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Analysis of Roller Tip Radius and Blank Thickness on The Aluminium Bowl Forming by Metal Spinning Method

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ABSTRACT

Metal spinning is used to form a circular metal plate by rotating the blank at high speed and then applying pressure using a roller regularly. So that, its shape will follow the shape of the mold or mandrel. There are still a few bowl-making industries in Indonesia that use the metal spinning method. In general, still use the manual method. The purpose of this study is to find the right and efficient parameters to produce the thickness and height of the bowl as expected. The method used in this study uses experimental data collection. This study uses variations in the radius of the roller tip with variations of 2 mm, 4 mm, and 6 mm, and variations in the blank thickness of 1 mm, 1.2 mm, and 1.4 mm. The results obtained from this study are good interaction results, namely a roller tip radius of 2 mm and a blank thickness of 1.4 produces the most appropriate formability, where a roller tip radius of 2 mm results in high elongation of the workpiece. The metal workpiece is given to experience deformation plastic without being damaged or torn and at a thickness of 1.4 mm experienced an increase in an area up to 44.6% from the initial blank position.

KEYWORDS: metal spinning, aluminium bowl, roller tip, blank thickness, indonesia industries

I. INTRODUCTION

Household furnishings including bowls, pots, glasses, and pans, are among the most essential items. Because aluminum has exceptional corrosion resistance, household furniture built of this material is particularly healthy for its consumers. Since aluminum is a flexible metal, it can be used to produce good material for home furnish [1-2].

Metal forming is a manufacturing procedure that uses plastic deformation to change the shape of a metal object. The metal being worked is altered in size and shape to meet the required shape by an external pressure force [3-6]. Metal spinning is one technique that can be used. By spinning the metal at a high speed, circular metal blanks can be formed. Afterward, it is pressed regularly using a roller so that its shape will follow the shape of the mold (mandrel). Metal spinning can be carried out manually (conventionally) or automatically using a machine (CNC). Compared to using CNC, manual metal spinning needs cheaper production expenses. The main piece of equipment is a lathe, which is less expensive than a CNC machine. In addition to casting and drawing techniques, metal spinning is another alternative for metal shaping [7-8].

Several factors can affect the defects resulting from metal spinning, namely the rotating speed of the mandrel, roller radius, and material thickness. Therefore, it is necessary to consider the appropriate parameters for the metal spinning process [9-11]. According to Saied et al (2019), the process of deep drawing with ironing at the same step is currently being studied in several literatures, but it still cannot reduce the wall thickness by 50 or 70%. From the results of his research, conventional spinning processes and flow forming processes can reduce the cost of spare parts by reducing production time and can also reduce the power required for the process [12].

The most significant influences on the geometry of the spinning cup were determined to be the feed ratio, quantity of spin producing passes, spinning ratio, and lubrication. In lubricated conditions, maximum quality and increased processing speed (productivity) are accomplished by using more spin forming passes at a high feed ratio and decreasing the slow spinning rules typically employed for accurate product [13-15] .

Frnčík.M, et al (2018) used the parameters of variation of tool path and tool feed speed for differences in thickness. In the variation of convex, linear, and concave chisel paths. The profile of the concave tool path is considered inappropriate because there is a reduction in the maximum thickness in the t_1 and t_2 zones and an increase in thickness in the minimum t_3 zone. Minimal thickness reduction occurs at high feed rates. Meanwhile, the wall thickness increases at the open end [16].

Therefore metal spinning method can be applied to the household furnishings fabricating industry such as; bowls, pots and cups. Currently the bowl fabricating industry uses manual forming, casting, and deep drawing methods. Several home industries in Indonesia still use the manual method of placing an aluminum metal sheet over a mold made of wood. The forming process (beaten) using a wooden hammer until the aluminum metal resembles the shape of the mold. The manually proccess takes quite a long time and the appearance of the bowl is not good because there are lots of marks from being beaten. To produce aluminum bowls; with a diameter of 14 cm and a height of 6 cm takes 1 hour. In this metal spinning process, research was carried out on the effect of the difference in the radius of the roller tip and the difference in the thickness of the blank on the thickness and height of the resulting bowl.

II. MATERIALS AND METHODS

A. The experimental variables

The research method used is a type of experimental research. Experimental research is used to prove that certain variables influence other variables, in addition to proving hypotheses. The purpose of this study was to determine the effect of variations in the radius of the roller tip and variations in plate thickness on the thickness and height of the metal bowl spinning.

The research variables used in this study are as follows: (i) independent variables, shown in table 1.

Table 1. Independent variables

No	Parameter	Level		
		1	2	3
A	Roller tip radius	2.0 mm	4.0 mm	6.0 mm
B	Blank thickness	1.0 mm	1.2 mm	1.4 mm

(ii) The dependent variables, in this study consist of; (1) The thickness of the spinning result, (2) The height of the spinning results. (iii) The control variables consist of; (1) aluminum type 1100, (2) spindle speed 200 rpm, (3) Lubrication with SAE 20-50 W, (4) roller lever position 30˚, (5) using hand or conventional emphasis.

B. The experimental procedure

Installation on a metal spinning machine using a lathe includes installing the mandrel on the chuck, installing the clamp on the tailstock, and installing the roller on the toolpost (Figure 1).

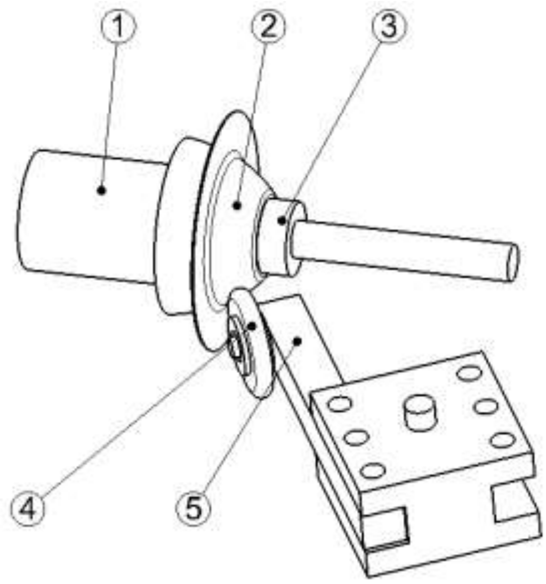

Figure 1. The experimental setup of metal spinning: *1*– mandrel, *2*– blank, *3*– clamp, *4*– roller, *5*– roller lever.

Figure 2 shows how a metal spinning machine works, namely the workpiece is held between the mandrel and the clamp, by applying pressure using a roller so that the blank can resemble the shape of a mold or mandrel.

Figure 2. Metal spinning process on a lathe

The metal spinning process (Figure 2) is carried out by pushing using a roller so that plastic deformation occurs in the workpiece, in order to obtain results that resemble the shape of a mandrel.

An outside micrometer and height gauge will be used to measure the aluminum bowl's height and thickness on the metal spinning product. So that the thickness of the bowl can be measured, it is cut into four parts using a hand grinder. Figure 3 shows the thickness measurement of spinning results with an outside micrometer.

Figure 3. Thickness measurement of the spinning result.

Futhermore the height measurement of the spinning results is carried out using a height gauge, as shown in Fig. 4

Figure 4. Measurement of the height of the spinning result.

The next step is to perform data processing with statistical analysis. It aims to determine the effect of the radius of the roller and the effect of the thickness of the workpiece on the bowl-forming process. After obtaining the data from the research results, the next step is to carry out processing along with data analysis to determine the effect of the independent variables on the dependent variable using data processing software. The method used is factorial in The Design of the Experiment (DOE).

III. RESULT AND DISCUSSION

Several bowls of metal spinning results can be seen from Figure 5-7. Figure 5 is a metal spinning bowl with a 2 mm roller setting with thickness variations of 1 mm, 1.2 mm and 1.4 mm.

Figure 5. A photograph of the bowl produced by the metal spinning for a 2 mm roller

Meanwhile, the bowls from the result metal spinning with roller settings of 4 mm with thickness of 1 mm, 1.2 mm, and 1.4 mm are shown in Figure 6.

Figure 6. A photograph of the bowl produced by the metal spinning for a 4 mm roller

Figure 7 shows a bowl of metal spinning results with a 6 mm roller at a thickness of 1 mm, 1.2 mm and 1.4 mm.

Figure 7. A photograph of the bowl produced by the metal spinning for a 6 mm roller

The results of the research are the process of grouping data which is carried out using justified statistical methods. Therefore, the results of measurement information from this experimental activity are shown in the table as follows:

A. Result of Spinning Thickness

Processing of bowl thickness data from spinning results, shown in table 2.

Table 2. Result of spinning thickness

Roller Tip Radius (mm)	Plate Thickness (mm)	Spinning Thickness (mm)						Average
		Point A			Point B			
2.0	1.0	0.494	0.488	0.490	0.476	0.480	0.478	0.484
	1.2	0.672	0.674	0.674	0.620	0.610	0.614	0.644
	1.4	0.828	0.832	0.844	0.674	0.676	0.668	0.753

	1.0	0.555	0.550	0.564	0.533	0.516	0.515	0.538
4.0	1.2	0.704	0.696	0.698	0.626	0.633	0.632	0.664
	1.4	0.892	0.89	0.88	0.756	0.760	0.758	0.822
	1.0	0.593	0.582	0.575	0.555	0.550	0.562	0.569
6.0	1.2	0.742	0.727	0.733	0.646	0.637	0.635	0.686
	1.4	0.916	0.910	0.900	0.852	0.848	0.846	0.878

Based on the results of the analysis of variance shown in Table 3, it was obtained that each independent variable (radius of the roller tip and plate thickness) had a P-Value of <0.05. So it can be stated that the null hypothesis (H0) was successfully rejected and the alternative hypothesis (H1) can be accepted. Meanwhile, the P-value obtained from the interaction of two variables (roller tip radius and plate thickness) is 0.333. The results show that the P-value > 0.05. So that the null hypothesis (H0) failed to be rejected, indicating that there was no difference in the effect arising from the interaction of the two variables on the thickness of the spining results.

Table 3. Results of the analysis of variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	8	18,4400	2,3050	0,76	0,643
Linear	4	17,8111	4,4528	1,46	0,254
Radius Ujung Roller	2	7,1089	3,5544	1,17	0,333
Ketebalan Plat	2	10,7022	5,3511	1,76	0,200
2-Way Interactions	4	0,6289	0,1572	0,05	0,995
Radius Ujung Roller*Ketebalan Plat	4	0,6289	0,1572	0,05	0,995
Error	18	54,7467	3,0415		
Total	26	73,1867			

Meanwhile, from the analysis of the model summary, which is indicated by a number of deformed coefficients (R^2). This number can show what percentage of the influence of the two independent variables on the dependent variable. From this results and data processing, it was found that, $R^2 = 87.18\%$. So that the two independent variables affect the dependent variable. The thickness factor of the spinning result is 87.18%. The remaining 12.82% are other variables or the presence of other factors that influence when conducting research.

Based on the test results in table 2, it can be made a graph of the effect of variations in the radius of the roller tip and the thickness of the blank on the thickness of the spinning result, as shown in Figure 5.

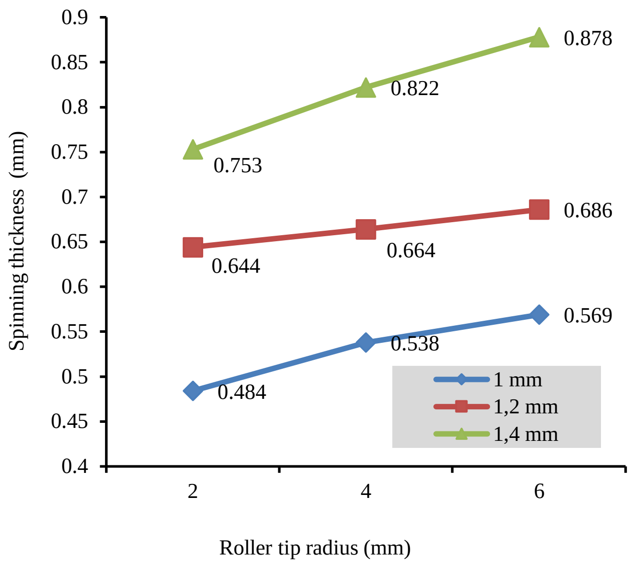

Figure 5. Effect of variations in the radius of the roller tip and the thickness of the blank on the thickness of the spinning result.

Figure 5 shows that a blank thickness of 1.4 mm with a roller tip radius of 6 mm has the highest spinning thickness value of 0.878 mm, and a blank thickness of 1 mm with a roller tip radius of 2 mm has the smallest spinning result thickness value of 0.484 mm. The 2 mm roller end radius causes the most thinning and the 6mm roller has little effect on the thinning of the thickness of the spinning results.

B. Result of Spinning Height

Data recapitulation of bowls height from metal spinning results, shown in table 4.

Table 4. The height of the bowl from metal spinning results

Roller tip radius (mm)	Plate Thickness (mm)	Spinning height (mm) 1	2	3	Avg
	1.0	67.0	65.3	67.6	66.6
2	1.2	69.4	65.8	68.8	68.0
	1.4	67.8	68.5	69.0	68.4
	1.0	67.0	64.3	67.2	66.1
4	1.2	69.0	65.8	67.0	67.2
	1.4	66.0	67.0	69.5	67.5
	1.0	64.5	66.6	66.0	65.7
6	1.2	66.0	66.4	66.5	66.3
	1.4	64.4	66.1	71.1	67.2

Furthermore, using analysis of variance, shown in table 5. In this study the value of α (alpha) used was 5% (0.05). The alpha value is the maximum value of the alternative hypothesis (H1) that can be accepted. So to facilitate research, the formulation is made, namely P-Value > 0.05, the null hypothesis (H0) is accepted. Conversely, if the P-Value < 0.05 then the alternative hypothesis (H1) is accepted. The results of data processing show that the independent variables (variations in the radius of the roller tip and variations in plate thickness) have a P-Value > 0.05. So that the null hypothesis (H0) fails to be rejected, meaning that it has no significant difference to the dependent variable.

Table 5. Results of the analysis of variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	8	18,4400	2,3050	0,76	0,643
Linear	4	17,8111	4,4528	1,46	0,254
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Error	18	54,7467	3,0415		
Total	26	73,1867			

In addition from the analysis of the summary model, the results of the research and data processing obtained an R^2 = 25.20%. So that these two independent variables affect the dependent variable where the height of the spinning bowl in the spinning process = 25.20% and the remaining 74.80%.

The graph in Figure 6 depicts how the thickness of the blank and the roller tip radius affect the height of the spinning process.

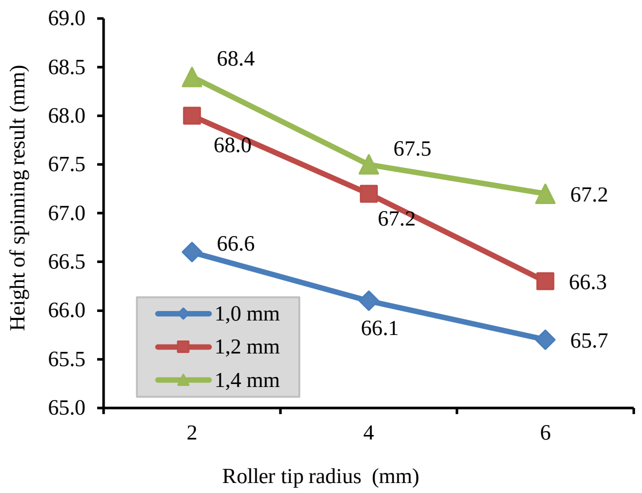

Figure 6. Effect of variations in the radius of the roller tip and the thickness of the blank on the height of the metal spinning results.

The graph in Figure 6 shows that the blank thickness of 1.4 mm with a roller tip radius of 2 mm causes the highest spinning result height value of 68.4 mm. While the thickness of the blank = 1 mm; radius of the roller tip = 6 mm, the lowest spinning height is 65.7 mm. So it can be concluded that the radius of the roller tip and the thickness of the blank affect the resulting height. Roller end radius = 2 mm has the greatest effect on the resulting height. This is because the roller trajectory or contact with the aluminum blank is more so that it produces friction. The friction that occurs causes greater deformation of the blank causing a large depletion, so the height value is higher.

The results obtained in this study were verified as carried out by Frnčík et al. (2018) [16]. The results of his research stated that a lower tool feeder would result in material deformation taking longer time. This treatment can result in a considerable thinning of the walls of the spun section so that the value of the wall height is higher.

This research can be expanded upon to produce exact and precice metal spinning results: 1) A CNC machine is used in the spinning process. 2) The roller's utilized tip has a smoother radius. 3. Larger bearings are used with rollers. 4) To make them stronger and less prone to wear out, rollers are given a heat treatment previously. 5) Creating a smooth result by polishing and sanding the finish.

IV. CONCLUSION

The thickness of the spinning results thins most when the roller tip's radius is 2 mm, while the 6 mm roller has minimal impact. The height of the spinning results is most significantly impacted by the 2 mm radius of the roller tip.

The thickness of the 1 mm blank experienced a thickness reduction of up to 52% with a thickness value of the spinning result of 0.484 mm. For a blank thickness of 1 mm, it is declared safe because nothing has failed (torn). And using a roller tip radius of 2 mm and a blank thickness of 1.4 mm produces a height of 14% with a height value of 68.4 mm.

There is an interaction between the radius of the roller tip and the thickness of the blank on the thickness and height of the metal spinning bowl. The most appropriate variables used are the radius of the roller tip of 2 mm and the thickness of the blank of 1.4 mm because they can produce the most appropriate formability. The 2 mm radius of the roller ends results in high elongation of the workpiece. In this condition, the given metal workpiece undergoes plastic deformation without being damaged or torn. Meanwhile, the 1.4 mm thickness experienced an increase in the area of up to 44.6% from the original blank.

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