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Chip Formation Analysis of the Turning of ST41 Steel

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ABSTRACTS

ST41 steel is commonly used for the shaft of ships. The shaft tends to corrode due to the interaction with the water. To recycle the used ST41, welding is normally done to repair the damaged or rusted surface of the shaft. The turning process is then conducted to obtain a better surface finish. This research used three types of cutting tools with different geometry at their cutting angle of 80º, 85º, and 90º. The chips from the turning process are collected and observed. Chip formation will indicate the quality of the turning process. The chip thickness and formation are observed to determine the effect of the cutting angle on the machining quality. The chip thickness value ranges between 0.13 mm to 0.3 mm, with a cutting angle of 90º producing the thinnest chips and 85º producing the thickest chips. Thicker chips indicate higher cutting force that leads to the wear of cutting tools. The cutting angle also affects obtained the chip formation. Several shapes are obtained, such as long continuous, medium, and short discontinuous shapes. A longer chip means a better process with less chatter on the cutting process. Long continuous chips are dominantly found by using 90º cutting tool. The other two angles are dominated by the discontinuous chips, with a slightly medium length of chips majorly found at 80º and short discontinuous chips recovered using an 85º cutting tool. From this research, it could be known that a 90º cutting angle will produce thinner and better chip formation.

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INTRODUCTION

ST41 is a type of steel that is commonly used as the shaft of some ships. For cost-saving action, the used shaft is usually can be restored to its original diameter, which value is always reduced due to the corrosion of water. The restoration of diameter is done by the welding and turning process, as the latter is conducted to obtain a better surface finish. A good surface finish is compulsory since a rougher surface would increase the deterioration of the shaft due to friction. The mean roughness is the most preferred aspect to determine the surface quality [1]. Good surface roughness of certain components, such as the ship's hull, is required before the ship is fit to sail [2].

Aside from the surface roughness, there are other categories to define the machining quality, such as the tool's wear and life and chip morphology. The chips resulting from the machining can indicate the quality of the machining. As the chips are obtained through the machining, the morphology, including the dimensions of the chips, could be considered to determine how well the process is executed. For instance, variation in cutting speed could alter the resulting chip formation resulted [3]. Higher cutting speed will generate a fitting chip's shape [4].

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Machining parameters affect and determine the output of the process with faster cutting or spindle speed are more suited for the finishing stage, unlike slower ones that are suitable for roughing stage. Other parameters, such as feed rate dan depth of cut, also contribute to the quality of the machining process. Previous studies involving the effect of the parameters on the machining quality were conducted. Zhu and Zhang [5] through the wear model at high-speed milling and Das et al. [6] in the research about the flank wear mechanism on cutting tools. Grzesik et al. [7] also developed a model based on the chip's volume and cutting speed on the flank wear to determine the tool's life.

The geometry of the cutting tools, however, is not only affecting the tool's life and wear but will also directly contribute to the surface integrity of the materials [8]. Any geometrical issues could lead to poor surface integrity in the machining process [9]. Tool geometry also contributes to the chip's thickness due to the friction resulting from the interaction between the chip and the tool [10].

In this research, the tool's angle is studied as the variation of geometry. This angle will affect the rake angle of the orthogonal cutting. The rake angle is the main influence on the chip formation of the machining process. The tool's angle mainly affects the vibration during the machining process [11]. The angle could also contribute to the chips resulted due to the direct interaction between the tool and the chip itself.

METHODS

The specimens for the turning process are from ST 41 steel with a diameter of 30 mm and a length of 100 mm. The specimens are first welded from the original dimension into 33 mm diameter using a SMAW welding machine with electrode NK-68 2.6 mm diameter. The welding is conducted at electrical current 100A.

The cutting tools used are High-Speed Steel with varying cutting angles, 80º, 85º, and 90º. The parameters of the machining used are constant with spindle speed 386 rpm, feed 0.06 mm/rev, and depth of cut 1mm. There is no coolant used during the machining process; hence the process is counted as dry machining.

Figure 1 to **3** show the main equipment and material used. From **Figure 2** as well, the measurement of the chip's thickness is also done by using a vernier caliper. Chip formations recovered from the turning process are also observed. The observations are the calculation of the thickness and visual observation of the chip's shape. They are done at the Laboratory of Materials and Manufacture in the Faculty of Engineering at Universitas Islam Riau.

Table 1 and **2** show the composition of the specimens and the electrode, respectively. The former shows the composition of the specimen, ST 41 is a low carbon steel. As for the other shows the composition of the electrode used in the welding process. **Figure 4** shows the process of the experiment through a flowchart.

Figure 1. Turning machine type C64240A.

Figure 2. HSS Cutting tool.

Figure 3. ST 41 steel.

Table 1. Composition of the ST 41.

Composition	**C**	**Si**	**Mn**	**P/S**	**Fe**
Percentage (%)	0.13-0.18	0.15-0.35	0.5-0.7	0.05 max	98.81-99.26

Table 2. Composition of the electrode NK-68.

Composition	**C**	**Si**	**S**	**P**	**Mn**
Percentage (%)	0.08	0.24	0.014	0.016	0.4

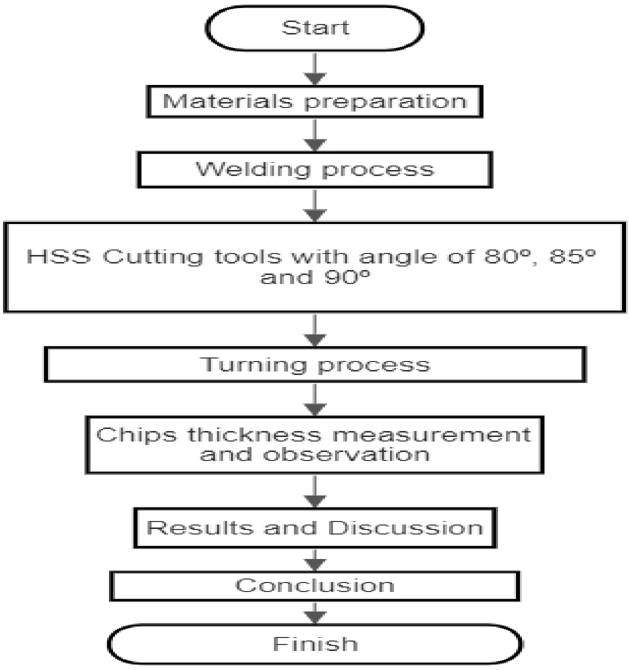

Figure 4. Flowchart of the experiment.

Table 3. Chip thickness.

No	**Cutting tool's angle (°)**	**Chip Thickness (mm)**			**Average (mm)**
		Run 1	**Run 2**	**Run 3**	
1	80	0.23	0.30	0.20	0.2
2	85	0.17	0.25	0.3	0.21
3	90	0.13	0.19	0.2	0.13

RESULTS AND DISCUSSION

Research Results

The chips resulting from the machining of welded ST 41 are obtained. The chips originated from the welded surface since there are no chips collected from the unwelded surface. This is due to the turning process that is conducted only on the welded area. **Table 3** illustrates the chip's thickness from each cutting tool. Each use of the tools is repeated three times to find the average value of the chip thickness.

Based on the cutting tool's angle value of the cutting tools, the chip's thickness depicts varying values. The thickest chip is found in the turning process using 80° and 85° cutting tool's angle, while the lowest value is produced by the 90°. The average value of the chip's thickness is similar between the 80° and 85° cutting tool's angles, around 0.2 and 0.21 mm. The chip's thickness for the 90° is lower at 0.13 mm.

Discussion

Figure 5 illustrates the trend of the chips resulting from the turning process. The trend is similar for 80º and 90º cutting tool's angle, with the value increasing from run 1 to run 2. Then the trend decreased to the third run. The chips obtained using an 80º angle varies at 0.23, 0.3, and 0.2 mm. As for the 90º angle, the trend of the chip's thickness is similar to 80º, but the value is lower. The chip's thickness resulted is below 0.2 mm, the lowest of all cutting tool angles used.

The result of chip thickness using an 85º angle, however, has a different trend compared to the other two angles. The chip's thickness increases from the first run to the third run. The thickest value of chips obtained at this is 0.3 mm. From these results, the higher cutting tool's angle will produce a smaller chip's thickness. This is proven by the average value of thickness at 90º angle having the lowest average of the chip's thickness. Thicker chips will require a higher cutting force in the process. This could lead to an increase in tool wear, which should be avoided to save the cost of machining.

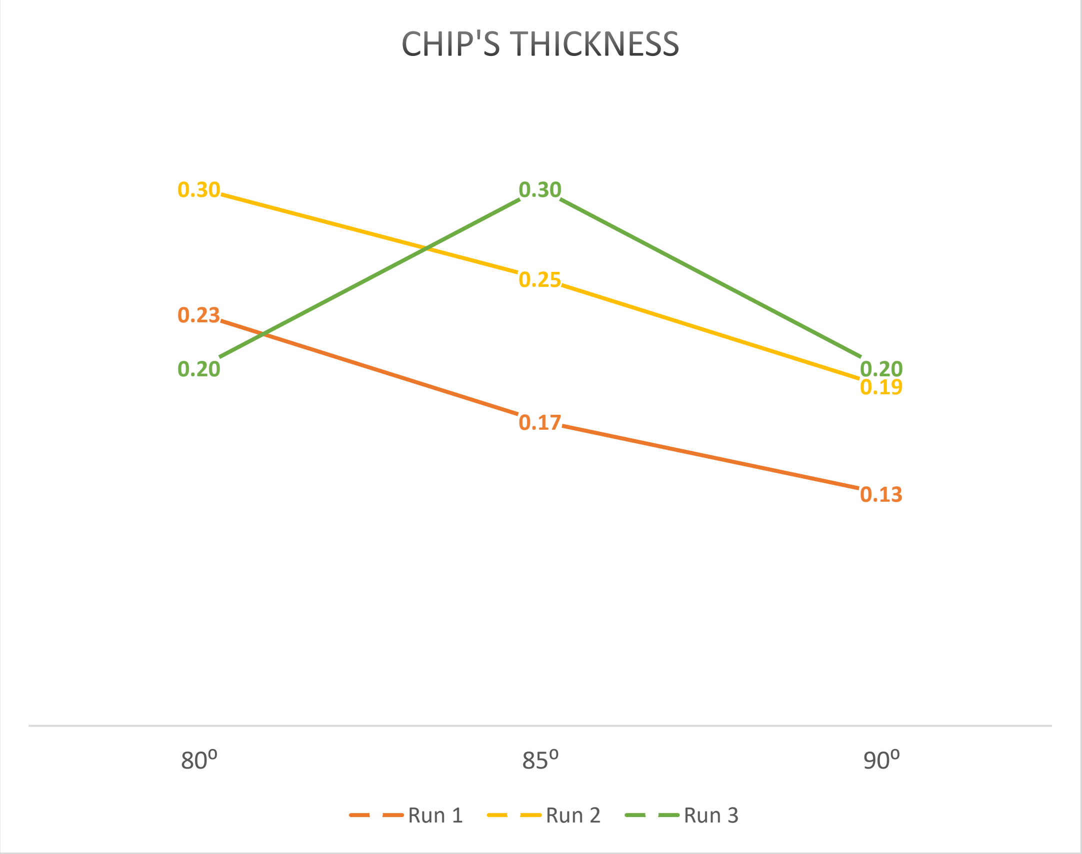

Figure 5. Chip thickness of varied tool's angle.

Chip's Formation

The chips obtained from the turning process have different formations due to the different geometry of the cutting tools. It is also possible that the variations of chip formation are due to the machining stages, such as roughing or finishing. **Figure 6** illustrates the chip formation recovered after each run of the turning process using an 80º cutting tool. The type of chip is dominated by the discontinuous shape. This shape is dominantly resulted from the first run to the third run. The chips resulted from using 85º cutting tool also dominantly in discontinuous shape as shown in **Figure 7**. The small increase in the cutting tool's angle does not significantly affect the chip's shape. But the length of the chips resulted by the 85º is shorter than the 80º. Hence, the increased angle of the cutting tool can affect the length of the chip but not affect the chip's shape significantly.

The 90º cutting tool produces chips differently than the previous two. The dominant chip's shape, illustrated in **Figure 8** tool is long continuous. There are only a few discontinuous or segmented shapes resulting from this cutting tool type. The increased angle to 90º will affect the shape and the length of the chips. A higher angle of cutting tools will produce a better continuous chip shape. Continuous shape indicates a good machining process with a better surface finish. The results also agree with the recent research of Munhoz et al. [12].

Figure 6. Discontinuous shape from 80º cutting tool.

Figure 7. Discontinuous shape from 85º cutting tool.

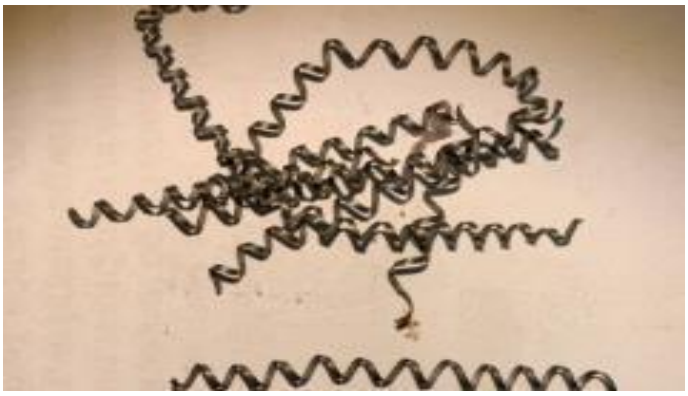

Figure 8. Continuous shape from 90º cutting tool.

CONCLUSION

The variation of the tool's angle did have an impact on the chip formation of the turning process. The chip thickness is decrease with the increase of the tool's angle. A higher tool angle will reduce the chip thickness, meaning that a higher angle is preferred. Thicker chips will require a higher cutting force that could affect the tool's life negatively. Higher tool angle also produced better chip formation, with dominantly produce longer and continuous chips. This shape indicates that there were few fluctuations and less vibration during the turning process. The tool's angle at 90º, in summary, is preferred due to the thinner, longer, and continuous chips.

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Author Contributions
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