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AIP Conference Proceedings 2187 , 030002 (2019); https://doi.org/10.1063/1.5138306 2187 , 030002 © 2019 Author(s). Effect of punch angle and punch radius on bend angle through air V-bending of sheet metal Cite as: AIP Conference Proceedings 2187 , 030002 (2019); https://doi.org/10.1063/1.5138306 Published Online: 10 December 2019 Muhammad Arsyad Suyuti , Muhammad Iswar , and Rusdi Nur Effect of Punch Angle and Punch Radius on Bend Angle through Air V-Bending of Sheet Metal Muhammad Arsyad Suyuti1, b), Muhammad Iswar1, c) and Rusdi Nur1, 2, a) 1Mechanical Engineering Department, Politeknik Negeri Ujung Pandang, Makassar 90245, Indonesia. 2Center for Materials and Manufacturing, Politeknik Negeri Ujung Pandang, Makassar 90245, Indonesia. a)Corresponding author: rusdinur@poliupg.ac.id b)muhammadarsyadsuyuti@poliupg.ac.id c)muh_iswar@poliupg.ac.id Abstract.

Nowadays, the process of metal forming in the industrial of welding and machinery is developing very rapidly, especially the bending process. In the manufacturing process, bending processes are often carried out to make and repair products such as electronic panel components, automobile vehicle panels, tool-boxes, burning fish, agricultural machinery and mechanization tools, etc. The complex-shaped bend parts with high precision are increasingly needed.

To achieve high precision of parts, especially the bend angle, a suitable design of process parameters is strictly considered. An experimental study was conducted to determine the effect of punch parameters (i.e. punch radius and punch angle) on the bend angle in the V-bending process. Bending tests carried out several variable variations, including the punch angle (i.e. 85º, 87.5º, and 90º), and punch radius (i.e. 1 mm, 1.5 mm and 2 mm).

The angle of 85º of die is constant. The analysis of variance (ANOVA) techniques was carried out to investigate the degree of significant process parameters in the air V-bending process. The results revealed that the degree of significant process parameters in air V-bending process depended on the punch angle.

It can be concluded that the punch angle is significantly affected to the bend angle (less than 90º or more than 90º) while compared to the punch radius. INTRODUCTION Processing metal forming of the machinery and welding workshop industry is developing very rapidly, especially the bending process. The buckling process is the formation of metals which are generally in the form of sheet plates or rods from both ferrous and non-ferrous metals by bending, which in the bending process will cause a stretching or stretching on the neutral axis along the bending area and produce a straight bending line (Kalpajian & Schmid, 2010).

The phenomenon of the development of metal formation through buckling processes occurs in the manufacturing industry in large cities in large-scale and small-scale welding machinery and workshops in rural areas. This was triggered by the increasing use of various kinds of mechanization technology, especially in the field of food security and security in everyday people's lives such as post-harvest process technology and other agricultural mechanization technologies.

In the automotive industry, steel sheets are widely used to produce various automotive components. The bending process is one type of sheet metal forming which is mostly perfomed in the automotive industry. The bending process utilizes a press brake system to bend sheet metal through punches to obtain the fixed bent components.

Air bending method is utilized to increase the flexibility and efficiency of the air bending process for shorter processing time and higher accuracy (De Vin, 2000). There are some different curvilinear angles that can be agreed to using the same set of tools in bending air. This can be done only by adjusting the delivery stroke and restoring the need to change tools A few investigate on the bend angle is obtained in various bending processes.

By using experiments and finite element simulation, Huang and Leu were presented that the punch load and bend angle are influenced by process variables after being dismantled in the V-bending process of steel sheets. (Huang & Leu, 1998). Some researchers have been investigated in the air V-bending process (Fei & Hodgson, 2006; Narayanasamy & Padmanabhan, 2008b, 2008a).

Also, Some researchers have investigated spring-back using the design of experiment

(DoE) method (Asgari, Pereira, Rolfe, Dingle, & Hodgson, 2008) (Thipprakmas & Phanitwong, 2011) (Srinivasan, Vasudevan, & Padmanabhan, 2013). The method of ANOVA and full factorial in DoE are used to determine the importance of cutting parameters, including punch radius and punch angle.

ANOVA is a statistically approach used to investigate and model the relationship between a response variable and one or more independent variables. The bending angle in the air V-bending from the experiments was also analyzed statistically using the full factorial and ANOVA methods in DoE to identify whether or not the punch radius and punch angle values are significant as input parameters to predict spring-back.

The above conditions indicate that the metal bending process carried out in some machinery and manufacturing workshops is still not effective because the results of the formation are not good and require a long time in the manufacturing process. Thus the application of appropriate technology is needed to increase the effectiveness of metal formation through this bending process.

The use of appropriate technology machines has been widely used to increase productivity, efficiency, and effectiveness in the production process for community businesses, especially those in the area. One of the appropriate technologies that allow it to be applied in the bending process is a hydraulic press machine equipped with a press tool.

EXPERIMENTAL DESIGN Punch Parameters The material of the punch set is carbon steel AISI S45C. This material was performed through the heat treatment process using hardening in 820oC of temperature and then continued with tempering in 300oC. Finally, the punch set has a hardness of 47 HRC and designed in form as follow figures (Figure 1 and 2) include its dimensions. FIGURE 1.

Punch set of air V-bending FIGURE 2. Die set of air V-bending The air v-bending tests are conducted on an instrumented 100 kN Universal Testing Machine (UTM) Galdabini PM 100 with the v free bending tool shown in Figure 3. The geometric parameters involved are: ? punch radius : 1, 1.5, and 2 mm ? punch angle : 85º, 87.5º and 90º ? stroke steps : 13.5, 14 and 14.5 mm ? Die angle : 85o FIGURE 3.

Schematic of air V-Bending process in UTM Machine RESULTS AND DISCUSSION The experimental results of air V-bending were represented in Table 1. TABLE 1. Bending results based on punch parameters for different strokes. Stroke 13,5 mm 14,0 mm 14,5 mm Punch Radius (mm) Punch Angle (o) Bend angle (o) Punch Angle (o) Bend angle (o) Punch Angle (o) Bend angle (o) 1,0 85 92.83 85 93.25 85 85.14 1,0 87.5 94.97 87.5 91.42

87.5 87.16 1,0 90 96.33 90 94.33 90 90.92 1,5 85 93.83 85 91.08 85 88.22 1,5 87.5 95.50 87.5 91.66 87.5 89.83 1,5 90 95.75 90 92.42 90 91.55 2,0 85 94.47 85 91.30 85 88.25 2,0 87.5 94.58 87.5 91.69 87.5 88.75 2,0 90 96.83 90 94.58 90 91.58 Based on Table 1, the bending results were presented only two types of stroke (13.5 and 14.5 mm) that can show the significant data in the ANOVA method.

Figure 4 shows the effect of the punch radius and punch angle on Bend angles in the air v-bending tests. It can be shown that only one factor has a significant effect on the bend angle, that is, the Bend angles increase with the increasing of punch angle while the punch radius has no effect. (a) (b) FIGURE 4. Bend angle results for the different stroke of 13.5 mm (a) and 14.5

mm (b) Effect of Punch Angle The data of experimental results were analyzed using Analysis of Variance (ANOVA) techniques. This method can be determined by the punch conditions that have an effect on the bend angle. The ANOVA analysis was shown in Table 2. TABLE 2. ANOVA for bend angle. Stroke Source Sum of Squares DF Mean Square F Value Prob>F 13.5 mm Model B Residual Cor Total 10.09 10.09 2.38 12.47 1 1 7 8 10.09 10.09 0.34 29.70 29.70 0.0010 0.0010 Significant 14.0 mm - - - - - - Not Significant 14.5 mm Model B Residual Cor Total 25.79 25.79 10.68 36.47 1 1 7 8 25.79 25.79 1.53 16.91 16.91 0.0045 0.0045 Significant The DoE method can be also presented the final equation in actual factors for both stroke of 13,5 mm (1) and 14,5 mm (2) as follow: Bend angle = +16.42222 + 0.82933 *Punch Angle (1) Bend angle = +49.62667 + 0.51867 *Punch Angle (2) These results were confirmed by (Özek & Bal, 2009) in their investigation.

It was concluded that the deep-drawing boundary ratio was getting bigger along with the increasing punch radius in the forming process of DIN EN10130-91 sheet metal. Other results obtained that the increase in springback value (including the bend angle) was influenced by the increasing punch radius in the V-bending air of stainless steel sheet metal (Buang, Abdullah, & Saedon, 2015).

Effect of Punch Radius According to the result data and analyzing the DoE method, the punch radius was not effected on the bend angle. In plastic deformation by incremental formation, the influence of radius (r) is most significant on the ability to form thin metal sheets. (Carrino, Giuliano, & Strano, 2006).

CONCLUSION By conducting technique of experiments and DoE, the results obtained that punch angle is important factors influenching bend angle in sheet metal in air V-bending. From the ANOVA analysis and the experimental results, it can be concluded that the punch angle is a more significant factor affecting the bend angle while the

punch radius not effect. In the air V-bending process, the punch angle is the most significant factor to be considered.

The experimental technique in accordance with the DOE results. ACKNOWLEDGMENTS The authors would like to thank the DPRM of Ministry of Research, Technology and Higher Education Republic of Indonesia for financial support under grant PTUPT No. 155/SP2H/LT/DPRM/2019 Also, we would like to acknowledge for P3M of Politeknik Negeri Ujung Pandang for supporting our research. REFERENCES 1.

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