LOGIC
Journal of Engineering Design and Technology
Vol.23 No.2 July 2023; p. 131 - 137

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

THE IMPACT OF PIPE Ø 0,5 HEATER LENGTH AND TEMPERATURE ON OVALITY and THE DIFFERENCE IN PIPE THICKNESS FOR ITS BENDING

1,2) Mechanical Enggineering Department, State Polytechnic of Malang, Jl. Soekerno-Hatta 9, Malang 65141, Indonesia

Email [1]:
Sholie.coy3@gmail.com

Musholli [1], Sudarmadji [2]

Abstract. *Ferrous metal is of material utilized mostly for many objects or kinds of stuff to help humans and their work easier. Low-carbon steel is one of the ferrous metal natures that could be utilized when transforms into more useful objects. There be cold as well as hot working to undertake. Molting by bending pipe includes cold working due to it being bent as its recrystallization temperature is lower. When the process is undertaken, the pipe dimension would be oval which needs to be examined by enumerating a lower-recrystallization temperature and whether or not to shrink the pipe ovality percentage. In addition, as the pipe is bent there would be changes in the pipe dimension because it would drives pulls as well as puts pressure on one of the cross-sectional areas so the pipe percentage of dimension/thickness changes should also be examined. Methods to apply are a series of experiments by firstly treating heating which is up to 650º C and bending pipe as its temperature goes lower between 410º C – 500º C. These two types of independent variables that differ only in their cross-sectional areas of heating also resulted in impacting on both ovality percentage and the pipe thickness of its cross-sectional area.*

Keywords : Pipe Bending, Pipe Heating, Pipe 0,5 Inch, Temperature, Ovality, Induction

1. INTRODUCTION

Ferrous metal is a kind of metal to have the chemical element of iron (Fe). Ferrous metal is categorized into two main types, namely cast iron with a 2,0 – 4,5% of carbon level and steel of 0,05 – 2,0%. Based on chemical composition [1]. Low-carbon steel has 0,05 % - 0,20% C of carbon level It is malleable and easy to machine [2]. There are two methods of metal forming, namely the process of cold working conducted through a lower-recrystallization temperature, exactly at room temperature and; and the process of hot working conducted through a high temperature. Changing the pipe shape, from straight to curve, is among the process of bending. In this procedure, the outer shape of the pipe would pull out, and its inner pressure that is resulted in the pipe wrinkles [4].

The hot bending is done through a plasticity process on metal at an upper-recrystallization temperature. One of the advantages of this kind of bending is to save power during the process that is resulted in fine and identical grains at the time of recrystallization [5]. "The advantages of this kind include: (a) can reduce metal's porosity, (b) inclusion impurity is fragmented and spread through metal, (c) rough and columned grain are softened, (d) physical trait expands, (e) need lower powers to change metal shape [36]". While the disadvantages include having rough grain due to oxidation and the difficulty of reaching a precise measure as having sustained diminution after a hot working [5].

There are various types of the metal formation including handling, forging, punching, pulling, and bending [5]. Pipe bending is among the approaches to bending pipe into a preferred shape to do. Of course, there are many approaches for shaping metal as well as pipe. To bend a pipe is to provide pressure on it so that it causes plasticity deformation on any part to bend. There are two kinds of shaping pipe, namely shaping pipe through piercing and welding.

The ultimate bending radius may be lower than that of the radius of the element referral compensated [5]. The fact that there would be a spring-back during the bending process generally brings significant impacts in adjusting the time needed.

On this spring back, material thickness is a dominantly input parameter and is followed by the punch radius and bending angle. While on the spring-go, bending angle material plays a dominantly input parameter and is followed by the material thickness and punch radius [7].

Other materials experiencing a force out of it would sustain strain. Strain is one of the parameters to use to measure the strength of materials so that the design should meet their requirements. The basic formula for force is as follows:

$$\sigma = \frac{F}{A} \frac{N}{m^2} \quad (1)$$

σ : Force (kPa)
F : force or load on body (N or kg)
A : Cross-sectional area of body (m2)

Stretching is a force of push and pull (P) of an workpiece interacting one another and pushing force on the workpiece's cross-sectional area (Figure 1). Because of pull forces are resulted in workpiece stretching and are followed by the workpiece length (δ), the comparative between this additional and initial lengthy is called stretching (ε) [8].

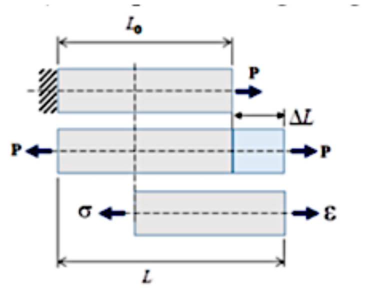

Figure 1. Workpiece with pulling and stretching [8]

The correlation between force and stretching is depicted in the form of force-stretch diagram as seen in Figure 2. Point A is the proportional limit (σp) in which a force and stretching linearity is depicted. At this point, as well, a body would back to its initial position together with the loss of body's load capacity or as it is known as elasticity limit. Nonetheless, if the body is pulled out of a proportional limit that reaches landing area, this body would endure plasticity deformation that result in the body remaining stable or is not to be back to its initial position though its load capacity is released.

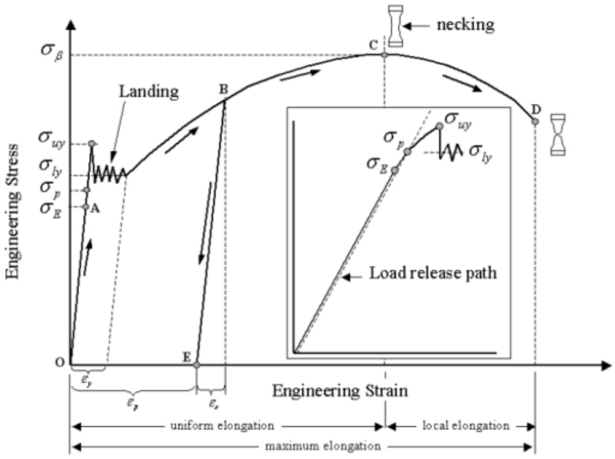

Figure 2. Diagram about the relation between force and stretching [8]

The working of bending pipe is throughout two force components: pulling and pushing. And on the process of bending, there be stretching, neutral, and wrinkling. Induction heating is a heat transfer without a direct contact between its heating source and the body. This happens because of the interaction among electromagnetic complexities.

According to Fauzi et al, in a study discussing acrylic plate roll versus acrylic machines, it was stated that the high heating temperature has less stress than the lower heating temperature.

This research was conducted to determine the percentage deviation of pipe ovality after various heating applications, and changes in the thickness of the pipe cross section. After obtaining the research data, the benefits can be used by the manufacturing industry in the field of pipe bending as a reference in pipe bending and the percentage change in ovality of the pipe being bent.

2. METHODS

This study is based on an experimental research. Arboleda [11] defines experimental research as conducting research by manipulating one or more variables so that is resulted in certain changes in one or more variables examined, of course by applying certain means or methods. In addition, Gay [12] said that experimental is the only method to use to examine truly hypotheses relating causality (cause-and-effect relationship).

In this regard, the step to undergo is to heat the iron specimen of diameter 0,5 inch and thickness 1,4 mm. When this specimen is deployed on the heater induction, the temperature should be set up to 650 ºC. And as the process reaches this desired temperature, the heater induction is switched off, then specimen is pulled out of bending position. While specimen is on this position, this is the time to wait for temperature reaching a specific level between 410 ºC – 500 ºC before having bent. The bending is undertaken by applying eight bending movements in 6 seconds.

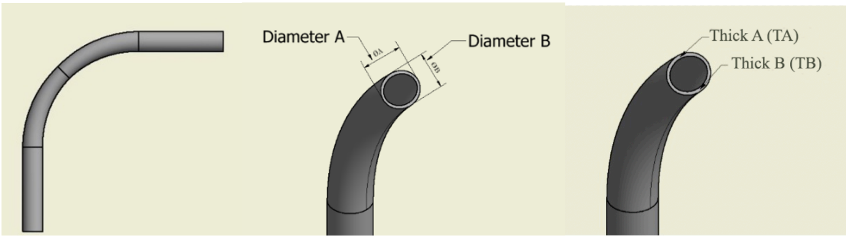

Figure 3. Sketch of experimental specimen pipe

Metal structure given a load through certain mean would remain changes. Slim pipe would wrinkle. It is due to the time allocated for bending is directly resulted in the unstable structure of geometry and it happens only when metal structure loaded with some loads that is equal to the metal critical load [13].

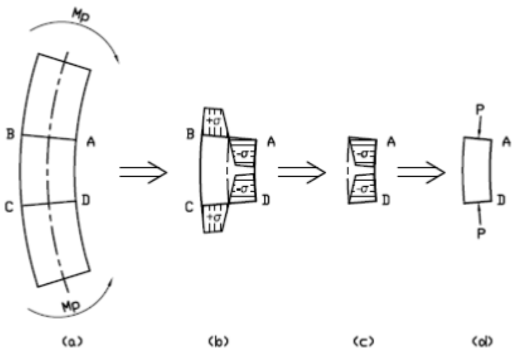

Figure 4. The transformation of pipe bending load toward the column pushed [13]

There are four steps for the load transformation; first, the time needed for bending as been indicated by Figure 4a; second, conducting analysis on strain distribution as in Figure 4b; third, isolating strain on the pipe parts where they are pulled out as seen in Figure 4c; forth, transforming distributed strain on the bent surface to become a pushed load as in Figure 4d [13].

To obtain accurate research data, it is necessary to provide tolerance limits, especially the angular shape of the specimen being bent. The maximum heating temperature is limited to 650 ºC before the temperature is reduced to the bending temperature.

2.1 Parameters to apply in this study

For some differences among the pipe diameters (ovality), there are two kinds of diameters to apply to specify their ovality, namely maximum diameter (right-left) or Dimeter A ($Ø_A$) and minimum diameter (up-buttom) or Dimeter B ($Ø_B$) (Picture 3). The initial diameter for a workpiece is 19mm that is eventually known as nominal diameter. To determine the level of ovality distortion, it need to be quantified using Equation (2)

$$\text{Ovality (\%)} = \frac{D_{max} - D_{min}}{D_{nom}} \times 100\,\% \qquad (2)$$

Where :

$Ø_A$: Maximum diameter (mm)

$Ø_B$: Minimum diameter (mm)

$Ø_{nom}$: Nominal diameter (mm)

The difference between pipe thickness because of pulling which is then initialed by Thick (T_A) and that thickness because of wrinkling which is now initialed by Thick (T_B) (Figure 3). The pipe initial thickness is 1,4 mm that now it is cited as nominal thickness. Their comparison is quantified by an equation:

$$\text{Thickness (\%)} = \frac{T_B - T_A}{T_{nom}} \text{ x } 100 \text{ \%} \quad (3)$$

Where:

T_A : Pipe thickness due to pulling or Thick A (mm)
T_B : Pipe thickness due to pushing or Thick B (mm)
T_{nom} : Nominal thickness (mm)

2.2 Steps to take in this Study

1) Cutting off specimen for 30 cm, in 50 pieces
2) Setting up the hydraulic of bending equipment through induction heating machine
3) Determining the range of temperature (410 ºC – 500 ºC). Here, the researchers undergo a series of experiments for temperature 100 ºC to 540 ºC.

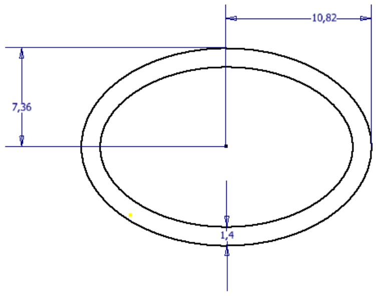

Figure 5. Creating Ovality on Specimen

Table 1. Ovality Percentage on Heating Temperatures

Heating Temperature	Ovality Percentage
100 ºC	36.42%
150 ºC	34.95%
200 ºC	35.47%
250 ºC	40%
300 ºC	39.53%
350 ºC	29.74%
400 ºC	25.74%
500 ºC	41.26%
540 ºC	46.47%

4) Then it is known that for the temperature ranging from 100 ºC – 300 ºC is distorted over 30 %, for 350 ºC – 400 ºC temperature is distorted over 20 %, and ranging from 500 ºC – 540 ºC be distorted its ovality over 40 %. Seen from this background, it is then determined its temperature's range that would be examined, that ranging from 410 ºC to 500 ºC
5) For the specimen hot working, the pipe is inserted into heating induction (Figure 6). On this process, the hot working is held that specimen parts attained by probe thermocouple reaching temperature 650 ºC. After having reached this temperature point, induction heater is not activated and specimen is pulled out of the bending machine of hydraulic pipe.

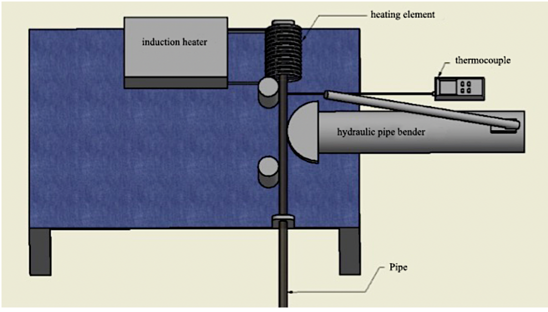

Figure 6. Heating for Steel Pipe

6) Within the process of specimen bending, this specimen is set down to a bending position and held up for the temperature goes down between 410 ºC to 500 ºC. Soon after the temperature points out a desired level, the bending procedure is undertaken by 8 bending moves in 6 seconds or through a constant speed of moves. This desired temperature, as intended in this study, is when it reaches the level between 410 ºC to 500 ºC. On every heating temperature would be taken 5 specimen data.
7) The process of collecting data. To gain a valid data, each specimen is examined for its elbows, and the pipe tolerable elbows to apply in this study is 10º of the aviation. If it is found that a specimen has an intersection below 80º, it should be reexamined under the mentioned temperature (Figure 8).

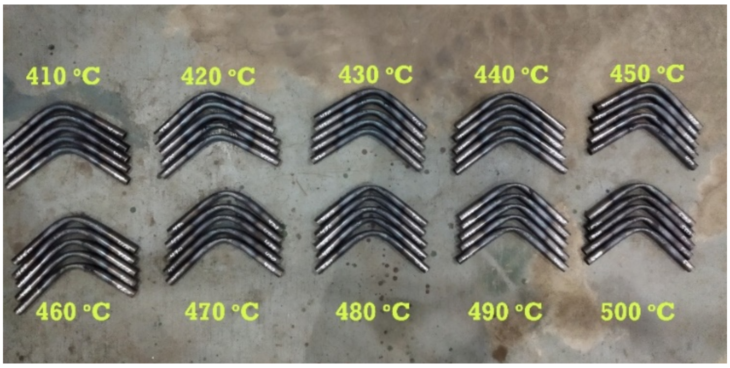

Figure 7. Example of Specimen after having been Bent on a Cross Section of Heating 10 cm

Figure 8 Example of a specimen with an angle of 80º or deviating 10º from a bending angle of 90º

3. RESULTS AND DISCUSSION

Low-carbon steel would be melted in a temperature 1500 ºC or when it is upper-recrystallization temperature. In this study, heating temperature is below recrystallization that metal structural adjustments is unspecified due to maximum heating to apply in this study is just 650 ºC. The embodied metal carbon is among 0.10 to 0.25 %. Because of its lower embodied carbon, the carbon is lenient, unable to be solidified, able to forge, pour, weld, and to harden its case (case hardening). Metal of 0.15 % has a lower mach ability and is generally used to build bridge, building, among others [14].

3.1 Ovality of the Pipe Diameter

For some differences among the pipe diameters (ovality), there are two kinds of diameters to apply to specify their ovality, namely maximum diameter (right-left) or Dimeter A and minimum diameter (up-buttom) or Dimeter B. The initial diameter for a workpiece is 19mm that is eventually known as nominal diameter. To count ovality percentage is to apply equation (2).

Table 2. Ovality Percentage

Heating Temperature (°C)	For Heating Section Length of 10 cm (%)	For Heating Section Length of 14 cm (%)
410°	47.43%	24.01%
420°	48.83%	25.15%
430°	51.54%	22.82%
440°	47.71%	22.04%
450°	53.93%	21.93%
460°	53.31%	23.38%
470°	54.85%	24.83%
480°	59.72%	24.61%
490°	63.44%	27.95%
500°	62.08%	31.23%

The above table shows that on the heater with 10 cm length and on temperature 410 °C would sustain the lowest adjustment of 47,43 %, of an initial diameter 19 cm. While the highest percentage is undergone on the heating temperature 490 °C, with adjustment up to 63,44 % of its initial thickness.

For the heating temperature of 14 cm, it is resulted in its lowest ovality on 450 °C, with adjustment of 21,93 % comparing to its initial diameter 19 cm. While the highest percentage is on 500 °C that adjust 31,23% of its initial diameter.

Hence, all the data presented above could be compare that between 10cm and 14 cm heating length are found a crucial differences due to their percentage is too distinguished among them. 14 cm heating length followed by ovality percentage of 21,93 % is far better than that of 10 cm that is followed by ovality percentage 47,43 % of its initial diameter.

3.2 Differences of the Pipe Thickness

The difference between pipe thickness because of pulling which is then initialed by Thick A and that thickness because of wrinkling which is now initialed by Thick B. The pipe initial thickness is 1,4 mm that now it is cited as nominal thickness. Their comparison is quantified by an equation(3)

Table 3. Differences of the Pipe Thickness

Heating Temperature (°C)	For Heating Section Length of 10 cm (%)	For Heating Section Length of 14 cm (%)
410°	12.14%	5.57%
420°	11.29%	6.71%
430°	12.71%	5.00%
440°	11.86%	5.29%
450°	12.71%	4.86%
460°	11.14%	5.57%
470°	11.43%	5.14%
480°	11.14%	5.71%
490°	12.00%	7.57%
500°	13.86%	6.71%

The above table indicates that on the heating length 10 cm, 460 °C and 480 °C makes the lowest pipe thickness 11,14 % of its initial thickness 1,4 mm. And the highest percentage is on 500 °C that makes adjustments up to 13,86 % of the pipe initial thickness.

For the heating temperature of 14 cm, it is resulted in its lowest ovality on 450 °C, with adjustment of 4,86 % comparing to its initial diameter 1.4 mm. While the highest percentage is on 500 °C that adjust 7,57% of its initial diameter.

Hence, all the data presented above could be compare that between 10cm and 14 cm heating length are found a crucial differences due to their percentage is too distinguished among them. 14 cm heating length followed by ovality percentage of 4,86 % is far better than that of 10 cm that is followed by ovality percentage 11,14 % of its initial diameter.

From research conducted by Rian G.A. states that there is no effect of the bending angle on the rolling quality value. The bending angle in this study was 90o so that the bending tolerance used in this study was 10o deviation of the specimen elbow. If there is a specimen with an angle below 80o, it will be re-taken at that temperature.

4. CONCLUSION

The data presented and discussed above can be concluded as follows:

1) The finest temperature for the heater cross-section is 10 cm.
   While the lowest is on temperature 410 ºC that makes the lowest adjustments 47,43 % of its initial diameter 19 cm.
   And, the thickness differences is among a heating level 460 ºC and 480 ºC that make the pipe adjustments 11,14 % of its initial thickness 1,4 mm.
2) The finest temperature for the heater cross-section is 14 cm.
   Whereas, the lowest ovality is under temperature 450 ºC that makes the lowest ovality adjustments 21,93 % of its initial diameter 19 cm.
   And, the thickness differences is among a heating level and 480 oC that make the pipe adjustments 4,86 % of its initial thickness 1,4 mm.
3) After having conducted research it is found that the more breadth is the more significant impact on the pipe bending, by which heater cross-section 10 cm is resulted in 47 % and for that 14 cm is 22 %. For the thickness comparison on a heater cross section 10 cm is 11 %, and for that of 14 cm is 5 %. Bending a pipe that is preceded by a heating would be resulted in mare orderly micro structure as well as fixing atom structure after the bending.

Suggestions for further research need to do further research that measures the hardness of the surface due to bending and analysis of metal structures after experiencing heating

5. ACKNOWLEDGEMENT

The researchers thank the board of Director of State Polytechnic of Malang that allow us to complete this study on Master Program in Applied Manufacturing Technology Engineering, Department of Mechanical Engineering, State Polytechnic of Malang for two years.

6. REFERENCES

[1] Surdia, T. & Saito, S. 1999. *Pengetahuan Bahan Teknik*. Pradnya Paramita, Jakarta
[2] Samlawi, A.K. & Siswanto, R. 2016. Material Teknik.
[3] Sukarman dkk, (2020). Analisis pengaruh radius dies terhadap springback Logam lembaran stainless-steel pada proses bending Hidrolik v-die. Jurnal Teknologi. Volume 12 No. 2 Juli 2020
[4] Mustaqim, A. 2012. Rancang Alat/Mesin Pengerol Pipa. Tugas Akhir.Yogyakarta: Universitas Negeri Yogyakarta.
[5] Dadang. 2013. *Teknik Dasar Pengerjaan Logam. Semester 1*. Malang. Indonesia. PPPPTK BOE Malang
[6] Troive, Lars et al. 2018. "Springback Compensation for a Vehicle's Steel Body Panel." International Journal of Computer Integrated Manufacturing 31(2): 152–63. https://doi.org/10.1080/0951192X.2017.1379096
[7] Phanitwong, W., Sontamino, A., & Thipprakmas, S. (2013). *Effects of part geometry on spring-back/spring-go feature in U-bending process*. Key Engineering Materials, 549, 100–107. https://doi.org/10.4028/www.scientific.net/KEM.549.100
[8] Paloboran, M. & Yahya, M.2021. *Mekanikan Bahan.Teknik Mesin*. Scopindo Media Pustaka. Surabaya
[9] Ambiyar dkk., 2008. *Teknik Pembentukan Pelat Jilid 3*, Jakarta: Direktorat Pembinaan Sekolah Menengah Kejuruan.
[10] Rudnev, V., Loveless, D., & Cook, R. L. (2017). Handbook of Induction Heating. CRC Press. From https://www.routledgehandbooks.com/doi/10.1201/9781315117485-3
[11] Arboleda, C. R. 1981. Communications Research. Manila: CFA.
[12] Gay, L. R. 1981. Educational Research: Competencies for Anlysis and Application. London: Prentice-Hall International (UK) ltd.
[13] Iswahyudi, S., 2011. Mekanisme pembentukan kerutan pada proses penekukan pipa. *In Prosiding Seminar Nasional Sains dan Teknologi* ke-2. hal. 65– 69.
[14] Ferdiansyah, E 2013. *Ilmu Bahan Teknik*. Jakarta. Indonesia. Direktorat Pembinaan Sekolah Menengah Kejuruan Kementerian Pendidikan dan Kebudayaan Republik Indonesia
[15] Sulaiman, 2010. *Pengaruh Proses Pelengkungan Dan Pemanasan Garis Pelat Baja Kapal Aisi E 2512 Terhadap Nilai Kekerasan Dan Laju Korosi*. Program Studi Magister Teknik Mesinprogram Pascasarjanauniversitas Diponegoro Semarang