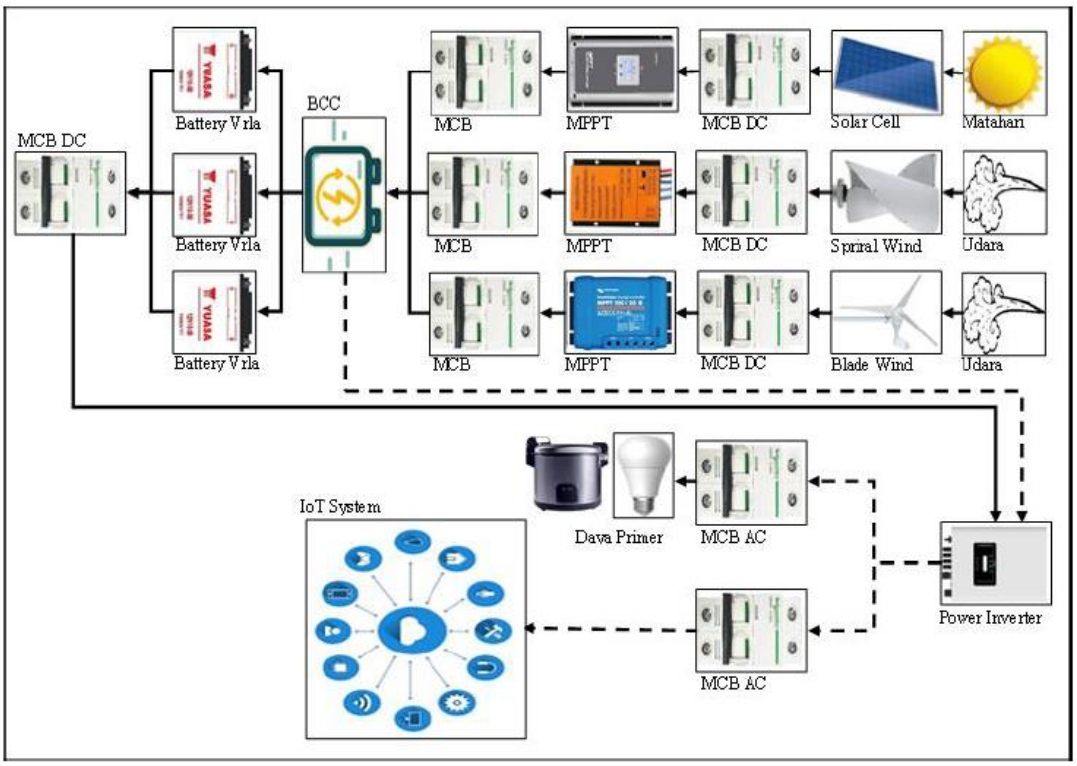


Figure 3. Design of solar and wind power plants

From the above system design from solar power → MCB → MPPT panel → BCC → Battery → Power Inverter 10,000 watt LF PSW → MCB AC 2 x 20 A → output to stalls, umm, audio and lighting. With this system, it can supply electricity to all activities in Bomo Beach in 24 hours, because the system uses solar energy and energy wind that has been carefully calculated, during the day solar energy can supply electricity, but at night can not afford, it will fix the system if the second energy is combined. Integration or merging of these 2 energy sources will have an impact on meeting the needs of Bomo Beach.

The monitoring results showed that the trial results of the system design were able to turn on four lamps, each lamp is a 25 watt LED lights, for a full day (24 hours). This shows that the system that has been built is

relatively stable in performance. The integration of solar power plants and solar power plants can be an innovation in the use of energy sources in coastal areas where solar energy and wind energy are highly available. Quite simple equipment can be optimally applied.

The energy education media aspect is a separate medium for tourist beach management partners and their members. Pokmaswas members run businesses, the majority in culinary form. The creation of a power generation system is a very useful learning material for partner activities. In addition, future development is possible as the need for electrical power increases. Partners also learn simple maintenance and repair aspects of the power plants.

Energy education media is also a special attraction for visitors to tourist attractions. Visitors can see up close the installation of solar power plants and PLTB. This attraction can be seen in the increase in the number of visitors where the number of visitors increases by ± 10% on weekdays (Monday to Friday) and increases by ± 20 - 25% at the end of the week (Saturday and Sunday). This shows that educational media provides economic benefits.

The increase in tourist attraction and visits can also be seen in the increase in the number of culinary entrepreneurs. Before the implementation of the power plant, 5 culinary business actors managed permanent stalls. After implementation, the number increased to 6 entrepreneurs. In addition, 12 food and beverage sellers are active on weekends. After implementation, this number increased to 18 people.

In general, the design of energy education media implemented on Bomo beach provides positive benefits for community partners. The generated electrical energy can be used for lighting needs and other needs. The attractiveness of educational media increases the number of tourist visits, opens up new business opportunities for local communities, and provides financial benefits. These positive benefits indicate that the design of energy education media can be applied to improve people's welfare.

The design of energy education media in the form of solar and wind power generators is relatively simple. Applications directly in the community can be implemented easily. Installation and maintenance of this generator installation are also relatively simple. This educational media can be applied in other places that have renewable potential energy. The development of tourist attractions that are managed by the local community can apply this educational media to increase the attractiveness of these tourist attractions.

Figure 4. Energy house and installation

On the other hand, the managing community and users need education regarding the maintenance and repair of this power plant installation. Managers also need to plan the cost of components that have a service life. Electrical storage batteries and various other components can be damaged due to use. Financial planning is required to ensure the sustainability of this installation.

4. CONCLUSION

Solar power plants and wind power plants have been integrated and applied at the Bomo beach of Banyuwangi regency as a medium for energy education. A relatively simple system design can bring benefits in terms of needs for daily activities and as an educational medium. Improvements still need to be made about the monitoring system of electrical power generated by the system.

5. ACKNOWLEDGEMENT

This activity is a series of Kedaireka *Matching Fund* (MF) Programs from the Indonesia Education Ministry for the 2022 funding year.

6. REFERENCES

[1] S. Darma, "Analisa Perkiraan Kemampuan Daya yang Dibutuhkan Untuk Perencanaan Pembangkit Listrik Tenaga Surya (PLTS)," *Ampere*, vol. 2, no. 1, pp. 40–53, 2017.
[2] T. Alamsyah, A. Hiendro, and Z. Abidin, "Analisis Potensi Energi Matahari Sebagai Pembangkit Listrik Tenaga Surya Menggunakan Panel Mono-Crystalline dan Poly-Crystalline di Kota Pontianak dan Sekitarnya," *Jurnal Tek. Elektro Univ. Tanjungpura*, vol. 2, no. 1, pp. 1–10, 2021.
[3] N. Arif and Kastono, "Potensi Energi Surya sebagai Energi Listrik Alternatif berbasis RET Screen di Kota Palopo, Indonesia," *Dewantara*, vol. XX, no. Xx, pp. 1–5, 2020.
[4] P. Gunoto and H. D. Hutapea, "Analisa Daya pada Panel Surya di Pembangkit 30 KVa Gedung Kantor PT. Energi Listrik Batam," *Sigma Tek.*, vol. 5, no. 1, pp. 57–69, 2022.
[5] M. K. Usman, "Analisis Intensitas Cahaya Terhadap Energi Listrik yang Dihasilkan Panel Surya," *J. Polektro J. Power Elektron.*, vol. 9, no. 2, pp. 52–58, 2020.
[6] X. Qin, Y. Shen, and S. Shao, "The Application Study in Solar Energy Technology for Highway Service Area: A Case Study of West Lushan Highway Low-Carbon Service Area in China," *Int. J. Photoenergy*, vol. 703603, pp. 1–9, 2015, doi: http://dx.doi.org/10.1155/2015/703603.
[7] T. Machado, P. Maria, S. Rocha, M. Aparecida, G. Machado, and G. Paschoal, "Future research tendencies for solar energy management using a bibliometric analysis, 2000 – 2019," *Heliyon*, vol. 6, no. e04452, pp. 1–10, 2020, doi: 10.1016/j.heliyon.2020.e04452.
[8] R. Hasrul, "Analisis Efisiensi Panel Surya Sebagai Energi Alternatif," *SainETIn (Jurnal Sain, Energi, Teknol. Ind.*, vol. 5, no. 2, pp. 79–87, 2021, [Online]. Available: https://journal.unilak.ac.id/index.php/SainETIn/index.
[9] N. R. Hutajulu and Setia Gunawan, "Studi Pemanfaatan Pembangkit Listrik Tenaga Surya Interkoneksi Dengan Sumber Listrik Utama pada Gedung Direktorat Jenderal Ketenagalistrikan Jakarta," *Ejournal Kaji. Tek. Elektro*, vol. 2, no. 2, pp. 129–140, 2018.
[10] B. H. Purwoto, Jatmiko, M. Alimul, and I. F. Huda, "Efisiensi Penggunaan Panel Surya Sebagai Sumber Energi Alternatif," *Emit. J. Tek. Elektro*, vol. 18, no. 1, pp. 10–14, 2000.
[11] S. Samsurizal, R. Afrianda, and A. Makkulau, "Simulasi Optimalisasi Kapasitas Pembangkit Listrik Tenaga Surya pada Atap Gedung," *J. Penelit. Saintek*, vol. 27, no. 1, pp. 31–37, 2022, doi: https://doi.org/10.21831/jps.v1i1.44461.
[12] S. Karim and D. Cahyanto, "Analisa Penggunaan Solar Cell Pada Rumah Tinggal Untuk Keperluan Penerangan dan Beban Kecil," *J. EEICT*, vol. 2, no. 1, pp. 22–32, 2019.
[13] M. Djamin, "Penelitian Penerapan Pembangkit Listrik Tenaga Surya dan Dampaknya Terhadap Lingkungan," *J. Tek. Lingkung.*, vol. 11, no. 2, pp. 221–225, 2010.
[14] H. Eteruddin, J. Sitompul, and M. P. Halilintar, "Analisis Dan Desain Pembangkit Listrik Tenaga Surya Untuk Kebutuhan Fakultas Teknik Universitas Lancang Kuning," *J. Politek. Caltex Riau*, vol. 8, no. 1, pp. 32–42, 2022.
[15] R. T. Basha and A. J. Qaderayeev, "Design and Evaluation of Solar Power Systems Using Different Techniques," *Int. J. Trend Res. Dev.*, vol. 5, no. 2, pp. 256–265, 2018.
[16] A. I. Ramadhan, E. Diniardi, and S. H. Mukti, "Analisis Desain Sistem Pembangkit Listrik Tenaga Surya Kapasitas 50 WP," *Teknik*, vol. 37, no. 2, pp. 59–63, 2016, doi: 10.14710/teknik.v37n2.9011.
[17] S. Buyung, Y. J. Lewerissa, and Yunus, "Pengembangan Hasil Penelitian Alat Pembangkit Listrik Tenaga Surya," *J. Pengabdi. Aedificate*, vol. 1, no. 1, pp. 21–26, 2020.
[18] S. D. A. Febriani, R. E. Rachmanita, and M. I. Nari, "Instalasi Pembangkit Listrik Tenaga Surya Berbasis Teknologi Informasi Guna Terbentuknya Pondok Mandiri Energi di PP. Nurussalam Ambulu Jember," in *Seminar Nasional Hasil Pengabdian Masyarakat dan Penelitian Pranata Laboratorium Pendidikan*, 2019, pp. 226–230.
[19] G. Santoso, S. Hani, S. Abdullah, and Y. Indra, "Pemanfaatan Pembangkit Listrik Tenaga Surya Sebagai Sumber Energi Listrik Cadangan Budidaya Burung Puyuh Dilengkapi Dengan Automatic Transfer Switch (ATS)," *J. Elektr.*, vol. 8, no. 2, pp. 45–52, 2021.
[20] K. R. A. Siregar, "Perencanaan Pembangkit Listrik Tenaga Surya untuk Memenuhi Kebutuhan Listrik pada Kolam Pemancingan di Desa Kalanganyar Sedati Sidoarjo," in *Seminar Nasional Sains dan Teknologi Terapan VIII 2020*, 2020, pp. 369–376.
[21] M. Idris, "Rancang Panel Surya Untuk Instalasi Penerangan Rumah Sederhana Daya 900 Watt," *J. Elektron. List. dan Teknol. Inf. Terap.*, vol. 1, no. 1, pp. 17–22, 2019.
[22] R. Ahshan, R. Al-Abri, H. Al-Zakwan, N. Ambu-said, and E. Hossain, "Design and Economic Analysis of a Solar Photovoltaic System for a Campus Sports Complex," *Int. J. Renew. Energy Res.*, vol. 10, no. 1, pp. 67–78, 2020.
[23] J. Sardi, A. B. Pulungan, Risfendra, and Habibullah, "Teknologi Panel Surya Sebagai Pembangkit Listrik Untuk Sistem Penerangan Pada Kapal Nelayan," *J. Penelit. dan Pengabdi. Kpd. Masy. Unsiq*, vol. 7, no. 1, pp. 21–26, 2020, doi: 10.32699/ppkm.v7i1.794.

[24] G. A. B. Wirajati, I. D. M. C. Santosa, I. B. A. J. Pramana, I. P. G. S. Haryasa, and I. A. G. B. Madrini, "Solar Power System Design Applications for Pool Water Pump Operation at Tourist Accommodation," *Logic*, vol. 21, no. 3, pp. 159–164, 2021.
[25] L. A. Gunawan *et al.*, "Rancang Bangun Pembangkit Listrik Tenaga Surya Portable," *J. Tek. Elektro*, vol. 10, no. 1, pp. 65–71, 2021.
[26] A. Prasetyo, R. Ramadani, and R. M. Yasi, "Implementasi Panel Surya sebagai Sumber Energi Listrik untuk Monitoring Lahan Pertanian Shifod Jagung," *Zetroem*, vol. 04, no. 02, pp. 30–33, 2022.
[27] H. S. Choi, "Architectural Experiment Design of Solar Energy Harvesting : A Kinetic Façade System for Educational Facilities," *Appl. Sci.*, vol. 12, no. 5853, pp. 1–11, 2022, doi: https://doi.org/10.3390/app12125853.
[28] A. S. Aziz *et al.*, "Design and Optimization of a Grid-Connected Solar Energy System: Study in Iraq," *Sustainability*, vol. 14, no. 8121, pp. 1–29, 2022, doi: https://doi.org/10.3390/su14138121.
[29] Y. I. Nakhoda and C. Saleh, "Rancang Bangun Kincir Angin Pembangkit Tenaga Listrik Sumbu Vertikal Savonius Portabel Menggunakan Generator Magnet Permanen," *Ind. Inov.*, vol. 5, no. 2, pp. 19–24, 2015.
[30] A. Darmawan and F. Winjaya, "Rancang Bangun Turbin Angin Aksis Vertikal Sebagai Alternatif Catu Daya Pada Perlintasan Sebidang Perkeretaapian," *J. Perkeretaapi. Indones.*, vol. III, no. 2, pp. 87–92, 2019.
[31] A. Nurdiyanto and S. I. Haryudo, "Rancang Bangun Prototype Pembangkit Listrik Tenaga Angin Menggunakan Turbin Angin Savonius," *J. Tek. Elektro*, vol. 09, no. 01, pp. 711–717, 2020.
[32] A. Clifton, S. Barber, A. Stökl, H. Frank, and T. Karlsson, "Research Challenges and Needs for the Deployment of Wind Energy in Hilly And Mountainous Regions," *Wind Energ. Sci.*, vol. 7, no. 2022, pp. 2231–2254, 2022, doi: https://doi.org/10.5194/wes-7-2231-2022.
[33] G. Bangga, "Progress and Outlook in Wind Energy Research," *Energies*, vol. 15, no. 6527, pp. 1–5, 2022, doi: https://doi.org/10.3390/en15186527.
[34] Y. I. Nakhoda and C. Saleh, "Rancang Bangun Generator Magnet Permanen Untuk Pembangkit Tenaga Listrik Skala Kecil Menggunakan Kincir Angin Savonius Portabel," *J. Ilm. Setrum*, vol. 5, no. 2, pp. 19–24, 2016.
[35] T. Purbaya, A. Jannifar, and S. Bahri, "Rancang Bangun Blade Kincir Angin Vertikal Axis Wind Turbin Model Savonius Dengan Variasi Tertutup dan Terbuka," *J. Mesin sains Terap.*, vol. 5, no. 2, pp. 65–70, 2021.
[36] V. Valentino, M. I. Yusuf, and A. Hiendro, "Rancang Bangun Turbin Angin Savonius Untuk Penerangan Penginapan di Desa Temajuk Kecamatan Paloh Kabupaten Sambas," *J. Tek. Elektro Univ. Tanjungpura*, vol. 2, no. 1, pp. 1–10, 2021.
[37] L. Saputra and R. W. Arsianti, "Rancang Bangun Turbin Angin Vertikal Portable Berdaya Listrik Rendah," *J. Otomasi*, vol. 1, no. 1, pp. 28–36, 2021.
[38] O. D. Cota and N. M. Kumar, "Experimental Design of Wind Turbine with an Airfoil Embedded Multiple Generators," *Int. J. Appl. Eng. Res.*, vol. 11, no. 3, pp. 4–7, 2016.
[39] R. Syahyuniar, Y. Ningsih, and Herianto, "Rancang Bangun Blade Turbin Angin Tipe Horizontal," *J. Elem.*, vol. 5, no. 1, pp. 28–34, 2018.
[40] M. Saputra, R. Kurniawan, and A. Munawir, "Rancang Bangun Turbin Angin Skala Kecil Untuk Kawasan Kampus Univ. Teuku Umar," *Mekanova*, vol. 5, no. 1, pp. 8–20, 2019.
[41] T. Multazam and A. Mulkan, "Rancang Bangun Turbin Angin Sumbu Horizontal pada Kecepatan Angin Rendah Untuk Meningkatkan Performa Permanent Magnet Generator," *Serambi Eng.*, vol. IV, no. Edisi khusus, pp. 616–624, 2019.
[42] S. Hernowo, "Rancang Bangun Turbin Angin Sumbu Horizontal Sederhana Dengan Panjang Sudu 1 Meter," *J. Voering*, vol. 5, no. 1, pp. 15–21, 2020.
[43] R. Nurhasanah, H. Maulana, B. Madi, A. Suardi, and V. Antono, "Rancang Bangun Turbin Angin Untuk Pembangkit Listrik Hybrid One Pole Energy," *J. Power Plant*, vol. 8, no. 2, pp. 82–89, 2020, doi: https://doi.org/10.33322/powerplant.v8i2.1125.
[44] S. Ssenyimba, N. Kiggundu, and N. Banadda, "Designing a solar and Wind Hybrid System for Small-Scale Irrigation : a Case Study for Kalangala District in Uganda," *Energy. Sustain. Soc.*, vol. 10, no. 6, pp. 1–18, 2020, doi: https://doi.org/10.1186/s13705-020-0240-1.

LOGIC
Journal of Engineering Design and Technology
Vol. 23 No. 1 March 2023; p. 23 - 31

p-ISSN : 1412-114X
e-ISSN : 2580-5649
http://ojs2.pnb.ac.id/index.php/LOGIC

STRENGTH ANALYSIS ON HORIZONTAL AXIS WIND TURBINE PROPELLER BLADE PVC PIPE WITH ANGLED ENDS

Aji Tisa[1], Hangga Wicaksono[1], Bagus Wahyudi[1]

1) Mechanical Engineering, State Polytechnic of Malang, Jl. Soekarno Hatta No. 9, Malang, Indonesia

Correponding email:

aji.tisa@gmail.com[1)]

Abstract. The basic problem of appropriate wind energy technology is how to design wind turbines from materials that are easily available on the market, one solution is PVC pipe as the blade material. For this reason, it is necessary to analyze the working stress that occurs in the blade construction, so that the PVC pipe propeller wind turbine is safe when applied in society. The purpose of this study was to determine the effect of wind speed and tip elbow width on working stress. The simulation test method uses SolidWorks Flow Simulation Software and then the results are exported to Static Simulation to determine the strength of the material. Simulation tests were carried out with wind loads on PVC pipe propellers with wind speeds of 5 m/s, 6 m/s, and 7 m/s and elbow tip widths of 100 mm, 110 mm, and 130 mm. The results of the maximum stress value in the wind turbine simulation test with the addition of an elbow tip were obtained at a wind speed of 7 m/s and an elbow tip width of 130 mm.

Keywords : HAWT, Propeller, PVC Pipe, Tip Elbow, and CFD Simulation.

1. INTRODUCTION

Compared to fossil fuels, such as coal and natural gas, wind is an environmentally friendly source of energy, no air pollution is released into the environment after consumption. Wind energy is one of the most promising because it is available in a wide geographical area, in contrast to other energy sources which are concentrated in several countries [1]. Wind energy is a renewable energy potential that can make a significant contribution to the need for electrical energy, especially in remote areas. Wind energy can be utilized as electrical energy in the presence of wind turbines [2]. In the design of wind turbines the most important part is the blade, because this part is the core in making wind turbine rotors. Most windmill designs use NACA profile blades, but in this study the blades used were made of PVC pipe, then the pipe was cut by splitting and twisting in order to optimally absorb wind energy.

Horizontal Axis Wind Turbine (HAWT) is a type of wind turbine that is widely used in Indonesia. HAWT is one type of wind turbine that has the ability to convert energy with the greatest efficiency because the blades always move perpendicular to the wind, receiving power through all rounds. The geometry, dimensions and number of blades determine the efficiency of the turbine. [3]

Wind is one of the renewable energy sources which is very abundant and easily available in nature. Based on its geographical location, each place has different wind potential, in the tropics and subtropics it has different wind potential. Based on the topography, if it is in a mountainous area, the wind tends to rise and if the topography is flat, the wind will tend to be straight and flat.

Model simulation tests using Computational Fluid Dynamic (CFD) software are generally used to determine the effect of interaction variables such as wind speed and number of blades on output power and to obtain the most optimum power coefficient.[4]

With CFD simulation, it is possible to predict fluid flow patterns, heat transfer, chemical reactions and other phenomena through mathematical equations or mathematical models. In general, the fluid flow calculation process is solved by using the energy equation, momentum equation and continuity equation. Numerical modeling of flow

(Fluent Manual, Fluent Inc.) was carried out using the conservation of mass equation and momentum equation in integral form at stationary and steady state.

Wind turbine models can also be tested experimentally using wind tunnels, the function of wind tunnels in aerodynamic research is to study airflow characteristics. Wind tunnels are also used to simulate the actual state of an object under the influence of aerodynamic forces in the field of aeronautics, namely to analyze the performance of flying mechanics of an object [6]. The magnitude and direction of the Lift and Drag force vectors depend on the shape of the airfoil profile, for example a fluid moving on a curved surface will be shown in detail the flow lines and aerodynamic forces due to changes in momentum. The schematic diagram of the aerodynamic forces is shown in Figure 1. It is therefore very important to understand the significance of the phenomena behind various Airfoil shapes [7].

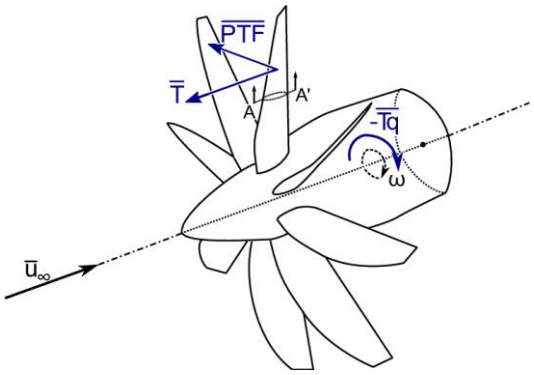


Figure 1 Aerodynamic Force on the Propeller Blade [8]

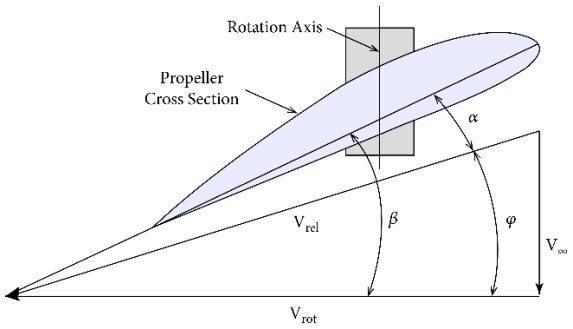


Figure 2 Blade Cross-sectional Velocity Diagram [9].

The increase in the lift coefficient occurs gradually as the separation point shifts above the airfoil body and the influence of the turbulent flow that is formed thus affecting the pressure resistance [9]. Based on Bernoulli's principle, because the air flow over the airfoil produces a low pressure zone and a high pressure zone is on the bottom surface, so that due to the pressure difference a lift force will be generated [10].

Previous studies on blades described a useful methodology for optimizing small size wind turbine blade geometries obtained from circular pipes with optimal chord distribution and airfoil sweep obtainable with proper cutting paths. Significant reductions in production costs and time can be achieved for blades which are an important element in wind turbine systems, especially in the case of renewable energy generation in developing countries [11], as shown in Figure 2 is the geometry of turbine blades made of pipes that divide by turning the clock wisely

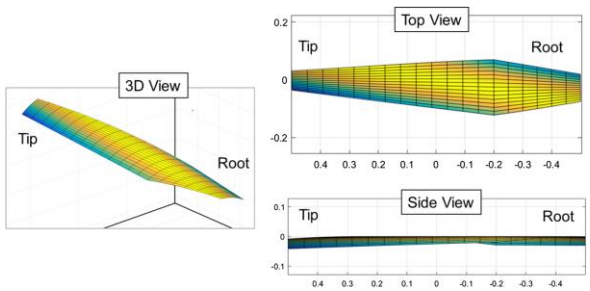


Figure 2: Geometric and braided pipe blades[11]

According to classical physics, the kinetic energy of wind for an object with mass m and speed v is E=½×m×v ^{2}, but with the assumption that the speed v is not close to the speed of light. Since mass can be replaced by air density, area A, and velocity v, it can be written: m = .Av is the mass flow rate of the wind. [12]

$$E = \frac{1}{2} \times m \times v^2 \quad (1)$$

where: E = Energy (joules); m = Mass of air (kg) and
v = wind speed (m/s).

Then the wind turbine power that can be generated per unit time is:

$$P_w = \frac{1}{2} \rho A v^3 \quad (2)$$

P $_w$: wind power (watts).

Energy Conversion from Wind energy potential is able to rotate the turbine rotor, where the rotor is connected to a shaft that has been connected to a generator to generate an electric current. The parameters obtained from wind turbine testing are usually wind speed (v), rotation speed (n), current strength (I) and voltage (V). The value of electric power (P) is obtained using the following equation:

$$P = V \times I \quad (3)$$

where: P = Electric Power (Watts)
V = Voltage (Volts)
I = Electric current (Amperes)

The tip speed ratio is the ratio of the rotor tip speed to the free wind speed. For a certain nominal wind speed, the tip speed ratio will affect the rotor speed. The lift type wind turbine will have a relatively larger tip speed ratio compared to the drag type wind turbine. Tip Speed Ratio is calculated by the following equation [13]:

$$\lambda = \frac{2.\pi.n.r}{60 \times v} \quad (4)$$

where: λ= tip speed ratio
r = rotor radius (m)
n = rotational speed (rpm)
v = wind speed (m/s)

According to the Betz limit theory that the maximum power coefficient that can be achieved is 59.26 percent. But in practice, the value that can be obtained from the center of the power coefficient is about 45 percent. This value is below the theoretical limit due to inefficiencies and losses caused by different configurations, blade geometries, finite flange, friction, and turbine design. Figure 3 shows the various types of wind turbine blades, and the actual wind turbine power coefficient (Cp) as a function of Tip Speed Ratio (TSR). [14]

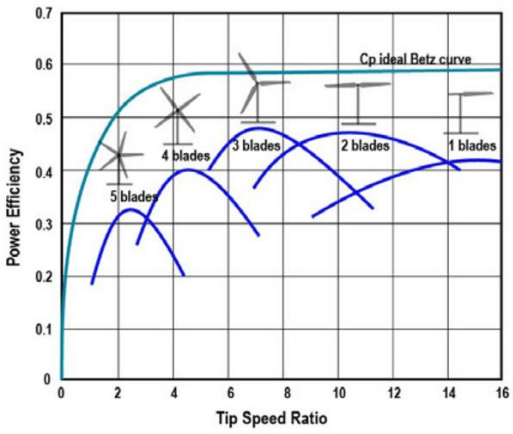


Figure 3. Wind Turbine Performance Diagram [14]

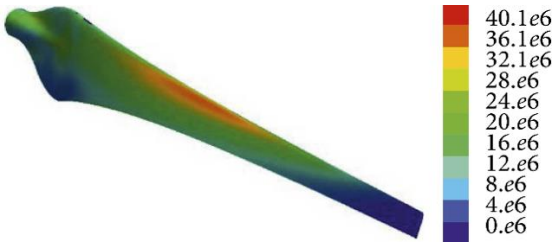


Figure 4. Von Mises stress evaluation for E-glass-epoxy and basalt-epoxy at 40 m/s using CFD simulation [15]

In the strength study of basalt-epoxy composite materials for wind turbine blades, maximum stresses were identified in two zones which could be considered critical, the first close to the shaft and the second in the center zone of the blade due to the pressure contours generated by the wind impacting the turbine blades. Based on the von Mises stress formula in CFD simulations, it was found that positive basalt fiber-based compounds for conventional material substitution can reduce deformation by up to 96%. [15]
The von Mises stress is a measure of the total overall stress acting on a material including the normal stresses in the x and y directions as well as the shear stresses.

$$\sigma_{VM} = \sqrt{\sigma^2 x + \sigma^2 y + \sigma x \sigma y + 3\tau xy} (5)$$

Von Voltage $_{\text{Mises}}$
x is the normal voltage of the x $_{\text{component}}$
y _ is the normal y component of Voltage
xy is the $_{\text{Shear Stress}}$

Wind turbine blades require high bending stiffness properties as they are subject to phenomena such as fatigue, traction and flexion. Therefore, the use of PVC pipe material to produce rigid but flexible wind turbine blades is still being debated because the fatigue properties cannot be predicted accurately.

2. METHODS

In this study, the numerical method used is in accordance with field conditions or actual conditions. The numerical method used is based on Computational Fluid Dynamics (CFD) simulations using AnSys and Solidwork, where the airfoil used is designed to be a blade that is used as a single rotor reference. Then the design results are simulated and will be validated with experimental results using wind tunnels and measurements on sensors attached to the blades. This study also refers to the experimental report of Bartl and Sætran using 4 blades obtained CP max = 0.468 at TSR = 6 with a wind speed of 11.5 m/s (rotor rotation 1395 rpm) [16]. Numerical calculations for the analysis of the static strength of the propeller blade structure were carried out using the commercial FEA SolidWorks Simulation software (SolidWorks, 2016).

The novelty of the blade shape of a windmill using a pipe with a torsion section is inspired by Newton's Second Law, when a force occurs due to a change in momentum when a fluid flows through a pipe elbow. The blade end of the pipe as shown in Figure 5 is made of elbow PVC pipe which is attached to the end of the propeller. The radial wind flow in the vane of the inner wall pipe and the wind flow from the main stream will strike the ends of the elbows which generate additional force due to the change in momentum.[17]

The wind turbine construction built in this study has the following parts: (1) Hub, (2) Blade, (3) Elbow Tip, (4) Shaft, (5) Generator Box, (6) Tail, (7) Tower, as shown in Figure 5.

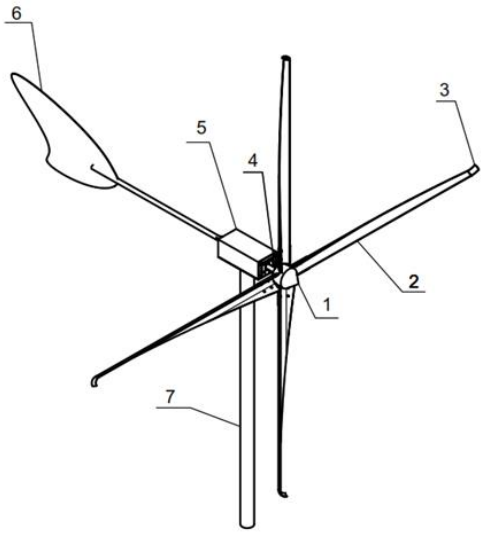


Figure 5. Wind Turbine PVC Pipe Propeller Design [17]

DOE (experimental design) comprises statistical and mathematical techniques for the development and improvement of optimization processes, which utilize experimental design, regression analysis, and analysis of variance. In this case, the working stress response variable "S" (y) is influenced by two independent variables, namely the width of the elbow "w" or (x1) and the wind speed "V" or (x2). The significant influence of the independent variables (x1, x2) on the maximum working stress can be obtained from the appropriate model formulation. Analysis of variance and regression equations can be used to estimate regression coefficients in quadratic polynomial models and to produce measures of uncertainty in the coefficients. [18].

3. RESULTS AND DISCUSSION

Based on the theory of fluid mechanics, water turbine designers always rely on changes in momentum to generate maximum torque and power. The design geometry is manifested in the diameter, the angle of curvature of the blade, the angle of the guide blade or nozzle, and others. Whereas in the design of wind turbines, especially horizontal turbines, the designer always considers the limitations of the Betz theorem (max Cp <0.59), as well as optimization of wind speed variables and geometric variables to produce lift and drag vectors in producing maximum torque. or power.

In previous research [19]-[21] a knife model of a spiral split PVC pipe was produced with an optimum angle of attack of 30 degrees to the wind direction on the hub side. Meanwhile, at the outer radius end the blade plane is twisted up to 90 degrees (the concave plane of the pipe is facing tangentially) as shown in Figure 6 below.

In the current study, the design in Figure 6 adds an elbow at the end using a standard elbow accessory on the market. Standard elbows are split to various widths and then connected to the tip of the blade so that the concave surface faces tangentially. By making the width of part number 3 in Figure 5 the research variable, it is hoped that it will be possible to find out how wide the size of the standard elbow section will be to be connected to the outer edge of the outer blade of this new windmill model.

Figure 6. PVC pipe propeller without Elbow End [21]

Table 1. Variable Speed and elbow width

Elbow width (mm)	Wind velocity (MS)		
100	5	6	7
110	5	6	7
130	5	6	7

In this study, the CFD simulation test uses wind speed and angle width variables as shown in table 1. With these variables, we want to know how the aerodynamic behavior in and around the blades is in the form of images of stress distribution, displacement (blade deflection) and current lines.

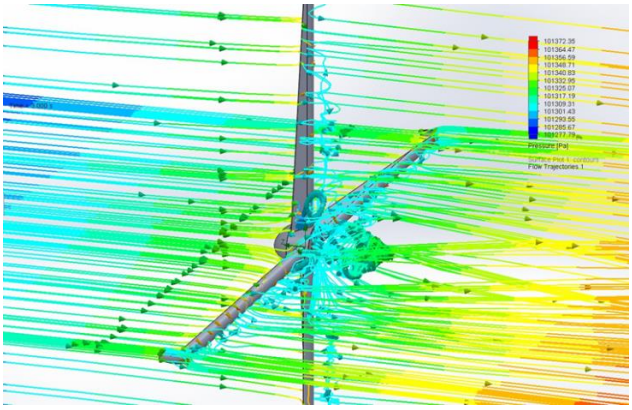


Figure 7. Aerodynamic flow lines around the blade when the wind speed is **7** m/s and the angle width is 110 mm.

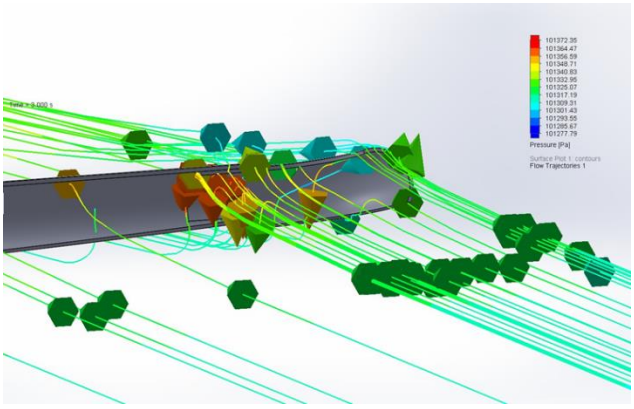


Figure 8. Current line density occurs on the outside of the blade radius when the wind speed is 7 m/s and the angle width is 110 mm.

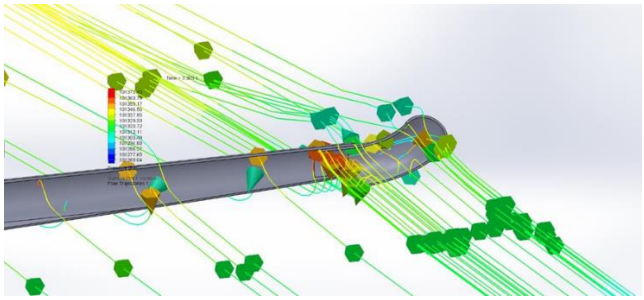


Figure 9. Current line density occurs outside the blade radius when the wind speed is 7 m/s and the angle width is 130 mm.

Simulation testing with an elbow width of 110 mm and a wind speed of 7 m/s results in Figure 8 shows that streamline compaction occurs in the direction of propeller rotation without any turbulence behind the blades. The air impact from the main stream direction on the concave section of pipe is transmitted in a radial direction to the end of the elbow, giving rise to the dual effect of increasing the torque. Usually this phenomenon is interpreted as a coanda effect on aircraft wings, which are equipped with flaps at the ends so as to increase lift. With the simulation results, the turbine with an elbow width of 110 mm works best among the other variables as shown in table 2 and produces a maximum torque of 12,031 Nm.

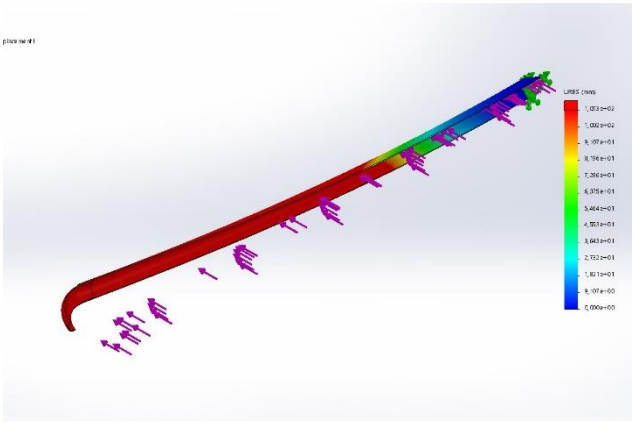


Figure 10. Von Mises Stress and displacement at a wind speed of 7 m/s and a 100 mm elbow width

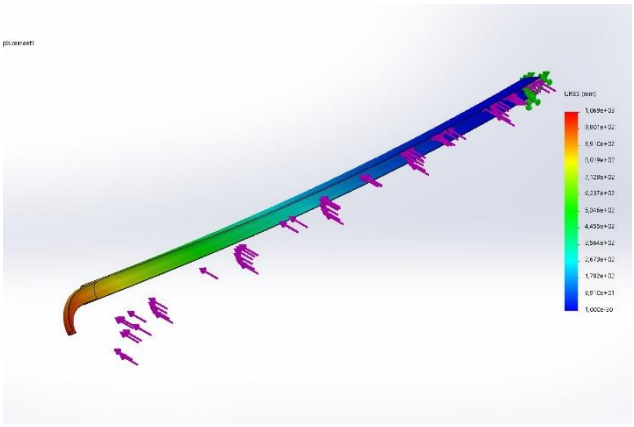


Figure 11. Von Mises Stress and displacement at a wind speed of 7 m/s and an elbow width of 110 mm

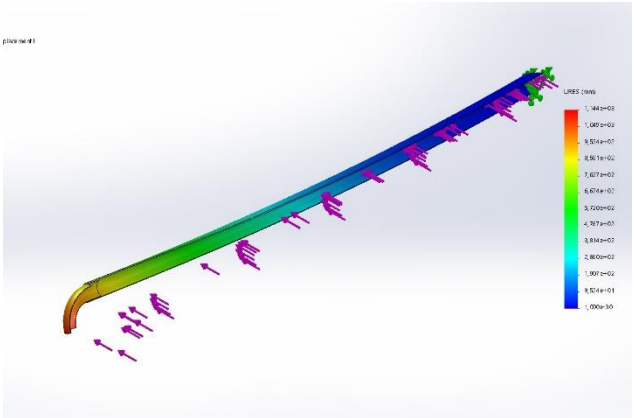


Figure 12. Von Mises Stresses and displacements at a wind speed of 7 m/s and an angle of 130 mm

It can be seen from table 2 and Figure 10 that shows critical operating conditions, the simulation results show a Von Mises stress of 39187892 N/m2 or 39.1 MPa and a total displacement of 1071 mm with a red mark on the blade body which is a very dangerous condition. when using a 100 mm wide elbow with a wind speed of 7 m/s. However, by using a 130 mm wide angle at the same speed, it can be seen in Figure 12 that the critical von Mises stress value of 39026256 Pa or 39.0 MPa appears near the hub. Stress analysis based on simulation results obtained under normal or critical conditions to ensure the safe operation of wind turbines. Based on Figure 11 and

Figure 8 of the CFD simulation for typical operating conditions of PVC pipe split twist blade by equipping the end elbow at the outer radius with an equivalent stress of 37931224 N/m2 or 37.9 MPa and a total displacement of 1069 mm when the wind speed is 7 m/s at elbow width 110 mm. The use of PVC pipe as a blade is better at capturing wind energy and is able to increase the strength and stiffness from the hub zone to the end zone.

3. CONCLUSION

The simulation results show that the Von Mises stress is 39187892 N/m2 or 39.1 MPa and a total displacement of 1071 mm with a red mark on the blade body is a very dangerous condition. when using a 100 mm wide elbow with a wind speed of 7 m/s. However, using a 130 mm wide angle at the same speed, the critical von Mises stress value of 39026256 Pa or 39.0 MPa appears near the hub. Stress analysis based on simulation results obtained under normal or critical conditions to ensure the safe operation of wind turbines. From the CFD simulation for typical operating conditions of PVC pipe split twist blade by equipping the end elbow at the outer radius with an equivalent stress of 37931224 N/m2 or 37.9 MPa and a total displacement of 1069 mm when the wind speed is 7 m/s at an elbow width of 110 mm. The use of PVC pipe as a blade is better at capturing wind energy and is able to increase the strength and stiffness from the hub zone to the end zone.

5. ACKNOWLEDGEMENT

The authors are grateful to Directorate of State Polytechnic of Malang for financial support on the activities Thesis Research Grant in Master of Applied Engineering and Manufacture (MTRTM) - State Polytechnic of Malang during March until November 2022.

6. REFERENCES

[1] Arifin Sanusi, Soedjito Soeparman, Slamet Wahyudi, and Lilis Yuliati, 2016, “Experimental Study of Combined Blade Savonius Wind Turbine,” IJRER vol. 6, no. 2.
[2] Mona Abdelwaly, et.al. 2019. Numerical study for the flow field and power augmentation in a horizontal axis wind turbine. Sustainable Energy Technologies and Assessments 31, 245–253.
[3] Peter J. Schubel and Richard J. Crossley. 2012. Wind Turbine Blade Design. Energies, MDPI 5, 3425-3449; doi:10.3390/en5093425
[4] Xin Cai, Rongrong Gu, Pan Pan and Jie Zhu. 2016. Unsteady aerodynamics simulation of a full-scale horizontal axis wind turbine using CFD methodology. Energy Conversion and Management 112 (146–156).
[5] Vinayak Chumbre, T. Rushikesh, Sagar Umatar, Shirish M. Kerur. 2018. CFD ANALYSIS OF AIRFOIL SECTIONS. International Research Journal of Engineering and Technology (IRJET) Volume: 05 Issue: 07 | July-2018
[6] Arnav Kulshreshtha, Sanjeev Kumar Gupta, Piyush Singhal. 2020. FEM/CFD analysis of wings at different angle of attack. Materials to day Proceedings Volume 26, Part 2, 2020, Pages 1638-1643
[7] Rohit Jain1, Mr. Sandeep Jain2, Mr. Lokesh Bajpai. 2016. Investigation on 3-D Wing of commercial Aeroplane with Aerofoil NACA 2415 Using CFD Fluent. International Research Journal of Engineering and Technology (IRJET) Volume: 03 Issue: 06 | June-2016
[8] Benoit G Marinus. 2011. Multidisciplinary Optimization of Aircraft Propeller Blades. P.Hd. Dissertation, Mechanical Eng- Polytechnic Faculty – ROYAL MILITARY ACADEMY. https://www.researchgate.net/publication/260622828.
[9] Sreenadh Chevula, Sankeerth Chillamcharal, Satya Prasad Maddula. 2021. A Computational Design Analysis of UAV’s Rotor Blade in Low-Temperature Conditions for the Defence Applications. International Journal of Aerospace Engineering. Hindawi. Volume 2021 .Article ID 8843453. https://doi.org/10.1155/2021/8843453
[10] Rohit Jain, Sandeep Jain, Lokesh Bajpai. 2016. Investigation on 3-D Wing of commercial Aeroplane with Aerofoil NACA 2415 Using CFD Fluent. International Research Journal of Engineering and Technology (IRJET) Volume: 03 Issue: 06 | June-2016
[11] Alessandro Ceruti. 2019. Meta-heuristic multidisciplinary design optimization of wind turbine blades obtained from circular pipes. Engineering with Computers (2019) 35:363–379
[12] B. Wahyudi, S Sudarmadji, S Sarjiyana and M Maskuri. (2021). Web innovation in horizontal wind pipe turbine propeller, IOP Conf Series: Materials Science and Engineering. Doi:10.1088/1757-899X/1073/1/012080
[13] Yassine Khalil, L. Tenghiri, Farid Abdi, Anas Bentamy. 2019. Improvement of aerodynamic performance of a small wind turbine. Wind Engineering Vol.1.
[14] Tsumoru Shintake. 2016. Harnessing the Power of Breaking Waves. Proc. Of 3rd the Asian Wave and Tidal Energy Conference (AWTEC2016). ISBN: 978-981-11-0782-5. http://dx.doi.org/10.3850/978-981-11-0782-5_229

[15] V. Garcia, et.al. 2016. Evaluation of Basalt Fibers on Wind Turbine Blades through Finite Element Analysis. Advances in Materials Science and Engineering- HINDAWI. Volume 2019, Article ID 1536925, 12 pages https://doi.org/10.1155/2019/1536925
[16] Dawid Cekus et al. 2019. Simulation research of a wind turbine using SolidWorks software. Journal of Physics: Conference Series. 1398 (2019) 012001 doi:10.1088/1742-6596/1398/1/012001
[17] B. Wahyudi, et.al. 2022. Simulation Study of Horizontal Axis Wind Turbine using PVC Pipe Propeller with Elbow Tip, Journal Physics and Engineering EUREKA No. 5 September.
[18] Magdi Ragheb, Adam M. Ragheb. 2011. Wind Turbines Theory - The Betz Equation and Optimal Rotor Tip Speed Ratio. Fundamental and Advanced Topics in Wind Power.
[19] Vicky K Rathod and S.Y. Kamdi, 2014, Design of PVC Blade Horizontal Axis Wind Turbine for Low Wind Speed Region, International Journal of Engineering Research and Application, vol 4, Issue 7, pp. 139-143.
[20] Vicky K Rathod and S Y Kamdi, (2014). Design and Fabrication of PVC Bladed Inexpensive Wind Turbine, Journal Mechanical and Civil Engineering (IOSR-JMCE), Vol 11. Issue 4, pp. 114-119.
[21] Yulfarida Indriana, 2020.Studi Simulasi Dan Eksperimen Turbin Angin Baling-Baling Pipa Sumbu Horizontal.
[22] Miftahul Huda, 2020. Analisis Kecepatan Angin Dan Sudut Serang Terhadap Tegangan Kerja Konstruksi Rotor Turbin Angin Sumbu Horizontal Baling-Baling Pipa Terbelah Spiral Berdaya 500 Watt.
[23] S.Ravikumar1, V.Jaswanthvenkatram , Y.J.N.V.Sai kumar , S.Md.Sohaib, 2017. Design and Analysis of Wind Turbine Blade Hub using Aluminium Alloy AA 6061-T6.
[24] Alessandro Ceruti, Pier Marzocca , Alfredo Liverani , Cees Bil , 2019. Maintenance in aeronautics in an Industry 4.0.
[25] Chiras, D., 2010. Wind power basics: a green energy guide. New Society Publishers.
[26] Syahrul Nur Wahyudi, 2020. Pengaruh Jenis Dan Jumlah Bilah Naca 3612 Terhadap Performa Turbin Angin Sumbu Horizontal (TASH).
[27] Firman Aryanto, I Made Mara, Made Nuarsa, 2013. Pengaruh Kecepatan Angin Dan Variasi Jumlah Sudu Terhadap Unjuk Kerja Turbin Angin Poros Horizontal.
[28] Jhon S. Duncan, 2016. The Pilot's Handbook of Aeronautical Knowledge.
[29] Teuku Multazam, Andi Mulkan, 2019. Rancang Bangun Turbin Angin Sumbu Horizontal Pada Kecepatan Angin Rendah Untuk Meningkatkan Performa Permanent Magnet Generator.
[30] Hemami, A., 2012. Wind turbine technology. Cengage Learning..
[31] Hugh Piggott, 2012. Windpower Workshop.
[32] Liubov Kliminaa,, Ekaterina Shalimovaa, Marat Dosaeva, Rinaldo Garziera, 2017 .Closed dynamical model of a double propeller HAWT. Procedia engineering, 199, pp.577-582.
[33] Sigit Iswahyudi, Sutrisno a, Prajitno, Setyawan Bekti Wibowo 2020. Effect of blade tip shapes on the performance of a small HAWT: An investigation in a wind tunnel. Case Studies in Thermal Engineering, 19, p.100634.

LOGIC
Journal of Engineering Design and Technology
Vol. 23 No.1 Maret 2023 ; p. 23 - 41

p-ISSN : 1412-114X
e-ISSN : 2580-5649
http://ojs2.pnb.ac.id/index.php/LOGIC

Designing of Goat's Food Processing Tools Using Quality Function Deployment Method

Isana Arum Primasari [1], Hapsoro Agung Jatmiko [1)*], Edo Rizki Drianbodo [1)], Oldy Riswan [1)]

1) Industrial Engineering, Universitas Ahmad Dahlan, Jl Ringroad Selatan Kragilan Tamanan, Yogyakarta, Indonesia

Correponding email *) : hapsoro.jatmiko@ie.uad.ac.id

Abstract. Goat, is one of the most consume meat in Indonesia, it provides much nutrition to the eater and highly recommended by several nutritionist. One of the most critical part in breeding goats, is feeding them, this process is one of the most time consuming and takes a lot of effort, as the food preparation requires a lot of item to mix. Breeder, nowadays mostly feed their goat with "dry food" which are mostly consist of concentrate, this process unfortunately still done manually which, not only takes time but also some chances of potential hazard because most of the concentrate are heavy and huge. This research takes place in Rejodani District in Sleman Regency thus the sample and population of the research are goat breeder around the area. Using Quality Function Deployment method, authors intended to create a new food processing tools for food preparation of the goats. Using the concept screening and selection, out of 3 proposed design, the best design is chosen, followed by validation process to the respondents of the research. The final design of the food processor is the one that could increase productivity of the breeder and less chance of hazard.

Keywords: goat, food processing, design, quality function deployment.

1. INTRODUCTION

Goat has become one of the most prominent livestock in Indonesia, it is estimated that goat breeding in Indonesia has reached 19,3 Million in 2021 [1], this number is even slightly higher compared to the population of cows in Indonesia by 2021 that is estimated by 18.05 million [2]. Yogyakarta, as one of the largest province in Yogyakarta, also contributing in national number for goat breeding. By 2021, it is estimated that there are 421.287 goat population in Yogyakarta [3], by that number, Yogyakarta itself getting a lot of benefit from it, ranging from *sate* stall all around Yogya to handicraft made by goat's leather. The rise of goat's meat consumption is none other by people's awareness to health, in every 100gram of goat meat, roughly contains 23 grams of protein, slightly lower compared to other livestock such as cow [4], but on the other hand, goat meat also has the lowest saturated fat, which is bad for human's body, compared to other animals such as sheep, lamb and even cow. To be able to gain such a good nutrition for each grams of food, one of the main and important thing that should be considered by breeder, is the food given to the goat that could affect the percentage of unsaturated fat and any other substance [5]. Unfortunately, most of the feeding process in most farm in Indonesia, even in Yogyakarta, done manually which could affect several things such as : the potential of getting injured, the quality of the feed which are poor, and time consuming. Each adult goat, needed about 350 grams of concentrate mixture per feeding session and 1500 grams of greens [6], the number seems small for one goat, but if it is a big farm, then the number needed to prepare one session for feeding process would be enormous, high effort and also time consuming, it is also possible to happened for both minor and major injuries.

Designing a new tools or product, basically needs to know what customer's really wanted, as it could affect how good a product to their like. Identifying customer's needs has become a main role in any product design process [7], by doing so, it is more likely the product that being designed will be accepted by customers. One of

the mostly used method in product design is Quality Function Deployment (QFD). QFD is defined as a tool to maximizing customer needs toward product designing [8], and connecting what customer's want with several technical requirements in order to assess and prioritizing which area should be and could be improved [9] while designing a new product. QFD was founded in Japan on the late 1960's as the result of Japan's blooming industry post world war [10], it was a huge success and could elevate Japan's industry into another level. As it emphasize on customer's point of view, there are a lot of research that using QFD, or even integrating it with another method, both in services or product designing. It has been used in redesigning process of a shoes [11], food packaging [12][13][14] or even a tool or machine [15]. Not only product, QFD has also been used a lot in order to increase one services such as in business [16], railway services [17], Small Medium Enterprise [18], and bus service [19]. The previous research showed that QFD has been a cornerstone in both product design and service quality by emphasizing on customer's needs.

Based on previous research, this paper will mostly cover and emphasize on designing process of goat's food processor using QFD method. The designing process will focusing on increasing breeder productivity in preparing goat's food and also reducing the chance of hazard while mixing and preparing the food

2. METHODS

This research is conducted in Rejodani District, Sleman Regency, Yogyakarta, for this research there will be several steps conducted.

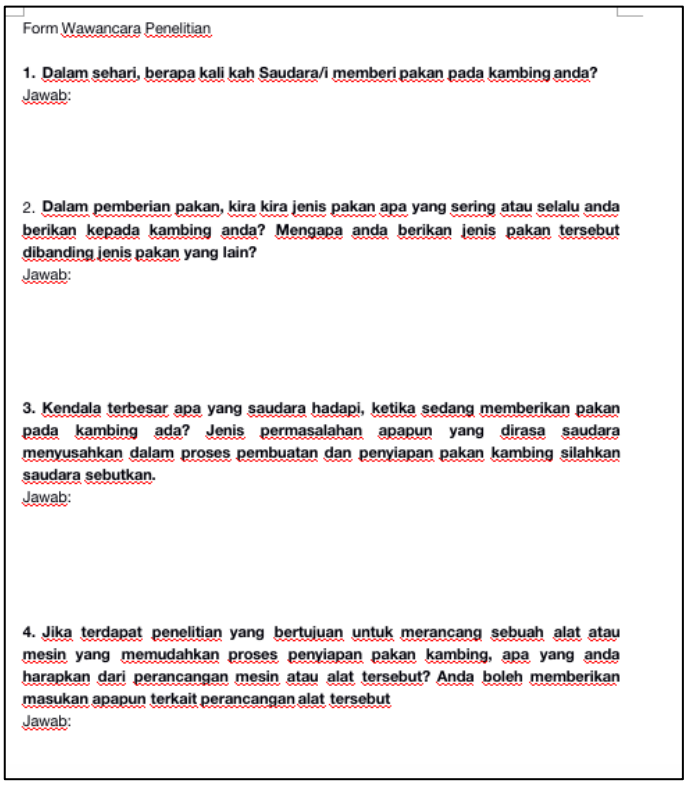
The first part of the research will be interview with breeder around Rejodani. There are 3 breeders around Rejodani district, that will be the sample and also the population for this research.The interviewing process most likely to find out what the breeders actually needed in feeding process. This part of research will be used as a way to find out the customers needs, thus it will be used in the next step of the research.

Following the interviewing process, the newly found out customer's needs will be used to create the house of quality (HoQ) where customer needs meet with technical requirements. In this part of the research, there will be several concepts and ideas regarding the newly design tools. The final design of the tool, then will be validated to the respondents of the research which are the breeders, to find out whether the newly design has already meet out the needs.

3. RESULTS AND DISCUSSION

3.1 Making an Interview Form

As it is aforementioned, this research will be using interview as a way to find out what the customer needs, a good interview will be crucial in any research steps, as it is one of the way for both researchers and research subject to interact [20], thus an interview form is needed as it is shown in Figure 1 below



Form Wawancara Penelitian

1. Dalam sehari, berapa kali kah Saudara/i memberi pakan pada kambing anda?
Jawab:

2. Dalam pemberian pakan, kira kira jenis pakan apa yang sering atau selalu anda berikan kepada kambing anda? Mengapa anda berikan jenis pakan tersebut dibanding jenis pakan yang lain?
Jawab:

3. Kendala terbesar apa yang saudara hadapi, ketika sedang memberikan pakan pada kambing ada? Jenis permasalahan apapun yang dirasa saudara menyusahkan dalam proses pembuatan dan penyiapan pakan kambing silahkan saudara sebutkan.
Jawab:

4. Jika terdapat penelitian yang bertujuan untuk merancang sebuah alat atau mesin yang memudahkan proses penyiapan pakan kambing, apa yang anda harapkan dari perancangan mesin atau alat tersebut? Anda boleh memberikan masukan apapun terkait perancangan alat tersebut
Jawab:

Figure 1. Interview Form

Using the interview form in Figure 1, authors then proceed to interview 3 breeder around Rejodani to find out what they needed most in designing a new tools.

3.2 Interviewing Process

The interviewing process is held to 3 respondents, which are goat breeders around rejodani. Using the result on this interview, it will be used to find out the needs statement and then being used to create the appropriate design. The result of the interview is shown in Table 1, 2 and 3 as followed

Table 1. Interview Result 1

Question Number	Answer
1	*"Selama ini, pada saat aku mau nyiapin pakan atau pas nyampur pakan kambingku Pak, itu selalu takes time alias suwe banget. Kadang iso satu jam atau 2 jam sendiri, itu cuman nyampur thok lho Pak"*
2	*"sehari nek aku makani kambingku 3-4 kali Pak, itu tak split 2 jenis, 3 kali pakan kering, 1 kali pakan basah"*
3.	*"Pakan kering? Kui saiki emang banyak yang geser kesitu Pak para pemilik peternakan, kenapa, soale weduse luwih lemu dan lemak nya sedikit. Pakan kering itu biasane pake konsentrat, terus ada beberapa item lain, nilai gizi lebih baik dibanding cuman pake suket thok Pak*
4.	*"Ya memang dadi luwih abot yah soale kan itu biasanya dilebokke karung, sehingga nek misal aku arepe makani kambing ya harus tak junjung Pak, baru dituang dan setelah itu baru diaduk. Sejauh ini nek ngaduk pakan itu masih manual setauku. Nek pakan basah kan luwih penak Pak, cukup modal ngarit thok beres"*
5	*"Ya harapannya kalo dirimu rancang mesin, sampai memikirkan distribusi pakannya juga Pak, karena itu lumayan PR juga"*

The first interviewing process is being held to the owner of *Waringi Farm* shown in Figure 2 below. As it shown in Table 1, the first respondent expressing several concern based on what have been asked by authors. It could be inferred from the first interviewing process that time or efficiency is the main factor as it is found that in one process of feeding preparation took couple of hours.

Figure 2 Interviewing Process of Waringi Farm's Owner

The second interview is done to another goat breeder in Rejodani, the second respondents have been a goat breeder for approximately 4 years. The interviewing process is done both in the house and in the farm as it shown in Figure 3 and 4 below

Figure 3 Interview Process 2 (at Farm)

Figure 4 Interview Process 2 (at Home)

The result of the second interview is shown Table 2 below

Table 2 Interview Result 2

Questions No	Answer
1	*"Nek saya sudah pakan kering mas, hasile wedusku memang lebih bagus. Bakul-bakul sate kambing sekarang mlayu ne ke tempat saya nek pada cari kambing. Kadang sebulan saya kesusahan untuk menyediakan kambing untuk para pemilik warung sate ini, yo maklum mas, ternak saya masih belum terlalu besar. Berapa? Sekitaran 150-200 ekor Mas punya saya"*
2	*"Sehari? Sehari biasane 4 kali mas le ku makani, kui wae isih do dokoh wedhus wedhus ku, hahahaha"*
3	*"Cukup lama mas untuk sekali proses penyiapan pakan kambing, kurang lebih 2 jam an cuman untuk ngudak dan nyampure. Itu karena murni pake tenaga manusia saya Mas, ngingu wedhus sekaligus makaryani tonggo teparo iki"*
4	*"Yang saya pakai bahannya? Macem macem Mas, mulai dari polar, ppgs, CGF, premix, itu? Kebanyakan kui impor mas bahannya, iyo lumayan kacek regane, hahaha. Kalau bahan lokal ada katul, kadang ya kopra, sawit juga tapi yo arang-arang mas. Kadang saya tambahi juga tetes tebu, buat perasa, iya bentuknya cairan gitu kemudian saya semprotkan ke pakan yang sudah saya campur*
5	*" Sebenarnya problem terbesarnya kalau dikerjakan dengan manual adalah kadang tidak rata dan belum tercampur mas. Iya, betul sekali, kadang beberapa bahan baku pakan tidak tercampur rata mas, kadang isih sok di ublek-ublek meneh ben nyampur, jadinya penjadwalan pemberian pakan agak mundur. Kambing termasuk kewan sek rodo sensitif terkait pakan, ketika jadwal bergeser ada potensi mengubah jadwal mereka selanjutnya mas."*

The second respondent have changed the feeding process for the goat using only dry food and concentrate, although there are several times that the goat still being fed with grass and greenery. The concentrate being used by the second respondent is shown in Figure 5 below.

Figure 5 Concentrated Food

The last interview is also done to one of the breeder around rejodani district, the result of this interview is shown in Table 3 below

Table 3 Interview Process 3

Question No	Answers
1	*"Nggih Mas, betul, saya sudah melihara semenjak tahun 2000 awal dulu, awalnya iseng coba coba, alhamdulillah malah laris wedhus wedhus e kula. Sehari biasanya untuk pakan 3 kali Mas, pagi-siang-sore ditengah tengahnya saya kasih tambahan pakan 2 kali, kalau di total? Berarti kurang lebih 5 kali sehari*
2	*"Menawi pakan, saya sudah tidak pakai suket melih mas, tetapi kadang-kadang memang masih pakai, banyak belajar dari teman teman sesama peternak kambing juga pakai pakan jenis baru ini"*
3	*"Kalau masalah, sebenarnya tidak ada, cuman memang agak kerepotan saya ketika harus nyampur semua pakan tersebut, karena saya garap dewean ini mas"*
4	*"Ngapunten saya belum ada bayangannya, mungkin intinya yang bisa memudahkan saya untuk memberi pakan mendha ne saya"*

The third respondents of this research, is also using dry and concentrated food for feeding process, although some grasses and greenery still being fed to the goat. Another key point on the third interview is that there are some difficulties occurred while mixing the food, because the weight of the concentrated food and the size of it while the breeder is an elderly person. Based on the interviewing process, authors could conclude the customers needs needed to create a new design.

3.3 Determining Need Statement and House of Quality

As the result of the three interview, it could be inferred and concluded that there are at least 5 main point that become a concern in the feeding process, the need statement determination is shown in Table 4 below.

Table 4 Need Statement Concept Design

Interview Recapitulation	*Need Statement*	*Simplified Needs Statement*
Breeder, usually feed their goats more than 3 times a day, and goats are time sensitive animals if their feeding time keep changing everyday whether it is because the food is not ready or anything else	**The Food provided should be sufficient enough for the daily need of the goats**	***Sufficiency Factor***
The food that being prepared, mostly dry and concentrated food. Each bag of dry food weighted minimum 50 kilos, and it need to be poured up and stirred up before being given to the goats	**The feeding process preparation should be considering the safety of the workers**	***Health and Safety System/tool | Safety Factor***
The mixing process still done manually, and it took a long time before the food finished	**Effectiveness is the key for every feeding process in every single day**	***Effectiveness Factor***
The mixing process, most of the time is not fully mixed, it could affect the nutritional value for the goats	**The consistency of the output (feeding item) is important**	***Consistency Factor***

Based on the result of Table 4, it could be found that there are at least 4 main points and needs statement that should be a concern for authors to create a newly designed, namely : a)sufficiency factors b)health and safety system c)effectiveness factor d)consistency factor. Using the 4 needs, it could be used in the next step of this research which is creating the House of Quality (HoQ) where needs will meet the technical requirements. The HoQ is shown in Figure 6 Below

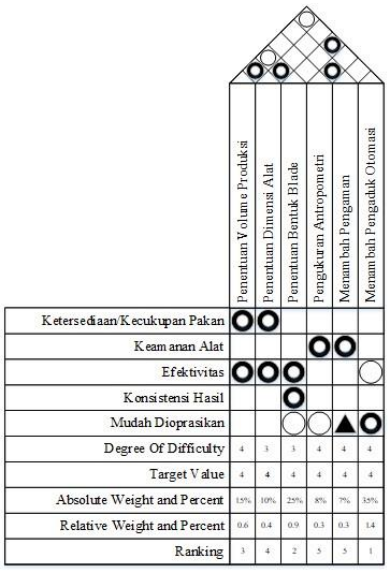


Figure 6 House of Quality

Based on Figure 6, it could be inferred that there are several technical requirements for the newly designed tools such as :

1. Adding automatic mixer
2. Blade design
3. Production Volume
4. Product dimensions
5. Anthropometric factors
6. Secure lock and extra safety features

3.4 Generating Concept, Screening and Selection

The house of Quality has provided guidance for the designing process, the aforementioned technical requirements of the product, can be used to generate several concept for the upcoming design. Another key point that should be considered, is the benchmark product. Benchmark could be used as a reference by inventors to identify the best product or service in order to create the same level of product or service based on the referenced product [21][22]. The referenced or benchmark product/tools in this research as it follows

Molen Machine : as one of the main problem stated in the need statement, breeder's problem is the effectiveness of the mixing process, mixing process' output and the effort of doing one. Thus *Molen* could be one of the tool that could help on this. *Molen* machine would be the benchmark product in the selection and screening process.

3.4.1 Concept Generation

Based on the technical requirements, the following step is to generate concept. Generating concept would be a crucial point in QFD method, as it would be a decision whether one design could help to answer the customer's needs or not. In this research, there are 2 Design Concept that have been generated, as it is shown in Figure 7 and 8 Below

Figure 7 Concept Design 1

The first concept design, provide several points that have become the concern by the breeder. The newly proposed design tool is provided with several improvement compared to the current process such as an enclosed process, stirrer and sufficient volume to feed the goats.

Figure 8 Concept Design II

The second concept is also providing convenience for breeder yet still answering the customer's needs in the previous segment. The difference between the first and the later design is in the shape of the design and the blade revolving inside the compartment that being used to mix and stir the concentrated food.

3.4.2 Concept Screening

Following the generated concept, the next step of the research, will be the selection concept between the two and the benchmark product. The selection process is shown in Table 5 below.

Table 5 Concept Screening

Criteria	Benchmark (*Molen* machine)	Concept I	Concept II
Automatic Mixer	0	+	+
Blade Design	0	-	+
Production Volume	0	+	-
Dimensions	0	0	0
Anthropometric Factors	0	+	+
Secure Lock & Extra Safety Feature	0	+	+
Σ +	0	4	4
Σ -	0	1	1
Σ 0	6	1	1
Total	**0**	**3**	**3**
Continue	no	**yes**	**yes**

Based on the result shown in Table 5, both concept I and II have the advantages over the benchmark product, security and safety has become the main concern in this research along with effectiveness and product output. Using the score in Table 5, the next step in this research is the concept scoring.

3.4.3 Concept Scoring

Following the previous result, the next step in this research is the concept scoring, to finally rate which concept should be brought into final design. The scoring result of both concept is shown in Table 6 below.

Table 6 Concept Scoring

Criteria	Weight (%)	Concept I		Concept II	
		Rating	Weighted Score	Rating	Weighted Score
Automatic Mixer	15	4	**60**	4	60
Blade Design	10	3	**30**	4	**40**
Production Volume	25	4	**100**	3	**75**
Dimensions	8	4	**32**	4	**32**
Anthropometric Factors	7	3	**21**	3	**21**
Secure Lock & Extra Safety Feature	35	5	**175**	5	**175**
Total Score		**418**		**403**	
Continue?		**COMBINE**		**COMBINE**	

3.5 Final Design and Validation

Both concept I and II are excel in their own, thus it comes to a decision that both design should be combine in order to find out the best proposed design. Figure 9 below shows the final proposed design of the product.

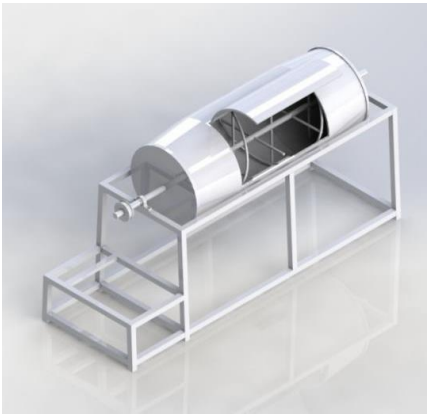


Figure 9 Final Design of the Product

The proposed design, will have to be validated by the three respondents of the research. The validation process is done by showing the proposed design to the respondent. The result of the validation process is shown in Table 7 below

Table 7 Validation Process

Respondent Number	**Is the Proposed Design correspond with the one you imagine?**	**Comments?**
1	Yes	"i would like to have the design to be made, even it is just a prototype, i need to make sure the machine good enough for daily use"
2	Yes	-
3	Yes	"It would help me to ease any mixing process. I will spend less effort in preparing my goat's daily food. I wont be burdened with heavy lifting which i have done several years back"

Based on the validation process, the proposed design has meet out what the customers wanted, as the three respondents of the research already agreed the proposed design. Emphasizing on customer's needs has made the designing process becoming easier, as the inventor only needed to create and made the proposed design based on the customer's needs. Current design should be manufactured next, in order to be tested in a real system.

4. CONCLUSION

Goat feeding is a crucial factor in breeding and raising goat, as the nutrition needed by goat will affect its growth and their meat composition. Sadly, most of the goat breeder still done the process manually, thus, affecting several factors such as safety, effectiveness and food output. Based on that, the newly proposed design for the process is imperative, using interview among breeder around Rejodani District, it could be found that there are 4 main concern of the food preparation for the goat. Using QFD, the customer's needs found is then being translated into 6 technical requirements which then be used to made the final design. Automatic mixer and safety factor plays an important role in the design as it appeared in the proposed final design

5. REFERENCES

[1] Karnadi, A. "Populasi Kambing Indonesia Capai 19,23 Juta Ekor pada 2021" https://dataindonesia.id/sektor-riil/detail/populasi-kambing-indonesia-capai-1923-juta-ekor-pada-2021. (Accessed Jan. 20, 2023)
[2] Karnadi, A. "Pasokan Sapi Potong Indonesia Capai 18,05 Juta pada 2021" https://dataindonesia.id/sektor-riil/detail/pasokan-sapi-potong-indonesia-capai-1805-juta-pada-2021. (Accessed Jan. 21, 2023)
[3] Badan Pusat Statistik. (2021). *Populasi Kambing Menurut Provinsi (Ekor)*.Jakarta

[4] Derendra, C. (1988). The Nutritional Value of Goat Meat. 76-86
[5] Correa, J. (2016). Nutritive Value of Goat Meat. 1-3
[6] Cosgrove, N. "How Much and How Often to Feed Goats [Feeding Chart & Guide]" https://petkeen.com/goats feeding-chart-guide/. (Accessed Jan.20, 2023)
[7] Muci-Küchler, K. H., & Weaver, J. M. (2004). Learning How to Identify Customer Requirements: A Key Component of Product Development Courses. Proceeding of American Society for Engineering Education Annual Conference & Exposition, 1–31.
[8] Hauser, J. R., Griffin, A., Klein, R. L., Katz, G. M., & Gaskin, S. P. (2010). Quality Function Deployment (QFD). In Wiley International Encyclopedia of Marketing. John Wiley & Sons, Ltd. https://doi.org/10.1002/9781444316568.wiem05023
[9] Erdil, N. O., & Arani, O. M. (2019). Quality function deployment: more than a design tool. International Journal of Quality and Service Sciences, 11(2), 142–166. https://doi.org/10.1108/IJQSS-02-2018-0008
[10] Akao, Y. (1997). International Symposium on QFD '97-Linköping QFD: Past, Present, and Future. International Symposium on QFD, 1–12.
[11] Jatmiko, H.A., & Nugroho, D.S. (2022). IMPLEMENTING KANSEI ENGINEERING AND QUALITY FUNCTION DEPLOYMENT METHOD IN DESIGNING SHOES 鈥 : CASE STUDY AT REJOWINANGUN ORIGINAL LEATHER. In Journal of Engineering Design and Technology 70 Journal of Engineering Design and Technology (Vol. 22, Issue 1). http://ojs.pnb.ac.id/index.php/LOGIC
[12] Ardian, A., & Jatmiko, H. A. (2021). Designing food packaging of bitter melon chips using Kano and quality function deployment: case study in KRIPIK Pare Pak IPHE. KKU International Engineering Conference, 82–89.
[13] Wattanutchariya, W., & Royintarat, T. (2012). Implementation of Quality Function Deployment and Kansei Engineering for GABA Rice Snack Development. Environment and Natural Resources, 10(2), 1–10.
[14] Andriani, D. P., Choiri, M., & Priharseno, D. (2017). Aplikasi Quality Function Deployment Untuk Redesign Kontainer Penyimpanan Pada Industri Kemasan Kaleng. Jurnal Teknik Industri, 18(2), 176–190. https://doi.org/10.22219/jtiumm.vol18.no2.176-190
[15] Sukardi, Setyaningrum, R., & Nuswantoro, Izzhari. D. (n.d.). PERANCANGANG SLICER MACHINE CRACKERS DENGAN MENGGUNAKAN METODE KANSEI ENGINEERING DAN QUALITY FUNCTION DEPLOYMENT (QFD) SEBAGAI UPAYA MENINGKATKAN PRODUKTIVITAS UMKM KERUPUK IKAN.
[16] Shrivastava, P. (2013). House of Quality: An Effective Approach to Achieve Customer Satisfaction & Business Growth in Industries. International Journal of Science and Research, 5(9), 1365–1371. www.ijsr.net
[17] Putri, S. I., Sumartini, S., & Sofia, A. (2017). Metode Service Quality (Servqual) dan Quality Function Deployment (QFD) sebagai Usulan Perbaikan Kualitas Pelayanan di PT. Kereta Api Indonesia (Persero). JURNAL ILMU MANAJEMEN DAN BISNIS, 8(1), 11–16. https://doi.org/10.17509/jimb.v8i1.12656
[18] Efendi, Z., Pertanian, J. T., Pertanian, F., & Bengkullu, U. (2007). Penerapan Quality Function Deployment (QFD) untuk Peningkatan Kinerja Industri Kecil Bakso Sapi Berdasarkan Kepuasan Pelanggan. 2(2), 85–91.
[19] Nurkertamanda, D., Husain, F., & Widharto, Y. (2021). Redesign of Bus Services Using Quality Function Deployment (QFD) to Improve Services to Passenger (Case Study: PO XYZ). OPSI, 14(1), 73. https://doi.org/10.31315/opsi.v14i1.4747
[20] All About Interviews. (2014). 1–12. www.aber.ac.uk/en/is/elecinfo/eiaz/
[21] Bhutta, K. S., & Huq, F. (1999). Benchmarking – best practices: An integrated approach. Benchmarking: An International Journal, 6(3), 254–268. https://doi.org/10.1108/14635779910289261
[22] Sammut-Bonnici, T. (2015). Benchmarking. In Wiley Encyclopedia of Management (pp. 1–2). John Wiley & Sons, Ltd. https://doi.org/10.1002/9781118785317.weom120043

LOGIC
Journal of Engineering Design and Technology
Vol. 23 No.1 March; p. 42-48

p-ISSN : 1412-114X
e-ISSN : 2580-5649
http://ojs2.pnb.ac.id/index.php/LOGIC

ANALYSIS OF LABOR PRODUCTIVITY IN FLOOR PLATE WORK USING THE WORK SAMPLING METHOD

(Case Study: Udayana University Faculty of Medicine Building and The Calna Villa)

Made Novia Indriani [1)], I Nyoman Suta Widnyana [1)], I Putu Agus Ari Mahendra [1)]

1) Department of Civil Engineering, Faculty of Engineering, Universitas Hindu Indonesia, Denpasar, Bali

Correponding email [1)] :

madenovia@gmal.com

Abstract. Labor productivity is very important in carrying out a job. In the field of construction, the output can be seen from the quantity of work that has been done, while input is the number of resources used such as labor. This study aims to determine the amount of labor required per 1 m^2 (units of labor per day) and the standard time for labor productivity in completing 1 m^2 of floor slab work. The method of collecting primary data is the source of research data obtained directly, such as the number of workers and observation of sampling data, while secondary data is obtained from projects such as working drawings. The data is then processed using Microsoft Excel. This research is a type of quantitative research with work sampling method. From the results of research on floor slab work in the Udayana University Faculty of Medicine Building Construction project, it shows that the calculation of the volume of labor per day (units of labor per day) requires 0.011 units of labor per day masons and 0.011 units of labor per day workers and the results of calculating the standard time to complete 1 m^2 of floor slab work is 3.15 minutes/m^2. The Calna Villa project shows that the calculation of the volume of labor (units of labor per day) requires 0.039 units of labor per day masons and 0.039 units of labor per day orkers and the results of calculating the standard time to complete 1 m^2 of floor slab work is 10.37 minutes/m^2.

Keywords: Labor, Productivity, Work sampling.

1. INTRODUCTION

In the current era of globalization, every workforce in all sectors including the construction sector must have high work productivity so that they can continue to exist and compete in their field. Productivity is very important for every workforce in completing a job. The lack of awareness of the workforce on the importance of productivity is one of the reasons for the low number of jobs produced[1].

The construction of a building includes many types of work, one of the parts in the construction of the superstructure of the building is the floor slab work. Slab structure work in building construction is a very important job, considering that slab work has a large volume [2]. The large volume of work on the floor slab structure makes the floor slab work quite a lot of time. However, these elements can still be optimized in terms of spending costs resulting from material requirements and the length of time in the process by choosing other alternatives in the process.

In general, productivity is the ratio between output (results) and input (input). While Labor productivity

is the ability of employees to produce compared to the input used, an employee can be said to be productive if he can produce goods or services as expected in a short or precise time [3]. If productivity increases, this is only made possible by an increase in efficiency (time-materials-labor) and work systems, production techniques, and an increase in the skills of the workforce [3]. Each productivity improvement planning action includes the main macro factors, measurement of the importance of each factor, determination on the priority, planning a system to increase the ability of workers, and improvement the attitude of workers.

Previous research on productivity was conducted [4]. Research conducted on the analysis of construction labor productivity on ceramic floor work and wall plastering uses the work sampling method [5]. A similar method was also used to calculate the labor productivity in column and beam work. Sampling or commonly called work sampling is a technique for making many observations of the work activities of machines, processes, and workers/operators. This work measurement is classified as direct work measurement because the implementation of measurement activities must be carried out directly at the workplace to be studied. Work sampling is very suitable for making observations on work that is non-repetitive in nature and has a relatively long cycle time [6]. Sampling is done instantaneously at randomly determined times. Therefore, the use of random tables is very necessarforin this method [7]. The work sampling method is more efficient because the desired information will be obtained in a relatively short time and the cost is not too expensive [8].

This research was mainly focused on labor productivity in floor slab work. Slabs are horizontal structural elements that support dead and live loads and transmit them to the vertical framework of the structural system [9]. Plates are used in architectural structures, bridges, hydraulic structures, road pavements, airplanes, ships, and so on. A floor slab is a thin structure made of reinforced concrete and with a horizontal plane, and the load acting perpendicular to the plane of the structure [10]. This reinforced concrete slab is very stiff and has a horizontal directin so that in buildings, this plate functions as a diaphragm/horizontal behavior element which is very useful for supporting the rigidity of portal beams [11].

The work sampling method was applied to calculate the labor productivity in floor slab work. The projects used as objects in this research are the Udayana University Faculty of Medicine building project and The Calna Villa development project. The difference in the gap here is in the varied technical work, namely in the Udayana University Faculty of Medicine Building project assisted by using a tower and in The Calna Villa project not using a tower crane. This research was conducted to know the amount of labor needed for every 1 m^2 of floor slab work (units of labor per day) and knowing the standard time for labor productivity in completing 1m^2 of floor slab work using the work sampling method.

2. METHODS

2.1 Research Locations

The research was done in two locations: The Udayana University Faculty of Medicine Building Project where the location is located on Jalan P.B. Sudirman, Denpasar, Bali ,and The Calna Villa Development Project where the location is located on Jalan Raya Kuta 27, Kuta, Bali.

2.2 Data Sources

In this study, primary data collection was carried out using the work sampling method, namely momentary and periodic observations of workers carrying out floor slab work, the duration of observation was 8 hours. Observations were made at intervals every 5 minutes and the results were recorded on the work sampling observation form. Furthermore, the results of observations are grouped into productive activities and unproductive activities. Meanwhile, secondary data was obtained from data related to the project, such as working drawings on the project. The secondary data was collected through a literature study which was carried out by reading and citing information from books, theses, and internet sites.

2.3 Data Analysis

2.3.1 Work Sampling

Data uniformity testing is a useful test to ensure that the data collected comes from the same system [12]. Through this test, we can detect the presence of differences and data that are out of control which we can draw on the control chart. Such data is discarded and not used in further calculations. The data uniformity test was carried out by choosing an accuracy level of 5% and a confidence level of 95% with an absolute value of 2. To make a control chart, we first determine the control limits using equation (1) – (3)

$$\bar{P} = \frac{p_i}{n_i} x\ 100\% \quad (1)$$

$$BKA = \bar{P} + k\sqrt{\frac{\bar{P}\,(1-\bar{P})}{n}} \quad (2)$$

$$BKB = \bar{P} - k\sqrt{\frac{\bar{P}\,(1-\bar{P})}{n}} \quad (3)$$

where
pi : productive percentage on day i
ni : the number of observations made on day-i
k : price index size depends on the level of confidence
n : the average number of observations overall

2.3.2 Data Adequacy Test

The data adequacy test is a process to find out whether the data from the measurements that have been carried out are sufficient or not [13]. Observation data is said to be sufficient if N > N', i.e. the number of measurements made is greater than the number of measurements required. The formula used to calculate data adequacy is using equation (4)

$$N' = \frac{k^2(1-p)}{s^2 p} \quad (4)$$

where:
N' : The amount of theoretical data
k : Absolute price based on the confidence level
s : level of accuracy
p : productive percentage of day-i

2.3.3 Standard Time Determination

If the measurements have been completed, that is, all the data obtained has the desired uniformity, and the numbers meet the desired levels of accuracy and confidence, the next step is to calculate the standard time from the data. Standard time calculation is done using equations (5) – (8).

$$\text{Productive working hours} = \bar{P}\ x\ \text{total minutes of observation} \quad (5)$$

$$Ws = JK/\ \text{Number of units produced} \quad (6)$$

$$Wn = (p\ x\ W_s) \quad (7)$$

$$\text{Standard time} = W_n + (I\ x\ W_n) \quad (8)$$

where:
JKP : Productive working hours
Q : Productive percentage
I : Allowance (relaxation)
Ws : Cycle time
W : Normal time

The calculation of standard time was done by using following steps:

- Counting the number of observed data
- Counting the number of minutes during the observation
- Calculating productive activities
- Calculate the productive percentage
- Calculate the number of productive minutes
- Calculating cycle time (Ws)
- Calculating the adjustment factor (p), the Westinghouse method
- Calculating normal time (Wn)
- Calculating allowance (I)
- Calculating standard time (Wb)

2.3.4 Volume of workers per day (units of labor per day)

Calculation of output or volume of workers for the total workforce is carried out in field observations. The current volume calculation is used to calculate the volume of one worker for floor slab work. The way to calculate the volume of work completed by 1 worker for 1 day (units of labor per day) is by calculating the total volume of work during the study divided by the number of days during the study and divided by the number of each workforce during the study.

3. RESULTS AND DISCUSSION

3.1 Udayana University, Faculty of Medicine Building Project

Udayana University Faculty of Medicine Building Project with a land area of 2,094 m^2. The scope of work taken in this study is on the 4th floor of the building.

Sampling data collection for floor slab work was carried out for 5 days of observation starting from Sunday (22/09/2019) to Thursday (26/09/2019) for 2 builders and 2 workers who worked on slab work. The collection of Floor Plate Sampling Data is carried out for 8 working hours using the Work Sampling observation

form.

Before determining the time of visit, must determine the number of visits to be made for the calculation and the conditions are as follows:

- Working time 08:00 - 17:00
- Lunch break 12:00 - 13:00
- Long working time 9 hours – 1 hour = 8 hours

Then th number of visits $= \frac{W \times t}{s} = \frac{8 \times 60}{5} = 96$ observations, where

W = Effective working time: 8 hours
t = unit of time in minutes: 60 minutes
s = Length of each visit: 5 minutes

In this study, it was tried to take 70 random numbers from 96 random numbers, by not taking random numbers during breaks, namely from 12.00 to 13.00.

3.1.1 Calculation of Labor Volume per Day (Units of Labor per Day)

In the floor slab work, there are 4 workers consisting of 2 builders and 2 workers with 5 days of work. The volume produced for 5 days by 4 workers is 842.70 m². So in 1 day by 4 worker,s it is 842.70 m²/5 = 168.54 m². So 1 worker in 1 day can do 168.54 m²/4 = 42.13 m². Builder is 2 workers who work on floor slabs in 1 day is 84.26 m². So for 1 m² of slab work it takes 1/84.26 m² = 0.011 worker days or in other words for slab work it takes 0.011 units of labor per day masons. While workers is working on floor slabs in 1 day is 84.26 m². So for 1 m² of slab work, 1/84.26 m² = 0.011 worker days or in other words, 0.011 units of labor per day workers are required for slab work.

3.1.2 Calculating Standard Time

- Calculating the amount of observational data
  Builder 1 data = 70 data x 5 days = 350 data
  Builder 2 data = 70 data x 5 days = 350 data
  Employee data 1 = 70 data x 5 days = 350 data
  Employee data 2 = 70 data x 5 days = 350 data
  Total observational data = 1400 data
- Counting the Number of Minutes of Observation
  8 (hours) x 60 (minutes) x 5 (days) = 2400 minutes
- Calculating the Number of Observable Productive Data
  Builder 1 data = 308 data
  Builder 2 data = 307 data
  Employee data 1 = 306 data
  Employee data 2 = 305 data
  Total Data = 1226 data
- Calculating the Number of Observable Productive Data
  Productive Number = 1226 data
  Number of Observations = 1400 data
  Productive Percentage = (1226/1400) x 100 % = 87.57 %
- Calculating the Number of Productive Minutes
  Productive Percentage = 87.57 %
  Total Minutes of Observation = 2400 minutes
  Number of Productive Minutes = 87.57 % x 2400 minutes = 2101 minutes
- Calculating the number of products (volume) produced
  First Day = 150.60 m²
  Second Day = 175.00 m²
  Third Day = 160.80m²
  Fourth Day = 170.90 m²
  Fifth day = 185.40 m²
  Total Volume = 842.70 m²
- Calculating Cycle Time (Ws)
  Number of Productive Minutes= 2101 minutes
  Total Volume = 842.70 m²
  Cycle Time (Ws) = 2101 minutes/842.70 m² = 2.50 minutes/ m²

- Calculating the Adjustment Factor (p)
  Where seen from the adjustment according to *Westinghouse*, Adjustment:
  Skills = Good (C1) = 0.06
  Effort = Good (C2) = 0.02
  Condition = Excellent (B) = 0.04
  Consistency = Good (C) = 0.01
  Total = 0.13
  Total Adjustment Factor (p) = 1+0.13 = 1.13
- Calculating Normal Time (Wn)
  Cycle Time (Ws) = 2.50 minutes/ m²
  Total Adjustment Factor (p) = 1.13
  Normal Time (Wn) = p x Ws = 1.13 x 2.50 minutes/ m²
  = 2.83 minutes/ m²
- Calculating Allowance (I)

Table 1. Allowance Data in Udayana University

No	Factor	Work	Load Equivalent	Allowance (%)
1	The energy released is very light	Stand	-	6%
2	Work attitude standing on 2 feet	Supported by 2 feet	-	1%
3	Normal working movement	Limited swing	-	0%
4	Eyestrain, eyes that are cut off	Bring measuring tools	-	2%
5	Normal working temperature conditions	22-28 C	-	1%
6	The atmosphere is good	Good ventilation	-	1%
7	The state of the environment is clean, healthy, bright with low noise	-	-	0%
Amount				11%

The total amount of allowance (I) is 11%

- Calculating Standard Time (Wb)
  Normal Time = 2.83 minutes/ m²
  Allowance (I) = 11%
  Wb= Wn + (I x Wn) = 2.83 + (0.11 x 2.83)
  = 3.15 minutes/ m²

3.2 The Calna Villa Project

The Calna Villa project with a land area of 1,600 m^2. The scope of work taken in this study is in the 2nd floor lobby building. Collecting Sampling Data for Floor Slab Work for 5 days of observation starting from Tuesday (28/04/2020) to Saturday (02/05/2019) for 2 builders and 2 workers working on the slab work. Sampling Data Collection Floor slab work was carried out for 8 working hours using the Work Sampling observation form. The number of visit was calculated similarly to the one done in Udayana University Project. It was also tried to take 70 random numbers from 96 random numbers, by not taking random numbers during breaks, namely from 12.00 to 13.00.

3.2.1 Calculation of Labor Volume per Day (Units of Labor per Day)

In the floor slab work there are 4 workers consisting of 2 builders and 2 workers for 5 workdays. The volume produced for 5 days by 4 workers is 251.90 m². So in 1 day by 4 workers it is 251.90 m^2/5 = 50.38 m². So 1 worker in 1 day can do 50.38 m^2/4 = 12.60 m^2. 2 builders work on floor slabs in 1 day and was able to finish 25.20 m². So for 1 m² of slab work it takes 1/25.20 m² = 0.039 worker days or in other words for slab work it takes 0.039 units of labor per day masons.While, 2 workers who work on floor slabs in 1 day was able to finish 25.20 m². So for 1 m² of slab work, 1/25.20 m² = 0.039 worker days or in other words, 0.039 units of labor per day workers are required for slab work.

3.2.2 Calculating Standard Time

1. Calculating the amount of observational data
   Builder 1 data = 70 data x 5 days = 350 data

Builder 2 data = 70 data x 5 days = 350 data
Employee data 1 = 70 data x 5 days = 350 data
Employee data 2 = 70 data x 5 days = 350 data
Total observational data = 1400 data

2. Counting the Number of Minutes of Observation
   8 (hours) x 60 (minutes) x 5 (days) = 2400 minutes
3. Calculating the Number of Observable Productive Data
   Builder data 1 = 305 data
   Builder 2 data = 303 data
   Employee data 1 = 304 data
   Employee data 2 = 305 data
   Total Data = 1217 data
4. Calculating the Number of Observable Productive Data
   Productive Number = 1217 data
   Number of Observations = 1400 data
   Productive Percentage = (1217/1400) x 100 % = 86.92 %
5. Calculating the Number of Productive Minutes
   Productive Percentage = 86.92 %
   Total Minutes of Observation = 1920 minutes
   Numberof Productive Minutes= 86.92 % x 2400 minutes = 2086 minutes
6. Calculating the number of products (volume) produced
   First Day = 49.25 m²
   Second Day = 50.00 m²
   Third Day = 50.75 m²
   Fourth Day = 50.90 m²
   Fifth day = 51.00 m²
   Total Volume = 251.90 m^2
7. Calculating Cycle Time (Ws)
   Numberof Productive Minutes = 2086 minutes
   Total Volume = 251.90 m²
   Cycle Time (Ws) = 2086 minutes / 251.90 m² = 8.28 minutes / m²
8. Calculating the Adjustment Factor (p)
   Where seen from the adjustment according to Westinghouse, Adjustment:
   Skills = Good(C1) = 0.06
   Effort = Good(C2) = 0.02
   Condition = Excellent (B) = 0.04
   Consistency = Good (C) = 0.01
   Total = 0.13
   Total Adjustment Factor (p) = 1+0.13 = 1.13
9. Calculating Normal Time (Wn)
   Cycle Time (Ws) = 8.28 min/m²
   Total Adjustment Factor (p) = 1.13
   Normal Time (Wn) = p x Ws = 1.13 x 8.28 minutes/ m²
   = 9.35 minutes/ m²
10. Calculating Allowance (I)

Tabel 2. Allowance Data in The Calna Villas

No	Factor	Work	Load Equivalent	Allowance (%)
1	The energy released is very light	Stand	-	6%
2	Work attitude standing on 2 feet	Supported by 2 feet	-	1%
3	Normal working movement	Limited swing	-	0%
4	Eyestrain, eyes that are cut off	Bring measuring tools	-	2%
5	Normal working temperature conditions	22-28 C	-	1%
6	The atmosphere is good	Good ventilation	-	1%

7	The state of the environment is clean, healthy, bright with low noise	-	-	0%
	Amount			11%

The total amount of allowance (I) is 11%

11. Calculating Standard Time (Wb)

Normal Time = 9.35 minutes / m²
Allowance (I) = 11%
Wb= Wn + (I x Wn) = 9.35 + (0.11 x 9.35)
= 10.37 minutes/ m²

4. CONCLUSION

The calculation of floor slab work using work sampling method in Udayana University and The Clna Villas was done. The floor slab work in Udayana University Faculty of Medicine Building, 4th floor, was involving two builders and two workers. The volume produced in 1 day by 4 workers is 168.54 m^2. From the results of the calculation of the volume of labor per day (units of labor per day) it is obtained that 1 m² of floor slab work it requires 0.011 units of labor per day masons and 0.011 units of labor per day workers. So, the standard time obtained is 3.15 minutes/m^2. Even though, the project in The Calna Villa was also used same number of builders and workers, the volume produced in 1 day by 4 workers is only 50.38 m^2. Thus, for 1 m^2 of floor slab work, 0.039 units of labor per day masons and 0.039 units of labor per day workers are needed. Therefore, the standard time obtained is 10.37 minutes/m^2 which is almost three time higher than standard time for construction in Udayana University.

5. REFERENCES

[1] Muchdarsyah, Sinungan. 2003. *Produktivitas apa dan bagaimana*. Jakarta : Bumi Askara
[2] Tunas, F., Tjakra, J., & Inkiriwang, R. L. (2020). Metode Pelaksanaan Pekerjaan Balok Dan Plat Lantai Dua Pada Pembangunan Mall Pelayanan Publik (Mpp) Manado. Jurnal Sipil Statik, 8(6).
[3] Hasibuan Melayu. 1996. *Organisasi Dan Motivasi Dasar Peningkatan Produktivitas*. Jakarta: Bumi Aksara.
[4] Hutasoit.J.P. 2017. *Analisis Produktivitas Tenaga Kerja Konstruksi Pada Pekerjaan Pasangan Lantai Kramik Dan Plesteran Dinding Menggunakan Metode Work Sampling*. Jurnal Sipil Statik Vol.5 No 4 (205-214)
[5] Walangitan, Ronny. 2012. *Produktivitas Tenaga Kerja Dengan Menggunakan Metode Work Sampling Pada Pekerjaan Kolom Dan Balok Mega Trade Center Manado*.
[6] Santoso, D. A., & Supriyadi, A. (2010). Perhitungan waktu baku dengan metode work sampling untuk menentukan jumlah tenaga kerja optimal. *Prosiding SNST Fakultas Teknik*, *1*(1).
[7] Hutasoit.J.P. 2017. *Analisis Produktivitas Tenaga Kerja Konstruksi Pada Pekerjaan Pasangan Lantai Kramik Dan Plesteran Dinding Menggunakan Metode Work Sampling*. Jurnal Sipil Statik Vol.5 No 4 (205-214)
[8] Walangitan, Ronny. 2012. *Produktivitas Tenaga Kerja Dengan Menggunakan Metode Work Sampling Pada Pekerjaan Kolom Dan Balok Mega Trade Center Manado*.
[9] Sudarmoko, 1996. *Diagram Perancangan Kolom Beton Bertulang*, Jurusan Teknik Sipil, Fakultas Teknik, Universitas Gadjah Mada, Yogyakarta.
[10] Handayani,Karissa. (2018). Pengukuran Beban Kerja Karyawan Pada Lantai Produksi Dengan Metode Work Sampling (Studi Kasus Di Pt. Teluk Luas). (Skripsi Sarjana, Sekolah Tinggi Teknologi Industri Padang)
[11] Asroni, Ali. 2010. *Balok dan Pelat Beton Bertulang*. Yogyakarta. Graha Ilmu.
[12] Diniaty, D., & Ariska, I. (2017). Penentuan jumlah tenaga kerja berdasarkan waktu standar dengan metode work sampling di stasiun repair overhoul gearbox (studi kasus: Pt. Imeco inter sarana). *Jurnal Teknik Industri*, *3*(1).
[13] Rafian, M. A., & Muhsin, A. (2017). Analisis Beban Kerja Mekanik pada Departemen Plant dengan Metode Work Sampling (Studi Kasus pada PT Xyz). *Opsi*, *10*(1), 35-42.

LOGIC
Journal of Engineering Design and Technology
Vol. 23 No.1 March 2023 ; p. 49 - 54

p-ISSN : 1412-114X
e-ISSN : 2580-5649
http://ojs2.pnb.ac.id/index.php/LOGIC

HEATING TREATMENT OF INCOMING AIR COMBUSTION CHAMBER ON THE E20 FUEL MIXTURE

Akbar Anugrah Ikhsani [1], Muh. Nurkoyim Kustanto [2], Boy Arief Fachri [3]

1) Automotive Engineering Technology Study Program, State Polytechnic of Malang, PSDKU Lumajang, Indonesia
2) Department of Mechanical Engineering, University of Jember, Jember, Indonesia
3) Department of Chemical Engineering, University of Jember, Jember, Indonesia

Correponding email [1] : akbar_anugrah@polinema.ac.id

Abstract. This research was conducted to improve engine performance with a mixture of ethanol and gasoline, because the mixture of ethanol and gasoline fuel causes the value of the flash point and evaporation of fuel heat to be higher. To overcome this, the air entering the combustion chamber is carried out by being heated to 26°C (standard), 30°C, 40°C and 50°C, the fuel used is the E20 with engine revolutions of 2000 to 8000 revolutions per minute. The results showed that the highest torque of E20 fuel at 30°C with a value of 9.004 Nm increased by 0.27%. At the highest power, it is located at 30°C with a power of 5.99 kW 0.5%. For the lowest consumption in the 2000 round, it was found in the 30°C temperature treatment with a value of 1.4 Kg / Hp.Hour and for exhaust gas emissions the lowest hydro carbon value was found in the 30°C temperature treatment while the lowest value of carbon monoxide was found at the 50°C temperature treatment. These results show that the air heating treatment can improve engine performance.

Keywords : Temperature,Combustion, Treatment

1. INTRODUCTION

Oil production is vulnerable in this regard can be seen in the production of domestic oil refineries. Energy versification is needed in the current energy crisis by developing alternative bio ethanol fuels to provide for national energy consumption needs. Researchers have begun to pay attention to the use of a mixture of ethanol and gasoline as vehicle fuel since the last 40 years[1]. The use of ethanol is generally widely used as an alternative fuel for transportation by mixing gasoline and ethanol with percentage levels, but the mixture of gasoline and ethanol fuel has a weakness due to the latent heat of ethanol and gasoline fuels has a difference of three times that of gasoline latent heat the treatment of the fuel system is needed when using a mixture of ethanol fuel and gasoline so that the use of ethanol fuel mixture can be applied to gasoline-fueled engines[2][3]. The advantage of ethanol is that it can reduce the value of CO and HC when mixed with gasoline[4]. Based on the problems above to get maximum performance in a gasoline-fueled engine, one of the things that can be done is to warm up the air into the combustion chamber aims to it is expected that the performance of engines with ethanol and gasoline fuel mixture can be better than gasoline engines[5][6][7]. Therefore it is necessary to obtain the right temperature of the inlet air of the combustion chamber on the mixture of ethanol and gasoline fuel.

2. METHODS

The method used in this research is an experimental method. This experimental method was used to determine the effect of a mixture of pertalite and ethanol fuel on the performance and exhaust emissions of the Beat esp engine.

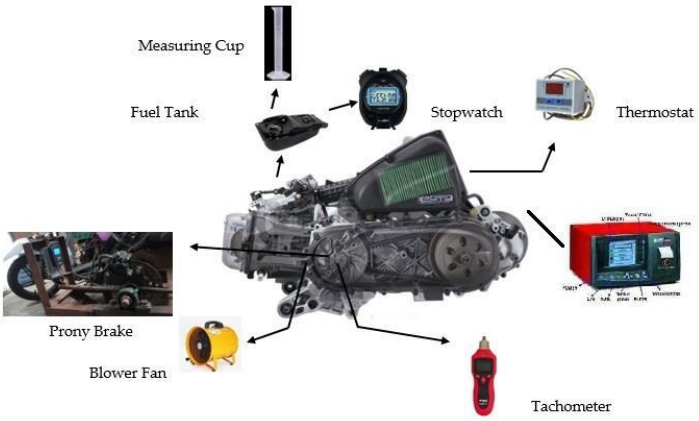


Figure 1. Experiment Setup

In this research, the fuel used was E20 fuel = 20% Ethanol + 80% Pertalite, while the ethanol used is 99.75% and the air heater treatment were placed in the air filter box by wrapping the air inlet pipe with nickel wire with a diameter of 0.3 mm, to regulate the heat of air entering the combustion chamber, using a thermostat. The temperatures used in this research were 26°C (standard), 30°C, 40°C and 50°C. This temperature was chosen because the fuel used uses a low concentration of E20 with a fuel composition of 20% ethanol and 80% pertalite. The parameters observed in this research are engine performance and exhaust emissions, engine performance testing using a Prony brake tool, this tool serves to measure the force generated by the engine crankshaft and then converted to torque for for testing exhaust emissions the observed results are CO and HC using a gas analyzer that is placed in the exhaust hole when the engine is started.

3. RESULTS AND DISCUSSION

The table below shows the results obtained during the research and visualized using the graphs contained in the explanation and performance analysis.

Table 1. Value of Research Results

Torque					Power				
RPM	26°C	30°C	40°C	50°C	RPM	26°C	30°C	40°C	50°C
2000	3,75	3,78	3,75	3,74	2000	0,78	0,79	0,78	0,78
3000	5,51	5,57	5,51	5,47	3000	1,73	1,74	1,73	1,71
4000	6,8	6,8	6,83	6,79	4000	2,84	2,84	2,85	2,84
5000	8,2	8,26	8,25	8,23	5000	4,29	4,32	4,31	4,3
6000	8,98	9,004	8,98	8,94	6000	5,64	5,67	5,63	5,61
7000	8,14	8,17	8,17	8,13	7000	5,96	5,99	5,98	5,95
8000	6,46	6,49	6,46	6,41	8000	5,41	5,43	5,4	5,36

Fuel Consumption					Gas Emission				
RPM	26°C	30°C	40°C	50°C	CO	2,81	3,16	2,95	2,57
2000	1,41	1,4	1,42	1,43	HC	393	354	465	524
3000	0,63	0,63	0,64	0,65					
4000	0,38	0,38	0,38	0,38					
5000	0,27	0,27	0,28	0,28					
6000	0,21	0,21	0,21	0,21					
7000	0,2	0,2	0,2	0,2					
8000	0,22	0,22	0,22	0,22					

3.1 Torque

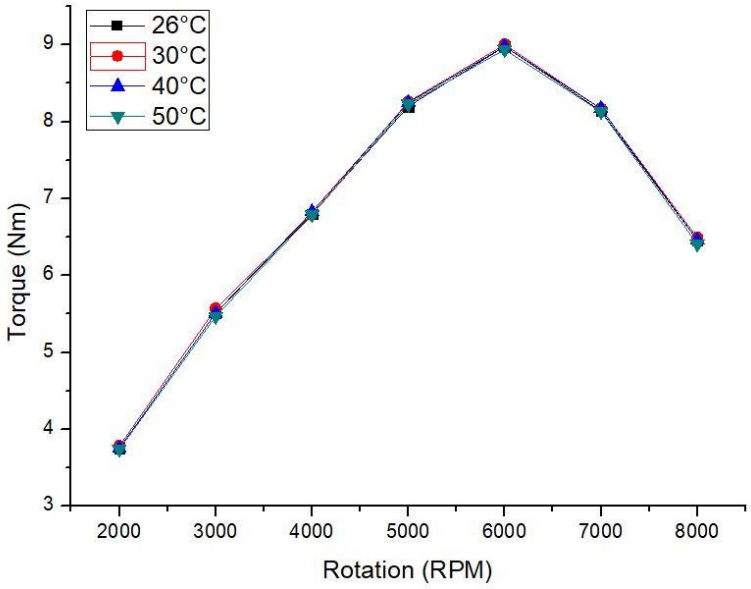


Figure 2. Torque Result

From picture 2, it can be seen that the highest torque is generated at the inlet air heating treatment with a temperature of 30°C at a revolution of 6000 with a torque value of 9.004 Nm and experiences a percentage increase of 0.27%, compared to without air heating treatment, this is because air heating can add energy during the combustion process so that the maximum combustion point is reached and for the lowest torque value is found in the inlet air heating treatment with temperature 50°C with a torque value of 8.94 Nm and experienced a percentage decrease of 0.44%, this is because the heating temperature that is too high can cause detonation in the combustion chamber to burn so that the pressure in the combustion chamber during the compression stroke is reduced. The temperature of the air in the combustion chamber greatly affects engine performance because the air temperature can affect the flash point value of the fuel in the combustion chamber, for gasoline fuel has a flash point value of -42°C and for ethanol fuel 12°C[5], so that the use of fuel mixture of ethanol and gasoline requires additional energy in the form of proper air heating so that the combustion process in the combustion chamber becomes homogeneous and burns optimally[8].

3.2. Power

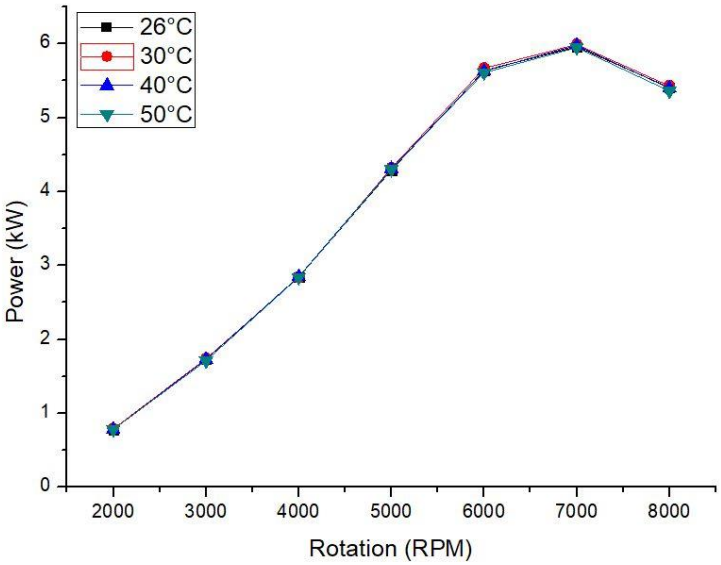


Figure 3. Power Result

From figure 3, it shows that the highest power is generated at the inlet air heating treatment with a temperature of 30°C at a revolution of 7000 with a power value of 5.99 kW and experienced a percentage increase of 0.5% compared to without air heating treatment and for the lowest power value was found in the inlet air heating treatment with a temperature of 50°C with a power value of 5.95 kW and experienced a percentage decrease of 0.16%, from this result shows the power results are directly proportional to the torque results obtained during this research, but the number of percentage increases and decreases in power is not the same in number as the percentage increase and decrease in torque, but the temperature treatment with the highest value and the lowest value of power is equal to the value of the treatment produced by torque[7][9][10].

3.3. Specific Fuel Consumption

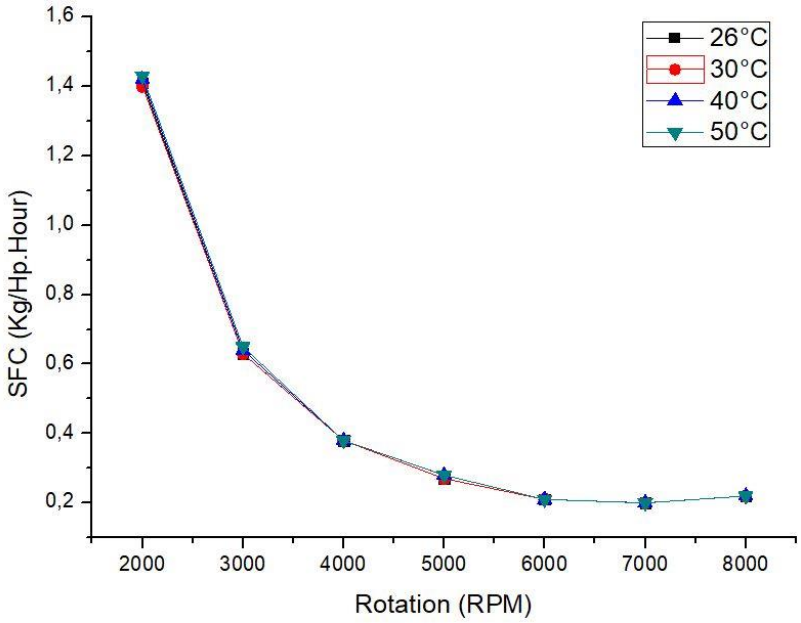


Figure 4. Specific Fuel Consumption

To measure fuel consumption the test is carried out by calculating the time it takes to spend 50 ml of fuel, this is done to find out the fuel consumption level of each fuel used. Figure 4 shows that in the 2000 round, the lowest consumption value is found in the heating treatment of the air temperature of 30°C with a value of 1.4 Kg / Hp.Hour and experienced a percentage decrease of 0.71% which indicates good results because for fuel consumption the more the decrease in the value of the percentage of fuel consumption, the better the results obtained. The highest consumption is found in the 50°C air temperature heating treatment with a consumption value of 1.41 Kg/Hp.Hour and a percentage increase of 1.41%, this indicates poor fuel consumption because the consumption value is higher than the consumption value without air heating treatment. Air heating causes the air temperature in the combustion chamber to increase so that the air and fuel in the combustion chamber become homogeneous, but improper air heating treatment on the use of a mixture of ethanol and gasoline fuel can cause the value of fuel consumption to increase, this is also the case in previous studies that air heating in the mixture of ethanol and gasoline fuel can affect fuel consumption[11][12][13].

3.4. Emission

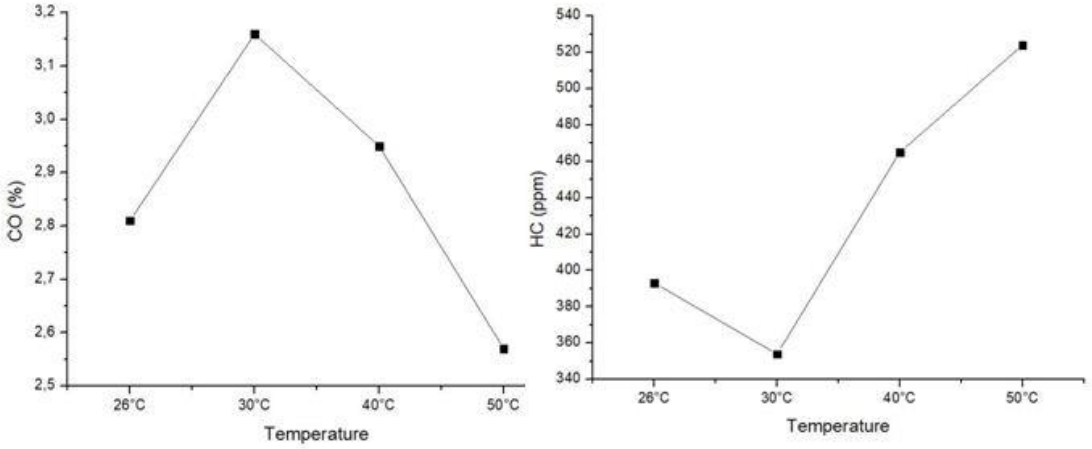


Figure 5. Emission

The increase in hydrocarbons caused by less than perfect combustion can be proven that the highest hydrocarbon value is found at a temperature treatment of 50°C with a hydrocarbon value of 524 ppm, while the lowest value is found in a temperature treatment of 30°C with a hydrocarbon value of 354 ppm, while for a carbon monoxide value the lowest value is found in a temperature treatment of 50°C with a carbon monoxide value of 2.57%. The increase in the value of carbon monoxide is caused by the low temperature in the combustion chamber[14]. with the treatment of air heating can increase the temperature in the combustion chamber so that the value of carbon monoxide becomes low.

4. CONCLUSION

In this research, the air heating treatment greatly affects the engine performance value as evidenced by the percentage of increasing torque by 0.27%, power by 0.5%, fuel consumption has decreased by 0.71%. For all the best results obtained on air heating treatment with a temperature of 30 °C and for exhaust gas emissions can be the lowest hydro carbon is found at a temperature treatment of 30 ° C while the lowest value of carbon monoxide is found at a temperature treatment of 50°C[15]. By adding an air heater, the use of E20 fuel can be done effectively without changing the engine compression and for further research, it is possible to heating treatmen of incoming combustion chamber by adding a higher concentration of ethanol mixture to pertalite fuel, because heating treatmen of incoming combustion chamber to a mixture of ethanol and pertalite fuel in this study is proven to improve engine performance.

6. REFERENCES

[1] E. D. Y. Muryanto, P. Studi, T. Mesin, F. Teknik, and U. M. Surakarta, “Study Pengaruh Campuran Bahan Bakar Premium Dan Ethanol Terhadap Unjuk Kerja,” 2016.

[2] S. Phuangwongtrakul, W. Wechsatol, T. Sethaput, K. Suktang, and S. Wongwises, “Experimental study on sparking ignition engine performance for optimal mixing ratio of ethanol-gasoline blended fuels,” *Appl. Therm. Eng.*, vol. 100, pp. 869–879, 2016, doi: 10.1016/j.applthermaleng.2016.02.084.

[3] A. A. Ikhsani, N. Ilminnafik, and B. A. Fachri, “Heating ethanol-gasoline fuel mixtures to improve performance and reduce exhaust emissions at gasoline engine - A review,” 2020, p. 020024, doi: 10.1063/5.0014535.

[4] A. D. Kurniawan and T. Suprajitno, “Analisa Penggunaan Bahan Bakar Bioethanol Dari Batang Padi Sebagai Campuran Pada,” vol. 3, no. 1, pp. 4–8, 2014.

[5] A. A. Ikhsani, M. N. Kustanto, and B. A. Fachri, “Heating Treatment of Air in Combustion Chamber For The Use of Mixture Ethanol and Gasoline Fuel,” *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 1071, no. 1, p. 012006, Feb. 2021, doi: 10.1088/1757-899x/1071/1/012006.

[6] Y. Huang and G. Hong, “Investigation of the effect of heated ethanol fuel on combustion and emissions of an ethanol direct injection plus gasoline port injection (EDI + GPI) engine,” *Energy Convers. Manag.*, vol. 123, pp. 338–347, 2016, doi: 10.1016/j.enconman.2016.06.047.

[7] C. Cinar, A. Uyumaz, H. Solmaz, F. Sahin, S. Polat, and E. Yilmaz, “Effects of intake air temperature on combustion, performance and emission characteristics of a HCCI engine fueled with the blends of 20% n-heptane and 80% isooctane fuels,” *Fuel Process. Technol.*, vol. 130, no. C, pp. 275–281, 2015, doi: 10.1016/j.fuproc.2014.10.026.

[8] R. K. Maurya and A. K. Agarwal, "Experimental investigation on the effect of intake air temperature and air-fuel ratio on cycle-to-cycle variations of HCCI combustion and performance parameters," *Appl. Energy*, vol. 88, no. 4, pp. 1153–1163, 2011, doi: 10.1016/j.apenergy.2010.09.027.

[9] J. Serras-Pereira, P. G. Aleiferis, D. Richardson, and S. Wallace, "Characteristics of ethanol, butanol, iso-octane and gasoline sprays and combustion from a multi-hole injector in a DISI engine," *SAE Int. J. Fuels Lubr.*, vol. 1, no. 1, pp. 893–909, 2009, doi: 10.4271/2008-01-1591.

[10] X. Deng, Z. Chen, X. Wang, H. Zhen, and R. Xie, "Exhaust noise, performance and emission characteristics of spark ignition engine fuelled with pure gasoline and hydrous ethanol gasoline blends," *Case Stud. Therm. Eng.*, vol. 12, pp. 55–63, 2018, doi: 10.1016/j.csite.2018.02.004.

[11] A. K. Thakur, A. K. Kaviti, R. Mehra, and K. K. S. Mer, "Progress in performance analysis of ethanol-gasoline blends on SI engine," *Renew. Sustain. Energy Rev.*, vol. 69, no. December 2015, pp. 324–340, 2017, doi: 10.1016/j.rser.2016.11.056.

[12] A. K. Thakur, A. K. Kaviti, R. Mehra, and K. K. S. Mer, "Performance analysis of ethanol–gasoline blends on a spark ignition engine: a review," *Biofuels*, vol. 8, no. 1, pp. 91–112, 2017, doi: 10.1080/17597269.2016.1204586.

[13] P. Chansauria and R. K. Mandloi, "Effects of Ethanol Blends on Performance of Spark Ignition Engine-A Review," *Mater. Today Proc.*, vol. 5, no. 2, pp. 4066–4077, 2018, doi: 10.1016/j.matpr.2017.11.668.

[14] I. Z. Arifin, W. Wirawan, and H. Rarindo, "The Effect of Sodium Hydroxide Absorbent on The Exhaust Emissions From Internal Combustion Engine," *Log. J. Ranc. Bangun dan Teknol.*, vol. 22, no. 1, pp. 27–34, 2022, doi: 10.31940/logic.v22i1.27-34.

[15] M. Mohamed Ibrahim and A. Ramesh, "Investigations on the effects of intake temperature and charge dilution in a hydrogen fueled HCCI engine," *Int. J. Hydrogen Energy*, vol. 39, no. 26, pp. 14097–14108, 2014, doi: 10.1016/j.ijhydene.2014.07.019.

LOGIC
Journal of Engineering Design and Technology
Vol. 23 No.1 March 2023; p. 55 - 61

p-ISSN : 1412-114X
e-ISSN : 2580-5649
http://ojs.pnb.ac.id/index.php/LOGIC

PROTOTYPE DESIGN OF E-BMX 2000 WATT ELECTRIC MOTORCYCLE

Utsman Syah Amrullah [1)*], Rilis Eka Perkasa [1)], Muhammad Fakhruddin [1)]

1) Department of Mechanical Engineering, State Polytechnic of Malang
Jl. Soekarno Hatta No. 9, Malang, Indonesia

Correponding email [1)] : utsman.syah@polinema.ac.id

Abstract. Limited supplies of fossil fuels such as gasoline, diesel and LPG resulting in vehicles that use internal combustion would be abandoned and replaced by electric vehicles. There have been many coverages that have reviewed the advantages of electric vehicles, where the advantages of electric vehicles include simple mechanical components, relatively low pollution, low noise levels, and could become a solution for future vehicles for an environmentally friendly life. This study aims to design and build a motorcycle prototype, a work which includes the design and manufacture of a BMX type motorcycle frame powered by a 2000 watt BLDC motor power, and testing the performance of the prototype using dynotest and compared to conventional motorcycles to compare the performance characteristics of both motorcycle. The frame is designed using Solidworks, then manufactured by cutting, bending, drilling, welding, and painting process. Mechanical components include frames that use mild steel pipes with diameter of 1.5 inches and thickness of 1.2 mm. Other mechanical components use components available on the market, such as headsets, front forks, disc brakes, hydraulic caliper brakes, and wheel assemblies. The electrical components used are 48V 2000-watt QS Motor, 60V 15 Ah Lithium battery, Yuyangking 80A controller and electric gas throttle with voltage indicator. The results of the dynotest show that the maximum torque reaches 204 NM (roller) which is achieved at 976 rpm. The maximum speed reaches 69.7 Km/hour. The range of the single-charged battery could cover a distance of 30 km. The characteristic of 2000 Watt E-BMX is very powerful at low revs and stable at high revs, shown by achieving maximum torque at low RPM. To save battery life, it is necessary to limit the remaining voltage, which is done at 55 Volts, so that the battery do not completely run out. It could be concluded that electric motorcycle developed in this study is suitable for use in urban areas (paved tracks or light off-road) with determined mileage and the path travelled, and battery management is needed so the battery does not run out in the middle of a trip.

Keywords : electric motorcycle, e-BMX, 2000 Watt, dynotest, BLDC motor.

1. INTRODUCTION

Since fossil fuels such as gasoline, diesel and LPG will deplete over time, vehicles that use internal combustion (fuel oil, BBM) will also be increasingly abandoned and replaced by electric vehicles. In 2030, Indonesia targets to produce 3 million electric vehicles [1]. While in 2060, PLN targets electric vehicles and zero emissions, which is in line with electrical energy which is domestic-based energy [2]. The reason of why electric vehicles are the vehicles of the future is because of their many advantages, including simple mechanical components, easy maintenance, non-polluting, low noise levels and are solutions for future vehicles for an environmentally friendly life.

An electric motor is a device that can convert electrical energy into mechanical energy. It could be said that all types of electric motors have two basic components, namely the stator which is a stationary component, while

the rotor is a rotating component. Through the role of these two basic components, electric motors can convert electrical energy, both direct (DC) and alternating (AC) electricity, into circular motion in the rotor which can be used for various purposes [3].

In principle, electric motors work by utilizing electromagnetic induction which can convert dynamic electrical energy into a magnetic field. With the help of permanent magnets, this induced magnetic field can produce a force that can move the rotor. This is due to the basic nature of magnets, where similar magnetic poles repel each other and opposite magnetic poles attract each other. The power of an electric motor is largely determined by the power of the electric current source, and also the configuration of the wire windings on the electromagnet. The more turns of wire on the electromagnet, the greater the power generated by the motor. To be able to produce circular motion, each type of magnet is placed on the stator and rotor. The electric circuit for the purposes of electromagnetic induction must be arranged in such a way that the magnetic polarity generated on the electromagnet can make the electric motor continue to rotate even though the magnet changes position due to the rotation of the motor.

The type of electric motor that will be used for this research is a brushless DC motor (BLDC) type electric motor. This motor uses a direct power source (DC). In conventional DC electric motors, the brush connects the electromagnet on the rotor with a DC power source so that the electric motor can move freely and an electromagnet polarity can be generated to rotate the motor. However, the use of this brush is known to generate friction which can cause noise and also reduce the component life. Therefore, in BLDC motor the brush is no longer used and the electromagnetic is placed on the stator, while the permanent magnet is placed on the rotor. Several electromagnets are placed on the stator in a radial configuration so that the rotor can move freely with the help of permanent magnets in all of the angular positions. Meanwhile, the function of controlling the direction of the electric current to control the direction of the magnetic field on the brush is replaced by a controller that can adjust the magnitude and direction of the electric supply for each electromagnet independently. The use of this controller system makes BLDC is advantageous when used as a motor for electric vehicles, where the motor torque and rotational speed can be easily controlled by the user as needed [4]-[9].

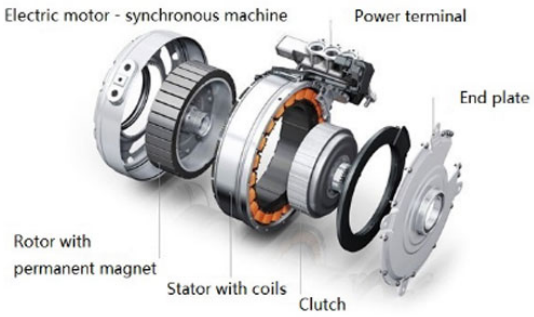


Figure 1. BLDC motor [10]-[13]

Generally, main components of electric motorcycles could be divided into 2 groups, namely electrical components and mechanical components. The electrical components consist of a BLDC motor which functions to convert electrical energy into mechanical energy, a lithium ion battery equipped with a charger to store electrical energy, a throttle handle and a controller which functions to adjust the speed of the BLDC rotation. Whereas, the mechanical components of an electric motorbike consist of a frame made of steel, a front fork which functions as a support for the front wheels, a brake set for the braking system on the front and rear wheels, a handle bar which functions as a steering system, a saddle for the driver seat and an electric box as a place to store electrical circuits.

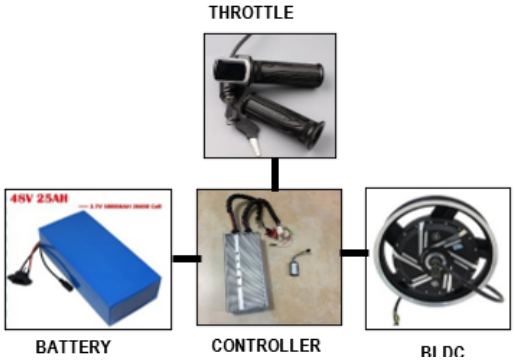


Figure 2. Electrical components

2. METHODS

Firstly, literature studies are needed to collect the references of frame design as base and comparison for the E-BMX frame.

Figure 3. Electric motorcycle frame references

From the existing references, a sketch is then made by considering the level of complexity, the capabilities of the existing production tool, and the availability of materials and working tools. Figure 4 shows the design sketch of an E-BMX that will be made. Mechanical components and electrical components are assembled into a single unit which is the basis of the electric motorcycle.

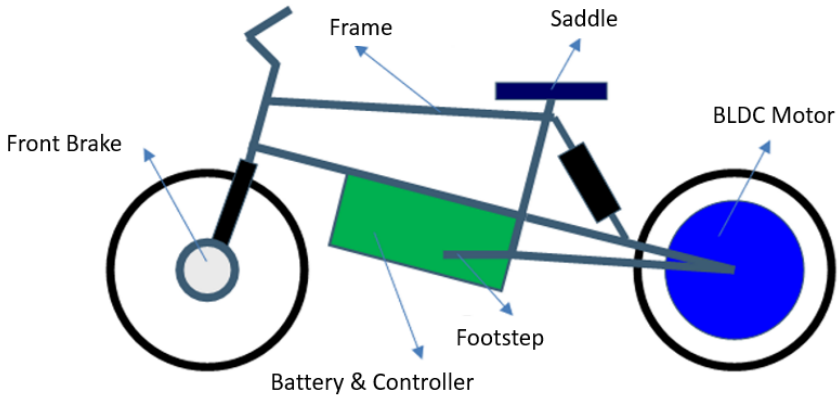


Figure 4. Design sketch

After the design sketches have been made and deemed feasible, the next step is to design the main frame with the predetermined concept, namely in the form of a BMX frame. The design process at this stage uses Solidworks software. This design step will produce technical drawing, which is ready for manufacturing processes. The 3D drawings of the frame are shown in Figure 5.

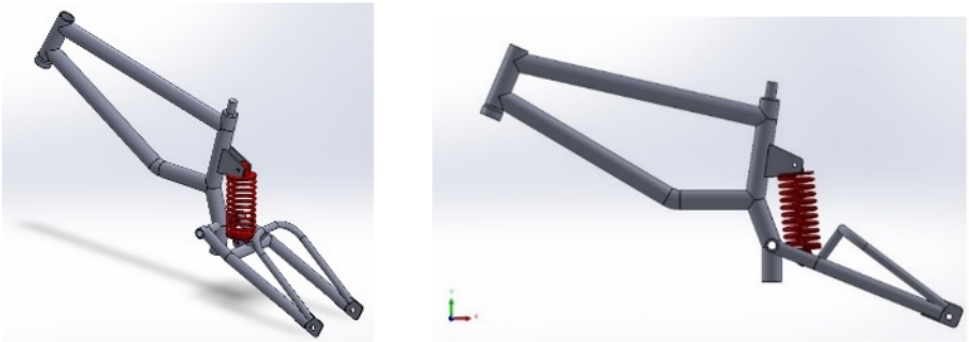


Figure 5. E-BMX frame design

The production and manufacturing process of the E-BMX frame consists of the cutting process, bending process, drilling and welding process and continued with the coating and finishing/painting process. After the manufacture of the frame is complete, the process of assembling the electrical and mechanical components is continued. The final result of the prototype is shown on Figure 6.

(a) (b)

Figure 6. E-BMX Prototype (a) side view, (b) isometric view

3. RESULTS AND DISCUSSION

3.1 Dynotest Testing

Power testing or commonly called dynotest on two-wheeled vehicles is intended to determine the maximum torque compared to RPM (wheel rotation). This test is also utilized to find out the characteristics of motorcycle performances such as the performance at low rpm up to high rpm. From the results of the tests conducted, it is shown that the E-BMX has the character of being immediately powerful at low rpm, then stable up to high rpm. In contrast to gasoline motorbikes, which tend to increase torque as the wheel RPM increases [14][15].

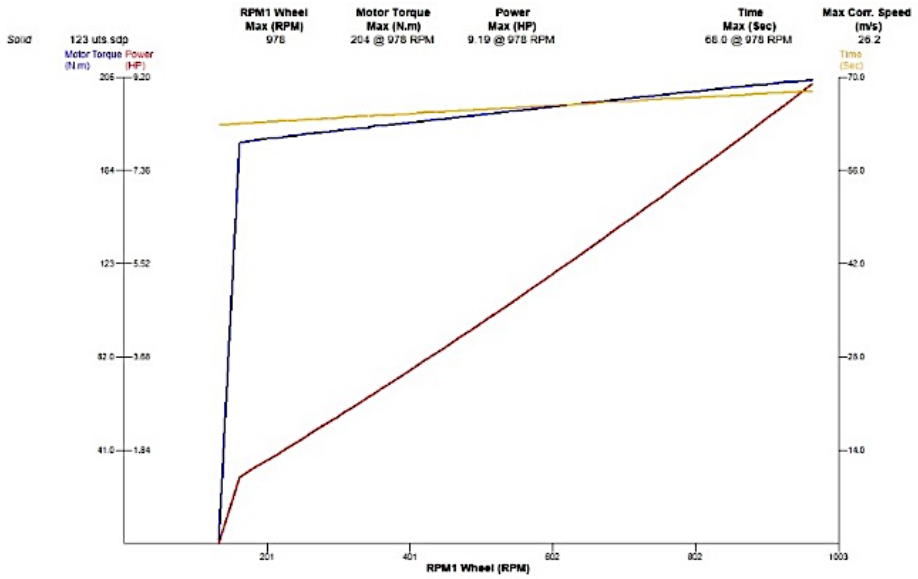
The equipment required for the dynotest test includes a set of test equipment consisting of two cylinders/rollers to support the rear wheel of the motorcycle being tested. Rotation input from the rear wheel of the motorcycle will rotate the roller which is then displayed in graphic form through software that can be read on a computer monitor screen. The tested E-BMX is placed on the test roller, as shown in Figure 8.

Figure 7. Roller used on dynotest

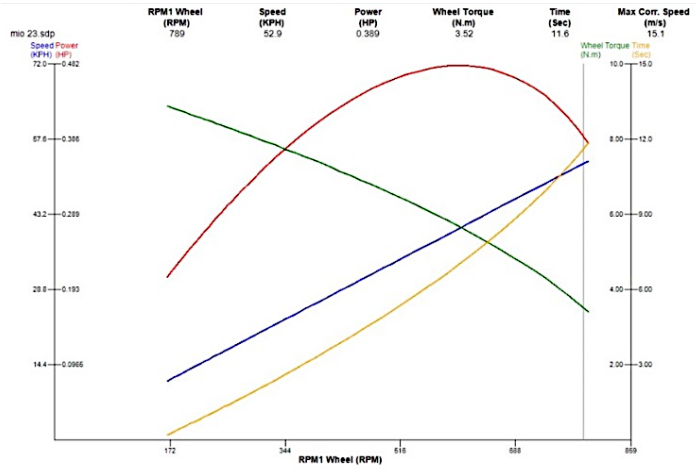
Figure 8. Testing setup process

3.2 Dynotest Result

The Dynotest carried out in this study produced a graph of Torque, RPM and Power (power) of the motor. The dynotest result of the E-BMX is shown in Figure 9 (a). As comparison, the dynotest also performed on a conventional motorcycle (Yamaha Mio), which the result is shown in Figure 9 (b).



(a)



(b)

Figure 9. Dynotest result plot of (a) 2000 watt E-BMX and (b) Yamaha Mio

3.3 Discussions

From dynotest test results for the 2000 Watt E-BMX, it is known that the character of an electric motorbike has a spontaneous torque increase at low rpm, while the character of a conventional motorbike (gasoline motorbike) is that the torque will reach its maximum as the rpm increases. The character of such an electric motor also depends on the setup and settings of the controller, in the sense that the controller can adjust the torque desired by the rider.

In this study using test equipment on a laboratory scale, the validity of the data still needs to be validated again, because it is indeed used for research. But from the existing dynotest equipment, the characteristics and performance of the 2000 watt E-BMX could be obtained.

3.4 Prototype Specifications

The technical specifications of the 2000 watt E-BMX prototype are shown in Table 1.

Table 1. 2000 watt E-BMX specifications

Component	Specifications
Driving motor	QS Motor 48V 2000 Watt
Battery	Lithium Ion 60V 15 Ah
Controller	Yuyangking 80A
Frame	Mild steel pipe, D 1.5 inch, t=1.2 mm
Maximum speed	69,6 Km/hour
Maximum distance	30 km (fully charged once). Maximum voltage: 67V Cut Off : 55V
Charging time	5-6 hours
Performance (dynotest)	Maximum torque 204 NM (roller) at 976 rpm
Wheelbase	1300 mm
Rear suspension	monoshock
Rear brake	Suzuki Satria FU 150 disc brake
Front brake	Yamaha Vega ZR disc brake
Head set	Honda Grand
Tire	Front: 2.25 x 17 Rear: 2.50 x 17

4. CONCLUSION

Conclusions that could drawn from this research are as following:

1. In the process of designing and designing the E-BMX frame, the software used is Solidworks. Details of the specifications for the frame material are 1,5 inch diameter mild steel pipe with the thickness of 1.2 mm, monoshock type suspension, and 1300 mm wheelbase. Other mechanical components used motorcycle components available on the market. Among them are head set bearings (Honda Grand), front forks (Yamaha Vega ZR), front disc brakes (Yamaha Vega ZR), handle bars (United Bike), rear disc brakes (Suzuki Satria FU 150), etc.
2. The result of the Dynotest conducted at the laboratory of Automotive and Electronical Engineering, Polinema shows that the maximum torque is 204 NM (roller) at 976 rpm.
3. The 2000 Watt E-BMX is very suitable for use on paved urban tracks or light off-road, and with a distance of up to 30 km for one full-charging, Hence it is also suitable for everyday use.
4. Battery management for the rider is needed in order to prevent the run out of the battery in the middle of a trip.

5. REFERENCES

[1] Kompas. 2021. Indonesia has set a target of 3 million units of electric vehicles by 2030. available at: https://otomotif.kompas.com/read/2021/11/19/072200915/indonesia-tatap-target-3-juta-unit-kendaraan-listrik-pada-2030
[2] Tribun. 2022. PLN Boss Encourages Use of Electric Vehicles to Achieve Net Zero Emissions in 2060. available at: https://www.tribunnews.com/bisnis/2022/10/18/bos-pln-dorong-penggunaan-kendaraan-listrik-untuk-capai-net-zero-emission-pada-2060
[3] Chalmers, B.J. 2018. *Electric Motor Handbook*, London, Butterworth & Co.
[4] Xia, Chang-liang. 2012. *Permanent Magnet Brushless DC Motor Drives and Controls,* John Wiley & Sons Singapore Pte. Ltd.,
[5] SDMMagnetics. 2022. Magnetic Assemblies. Available at: *https://www.magnet-sdm.com/* accessed on November, 12th 2022
[6] Salman Alfarisi, I Wayan Jondra, I Nyoman Sugiarta. 2021. *Perencanaan Konversi Sepeda Motor Bakar Menjadi Sepeda Motor Listrik*, Seminar Nasional Terapan Riset Inovatif (SENTRINOV) Ke-XX

[7] Muhammad Awwaluddin. 2019. *Analisa Kekuatan Rangka Sepeda Listrik Menggunakan Software SolidWorks*, Journal of Technical Engineering Piston Vol. 3, No. 1, (2019) 5-16
[8] Bagia, I Nyoman; Parsa, I Made, 2018, *Motor-Motor Listrik*, Kupang, CV. Rasi Terbit
[9] Fajar Sodiq, Bambang Tristiyono. 2015. *Desain Sepeda Listrik Untuk Ibu Rumah Tangga Sebagai Sarana Transportasi Sehari-hari yang Dapat Diproduksi UKM Lokal*, Jurnal Sains dan Seni ITS Vol. 4, No.2, (2015) 2337-3520 (2301-928X Print)
[10] Curtis D. Anderson, Judy Anderson. 2010. *Electric and a History Hybrid Cars: Second Edition*, Jefferson, McFarland & Company, Inc.,
[11] J. Larminie, J. Lowry. 2003. *Electric Vehicle Technology*, John Wiley & Sons, Ltd.
[12] Tom Denton, *Automobile Electrical and Electronics Systems: 3rd edition*, IMI Institute of the Motor Industry
[13] Wahyudi Budi Pramono, Habib Putra Pratama, Warindi. 2016. *Perancangan Motor Listrik BLDC 10 KW untuk Sepeda Motor Listrik*, 3rd SNATIF Proceedings. ISBN: 978-602-1180-33-4
[14] Lin. DY, Hou. BH, and Lan. CC. A. 2017. Balancing cam mechanism for minimizing the torquefluctuation of engine camshafts. Mechanism and Machine Theory. 108. pp. 160-175.
[15] Thomas. G, Simon. D, and Michelini. J. 2015. Biogeography-based optimization of a variable camshafttiming system. Engineering Applications of Artificial Intelligence. 45. pp. 376–387.

LOGIC
Journal of Engineering Design and Technology
Vol. 23 No.1 March 2023; p. 62 - 67

p-ISSN : 1412-114X
e-ISSN : 2580-5649
http://ojs2.pnb.ac.id/index.php/LOGIC

PERFORMANCE ANALYSIS OF PUBLIC TRANSPORT IN GIANYAR REGENCY (Case Study: Batubulan Terminal Route - Ubud)

Ida Bagus Wirahaji [1)], I Ketut Sutapa[2)], I Gede Fery Surya Tapa[3)],

1) Department of Civil Engineering, Faculty of Engineering, Universitas Hindu Indonesia, Denpasar, Bali
2) Civil Engineering Department, Politeknik Negeri Bali, Bukit jimbaran, Badung Bali
3) Department of Civil Engineering, Faculty of Engineering and Informatics, Universitas Pendidikan Nasional, Denpasar, Bali
Correponding email [1)] : gustu107@gmail.com

Abstract. The performance of urban public transport plays an important role in accommodating population mobility and realizing sustainable transportation. Public transport performance can be influenced by several factors, including the quality of public transport services and the accessibility of the roads they pass. Service quality concerns arrival frequency, waiting time, travel time, etc. Road accessibility is influenced by the presence of side barriers, such as parking vehicles on the road, cars in and out, slow vehicles, and so on. This study analyzes the exogenous latent variables of service quality and road accessibility that affect the endogenous variables of public transportation performance in the Gianyar Regency, especially on the Batubulan-Ubud Terminal Route. Perception data was collected by distributing 250 questionnaires to people living along the Batubulan-Ubud highway corridor. The data analysis was performed by Statistical Equation Modeling (SEM) AMOS. Validity and reliability tests were carried out using the confirmatory factor analysis (CFA) method. After going through the index modification process, all goodness of fit parameters were fulfilled very well, it was found that the quality of public transportation services had a significant positive effect, with p-value = 0.000 < 0.05, path coefficient 0.498. Road accessibility also has a significant positive effect, with p-value = 0.000 < 0.05, path coefficient 0.308. The quality of public transport services is indicated by the frequency of arrivals, waiting times, and travel times. Road accessibility is indicated by on-street parking and the number of intersections. The number of passengers, driver salaries, and operating duration indicates public transport performance.

Keywords : Public Transport Performance, Service Quality, Road Accessibility

1. INTRODUCTION

Public transportation is one of the main actors in sustainable transportation. Increasing the use of public transport systems and reducing the use of private cars is one of the main goals of decision-makers in many countries. The use of the public transport system is closely related to the quality of service. Service quality includes parameters such as convenience, frequency, information systems, and so on. [1]. Other factors that have been identified as attributes of the quality of public transport services are waiting time, travel time, vehicle cleanliness, ease of route, being equipped with driver assistants, and security [2]. The quality of urban public transport services can be measured by several indicators, namely: headway, waiting time, travel time, and speed [3].

Service quality is the biggest subject for both planners and transport operators. The performance of public transport has an important role in accommodating the mobility of the population. In general, service quality is measured by asking about users' perceptions and expectations about several aspects of service quality. Taking into account the level of importance and satisfaction expressed by users [4]. Encouraging people to use public transportation is not an easy task for the government, because public transportation is often considered a bad alternative to car use [5].

To measure and ensure the continuous improvement of the quality of public transport, performance criteria are an important tool for transport operators and focus on their strategic objectives. So far, in developing countries, public transport services have provided substandard quality and limited capacity. Lack of awareness of perceived

quality and missing quality management systems are the main causes of poor quality of public transport services. respond to the demand-side needs for accessible, affordable, fast and reliable modes [6].

Road accessibility has always been a major problem in public transportation services and can reduce public interest in using public transportation [7]. One measure of road segment accessibility is providing access to various activity centers [8]. Accessibility refers to the ability of the community to reach goods, services and activities, which are the ultimate goal of most transportation activities. Many factors affect accessibility, including mobility (physical movement), quality and affordability of transport options, connectivity of transport systems, mobility substitutes, and land use patterns [9].

Service quality and road accessibility are two factors that affect the performance of public transport. Performance is the ability or potential of public transportation to serve the needs of movement in an area, both in the form of transportation of goods and transportation of people. Performance is also the level of achievement or results of the company's work from targets to be achieved or tasks to be carried out within a certain period [10]. Operational indicators of public transport performance include the number of passengers, distance traveled, fuel consumption, and load factor [3].

This research takes the location of the Batubulan-Ubud Terminal route, Gianyar Regency, which is served by microbus vehicles, with a capacity of eight passengers. The routes are: Batubulan-Celuk-Sukawati-Batuan-Sakah-Peliatan-Mas-Ubud Terminal. From the observations, it can be seen that the public transportation fleet serving this route is very small and only operates in the morning. Meanwhile, this route passes through a road corridor with a relatively dense population, there are side obstacles in the form of parking on the road, vehicles are going in and out, traditional market activities, and vehicles slowing down. People are more likely to use private transportation to fulfill their mobility so transportation becomes worse.

This study aims to determine the performance of public transportation on the Batubulan-Ubud Terminal route by analyzing the effect of exogenous variables on service quality and accessibility of the road routes served on the endogenous variable, namely the performance of public transportation. respondent's perception data were analyzed by statistical equation modeling (SEM) AMOS.

2. METHODS

Statistical Equation Modeling (SEM) is a strong analytical technique because it considers interaction modeling, nonlinearity, correlated independent variables, measurement errors, correlated error terms, and multiple latent independents where each is measured using many indicators, and one or two latent dependent variables are also each measured by several indicators. SEM is stronger than using multiple regression, path analysis, factor analysis, time series analysis, and analysis of covariance [11]. Table 1 shows the goodness of fit parameters in SEM.

Table 1. Parameter *Goodness of Fit* [12] [13]

No	The goodness of Fit Index	Cut-off Value	Note
1	*Chi-square* (x^2)	Expected small	Testing the level of fit between the sample variance matrix and the model covariance matrix
2	*Significance of Probability*	≥ 0,05	When using a 95% confidence level. This indicates that the hypothesis is accepted and the predicted input matrix is not statistically different.
3	CMIN/DF *(The Minimum Sample Discrepancy Function*)	≤ 2,00	The fit between the two models.
4	GFI (*Goodness of Fit Index*)	≥ 0,90	Nothing but Chi-square divided by DF
5	AGFI (*Adjusted Goodness of Fit Index*)	≥ 0,90	Measuring the relative amount of variance and covariance
6	TLI (Tucker Lewis Index)	≥ 0,95	Its function is the same as the GFI, the difference lies in the adjustment of the DF value to the specified model.
7	CFI (*Comparative Fit Index*)	≥ 0,95	Comparison between the tested model and the baseline model
8	RMSEA (*The Root Mean Square Error of Approximation*)	≤ 0,08	Test the feasibility of a model that is not sensitive to the sample size and complexity of the model

This research is an observational study with a survey method, taking a sample of 250 respondents, and using a questionnaire as an instrument for collecting data from the population in Gianyar Regency. The

measurement is in the form of public perception of the quality of public transportation services, road accessibility, and public transportation performance.

Data analysis used the Amos Structural Equation Modeling (SEM) method, with software ver.22. The measurement scale used is a Likert scale with a score of 1-5, namely: strongly disagree (STS) score 1, disagree (TS) score 2, Slightly agree (US) score 3, Agree (S) score 4, and Strongly Agree (SS) score 5

3. RESULTS AND DISCUSSION

3.1 Validity and Reliability Test

Validity and reliability tests were carried out using the confirmation factor analysis (CFA) method. Tables 2 – 4 show the results of the validity and reliability tests of each latent variable indicator. The value of construct reliability (CR) is obtained from Equation $CR = \frac{(\Sigma\lambda)^2}{(\Sigma\lambda)^2+\Sigma(1-\lambda^2)}$ ---------- (1)

Where:

CR : construct reliability
λ : loading factor

Table 2. The results of the validity and reliability test of the quality of public transportation services (X1)

Indicator Service Quality (X1)	Notation	p	Load (λ)	CR
Arrival frequency is rare	X1.1	0.000	0.812	0,906
Not equipped driver assistant	X1.2	0.000	0.670	
Long waiting time	X1.3	0.000	0.728	
The vehicle is not clean	X1.4	0.000	0.765	
The room is not air-conditioned	X1.5	0.000	0.657	
Small fleet size	X1.6	0.000	0.805	
Long travel time	X1.7	0.000	0.753	
Less comfort	X1.8	0.000	0.723	

Source: Analysis Results (2021)

Table 3 Test results of the validity and reliability of Road Accessibility (X2)

Indicator Road Accessibility (X2)	Notation	p	Load (λ)	CR
Lots of vehicle on-street parking	X2.1	0.000	0.626	0,845
Many vehicles in and out	X2.2	0.000	0.604	
There are many intersections	X2.3	0.000	0.511	
Many vehicles slow down	X2.4	0.000	0.754	
Frequent switching of currents	X2.5	0.000	0.686	
Uneven pavement	X2.6	0.000	0.631	
There are frequent road repairs	X2.7	0.000	0.639	
There is morning market activity	X2.8	0.000	0.630	

Source: Analysis Results (2021)

Table 4. The results of the validity and reliability test of Public Transport Performance (Y1)

Indicator Public Transport Performance (Y1)	Notation	p	Load (λ)	CR
Few passengers	Y1.1	0.000	0.702	0,852
Driver's salary below standard	Y1.2	0.000	0.605	
Short travel distance	Y1.3	0.000	0.628	
High operating costs	Y1.4	0.000	0.604	
Exhaust gas/big emissions	Y1.5	0.000	0.712	
Minor passenger change	Y1.6	0.000	0.694	
Less fuel consumption	Y1.7	0.000	0.628	
Short drive operation time	Y1.8	0.000	0.603	

Source: Analysis Results (2021)

The construct reliability (CR) cut-off value is 0.7, loading factor is 0.50 [14]. From the results of the validity and reliability test using the CFA method, it was found that all indicators had a value of p = 000 < 0.05, loading factor (λ) > 0.50, then all indicators were declared valid. If the value of construct reliability (CR) > 0.7, then all indicators can be declared reliable.

3.2 Public Transport Performance Model

After fulfilling the validity and reliability tests, it is continued to test the model with the goodness of fit, using the maximum likelihood method. Modifications are made so that the model meets several parameters in the goodness of fit. By the table on the modification indices, a reduction or correlation of several indicators is carried out for each latent variable. So that the model is obtained as shown in Figure 1.

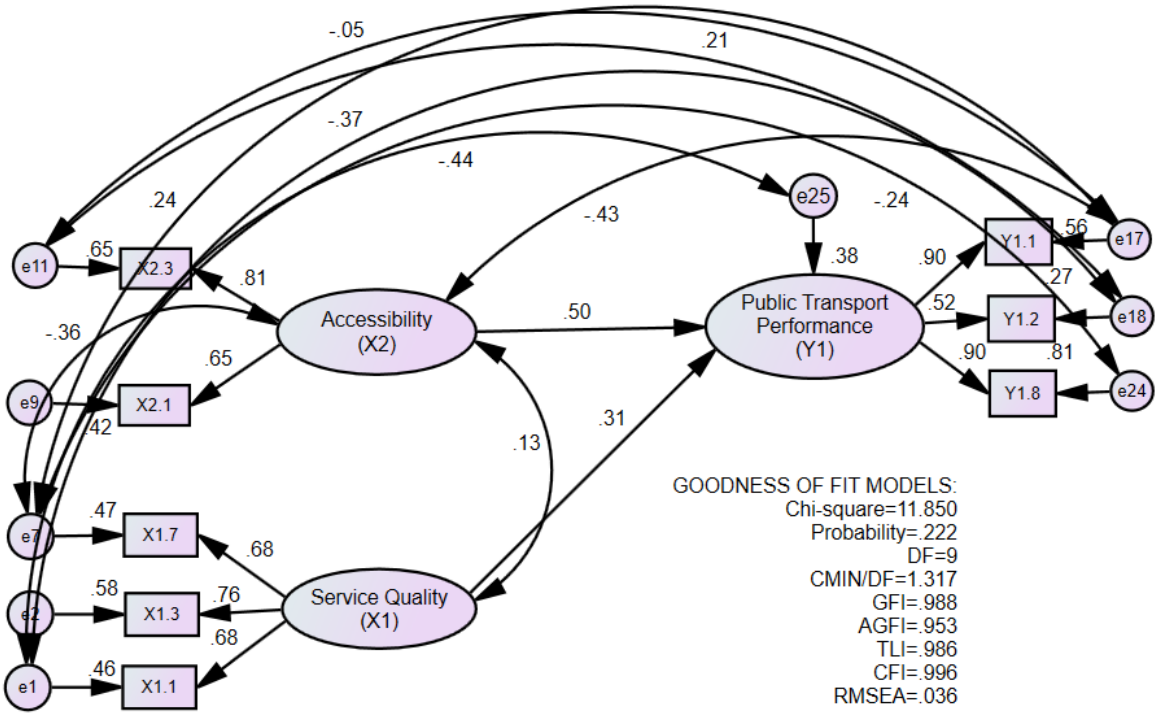


Figure 1.Diagram of Public Transport Performance Model
Source: Analysis Results (2021)

After modifying the model, there are only three indicators that can measure the latent variable of service quality (X1), namely: arrival frequency is rare (X1.1); long waiting time (X1.3); and long travel time (X1.7). Two indicators can measure the road accessibility variable (X2), namely: lots of vehicle on-street parking (X2.1) and there are many intersections (X2.3). Three indicators can measure the public transport performance (Y1) variable, namely: Few passengers (Y1.1); driver's salary below standard (Y1.2); standard drive operation time (Y1.8).

Table 5 shows that the service quality variable (X1) has a significant effect on public transport performance, with a value of p = 0.000, which is smaller than α = 0.05. Likewise, road accessibility has a significant effect with the value of p = 0.000 which is smaller than α = 0.05.

Table 5 Regression Weights

Latent Variables			P
Public_transport_performance_Y1	<---	Road Accessibility_X2	.000
Public_transport_performance_Y1	<---	Service_quality_X1	.000

Source: Analysis Results (2021)

Table 6 shows the path coefficient value for the latent variable of service quality (X1), which is 0.498, and the coefficient value. Pathway road accessibility latent variable path (X2) is 0.308.

From Table 6, it can be obtained the following public transport performance model:

Y1 = 0.498 X1 + 0.308 X2 ..... (2)

Where:

X1 : Service quality
X2 : Road accessibility

Table 6 Standardized Regression Weights

Latent Variables			Estimate
Public_transport_performance_Y1	<---	Road_Accessibility_X2	.498
Public_transport_performance_Y1	<---	Service_quality_X1	.308
Arrival_frequency_is_rare_X1.1	<---	Service_quality_X1	.681
Long_waiting_time_X1.3	<---	Service_quality_X1	.762
Long_travel_time_X1.7	<---	Service_quality_X1	.683
Lots_vehicle_on-street_parking_X2.1	<---	Road_Accessibility_X2	.650
There_many_intersection_X2.3	<---	Road_Accessibility_X2	.807
Few_passengers_Y1.1	<---	Public_transport_performance_Y1	.903
Driver's_salary_below_standar_Y1.2	<---	Public_transport_performance_Y1	.516
Short_drive_operation_time_Y1.8	<---	Public_transport_performance_Y1	.902

Source: Analysis Results (2021)

Parameters of Goodness of Fit Models

In this study, eight goodness of fit parameters were tested. The Chi-Square test is useful for testing the relationship or effect of two nominal variables and measuring the strength of the relationship between one variable and another nominal variable. The Chi-square value is very sensitive to the number of samples. The bigger the sample, the bigger the value. Where, with a value of the degree of freedom (DF) = 7 and a significance level of 0.05, the Chi-square table is 16.919 > Chi-square count is 11,850, meaning the model meets.

The probability value in this study reached 0.222 > 0.05. Models meet. The significance value is required to increase beyond 0.05 to reduce the calculated Chi-square value so that it does not exceed the Chi-square table.

The value of CMIN/DF obtained is 1.317 < 2.00, which fulfills. CMIN/DF is one of the indicators to measure the fitness level of a model. CMIN/DF is nothing but the Chi-square value divided by the DF value. A CMIN/DF value less than 2.00 is an indication of an acceptable fit between the model and the data [12].

The GFI value in this study was 0.988 > 0.900 (very good). GFI is a non-statistical measure that has a range of values between 0 (poor fit) to 1.0 (perfect fit). A high value in the index indicates a better fit and a model is said to be very good if the GFI value is more than or equal to 0.90.

The AGFI value in this study was obtained at 0.953 > 0.900, a good overall model fit. AGFI is a criterion that takes into account the weighted proportion of variance in a sample covariance matrix. The recommended acceptance rate is when AGFI has a value equal to or greater than 0.90. A value of 0.95 can be interpreted as a good level-good overall model fit (good) while a value between 0.90 - 0.95 indicates a sufficient-adequate fit level.

The TLI value in this study was 0.986 > 0.950. TLI is an alternative incremental fit index that compares a tested model against a baseline model. A value that is very close to 1 or more than 0.95 indicates a very good.

The CFI value in this study was 0.996 > 0.950. The magnitude of this index is in the range of values 0 (poor fit) to 1.0 (perfect fit). Values greater than or equal to 0.95 identify the highest level of fit, a very good fit.

The RMSEA value in this study was 0.036 < 0.08. RMSEA is another test tool showing the goodness-of-fit that can be expected when the model is estimated in the population [14]. The RMSEA value which is less than or equal to 0.08 is an index for the acceptance of the model which shows a close fit of the model based on the degrees of freedom. Furthermore, the parameters of the goodness of fit Models can be seen in Table 7.

Table 7 Results of calculation of goodness of fit parameter.

No	Goodness of Fit Index	The calculation results	*Cut off Value*	Information
1	Chi-square (x^2)	11.850	≤ x^2 table (=16.919)	Very good
2	Probability	0,222	≥ 0,05	Very good
3	CMIN/DF	1,317	≤ 2,00	Very good
4	GFI	0,988	≥ 0,90	Very good
5	AGFI	0,953	≥ 0,90	Very good
6	TLI	0,986	≥ 0,95	Very good
7	CFI	0,996	≥ 0,95	Very good
8	RMSEA	0.036	≤ 0,08	Very good

Source: Analysis Results (2021)

4. CONCLUSION

The results show that all the goodness of fit parameters is fulfilled very well. The exogenous variable of service quality (X1) has a significant positive effect on public transport performance (Y1), with a value of p = 0.000 < 0.05, meaning that the higher the service, the higher the performance of public transportation, and vice versa. Service quality is indicated by: arrival frequency (loading factor = 0.681), waiting time (0.762), and travel time (0.683). The exogenous variable of road accessibility (X2) has a significant positive effect on the performance of public transportation, with a value of p = 0.000 <0.05, meaning that the higher the road accessibility, the higher the performance of public transportation, and vice versa. Road accessibility is indicated by: on-street parking (0.650), and intersection (0.807)

Public transport performance (Y1) as an endogenous variable is indicated by: the number of passengers (0.903), Driver's salary (0.516), and operating duration (0.902). The performance of public transportation on the Batubulan-Ubud Terminal route is very poor, which is caused by poor service quality and poor road accessibility. The low quality of service is evidenced by the small arrival frequency, long waiting time, and long travel time. Poor road accessibility is evidenced by the number of vehicles parked on the road, and there are many intersections along the route.

5. REFERENCES

[1]. Murat, Y.S., and Cakici, Z. 2017. "Comparative Analysis of Public Transport Users' Perception Targeting Sustainable Transportation." *Engineering Tools and Solutions for Sustainable Transportation Planning*:23. doi: 10.4018/978-1-5225-2116-7.ch004.

[2]. Seran, E.N.B.S., and Joewono, T.B. 2015. "Atribut Kualitas Pelayanan Angkutan Publik di Kota Bandung". *Jurnal Teknik Sipil*, 11(2),Oktober 2015, 76-168.

[3]. Direktorat Jenderal Perhubungan Darat. 2002. Pedoman Teknik Penyelenggaraan Angkutan Penumpang Umum di Wilayah Perkotaan dan Trayek Tetap dan Teratur. Jakarta: Departemen Perhubungan RI

[4]. Eboli, L., and Mazzulla, G. 2008. "Willingness-to-pay of public transport users for improvement in service quality." *European Transport\Transporti Europei* 38:107-118.

[5]. Steg, L. 2003. "Can Public Transport Compete with the Private Car?" *IATSS Research* 27(2):27-35.

[6]. Ngoc, A.M., Hung, K.V., and Tuan, V.A. 2017. "Towards the Development of Quality Standards for Public Transport Service in Developing Countries: Analysis of Public Transport Users' Behavior." *Transportation Research Procedia* 25 4560–4579.

[7]. Chowdhury, S., Zhai, K., and Khan, A. 2016. "University of Auckland Research Repository, Research Space." *Journal of Public Transportation* 19(1):97-113. doi: 10.5038/2375-0901.1.17.

[8]. Mavoa, S., Witten, K., McCreanor, T., and O'Sullivan, D. 2012. "GIS-based Destination Accessibility via Public Transit and Walking in Auckland, New Zealand." *Journal of Transport Geography* 20:15-22.

[9]. Shah, J., and Andhvaryu, B. 2016. "Public Transport Accessibility Levels for Ahmedabad India". *Journal of Public Transportation*, 19(3), 19-35.

[10]. Hazian, M. 2008. *Analisis Kinerja Operasional Angkutan Kota di Kota Jambi*. Medan: Universitas Sumatera Utara.

[11]. Sarwono, J. 2010. "Pengertian Dasar Structural Equation Modeling (SEM)." *Universitas Kristen Krida Wacana.*

[12]. Ferdinand, A. 2006. *Structural Equation Modeling Dalam Penelitian Manajemen*. Semarang: Badan Penerbit Universitas Diponogoro.

[13]. Schumacker, R., dan Lomax, R. 2010. *A Beginner Guide to Structural Equation Modeling*. New York: Routledge.

[14]. Hair, J., Black, W., Babin, B., dan Anderson, R. 2010. *Multivariate data Analysis: A global perspective* 7ed. New Jersey: Pearson Education, Inc.

LOGIC
Jurnal Rancang Bangun dan Teknologi
(Journal of Engineering Design and Technology)
Address : Gedung P3M, It.1 Politeknik Negeri Bali, Bukit Jimbaran
PO BOX 1064 Kuta Selatan, Badung, Bali - Indonesia
Telp. (+62)361 701981 Fax. (+62)361 701128
Email: logic@pnb.ac.id

1412-114X