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Drilling Characteristics of PVC Materials

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PVC 재료의 드릴링 특성

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ABSTRACT

This paper develops and evaluates a mechanical machining process which involves drilling on PVS material. According to the material, two treatment experiments were conducted, one involving drilling in a wet condition or using a lubricant and one involving drilling in a dry condition with no lubricant. Drilling in a dry condition showed better performance in terms of the cutting time than in the wet condition. Otherwise, the wet condition has several advantages. The lubricant influenced the burr diameter size and minimized the temperature on the surface of the work piece. During the wet condition drilling process, a smaller burr diameter size was noted as compared to the dry condition. The temperature showed a linear correlation with the drill bit size, where a least-square analysis provided an R^2valuewhichexceeded 0.95. The wet condition required more cutting time than the dry condition. In this condition, the water provides a lubrication effect. A thin layer between the cutting edges and the surface of the work piece is formed. The chip formation is affected by the drilling depth. The color on the tips of the chips was darker than in the initial condition. No correlation between the drilling depth and the bore roughness was noted, but the variation of the cutting speed or the RPM influenced the roughness of the bore. The optimum cutting speed ranged from 40 RPM to 45 RPM in the condition which provided the finest roughness surface.

Key Words : PVC, Burr, Drilling Chips, Fluid Cutting

1. Introduction

At high speed conditions, machining process generally reduces the hardness and strength of cutting tools due to associated rise in cutting temperature. This generally weakens the bond strength of the tool substrate, thus accelerating tool wear by mechanical and/or thermally related wear mechanisms and possibly plastic deformation of the cutting edge of the tool[1]. Machining process generates the heat, and cooling is needed to minimize the damaged of work piece.

Coolant must be able to penetrate directly onto cutting zone for minimizing the temperature during cutting process. All tool materials, their tool life is limited by extreme temperature and/or pressure generated at the cutting interface. Since all tool

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materials lose their hardness at higher cutting conditions there is a genuine need to harness technologies tailored specifically to minimizing the temperature generated at the tool–work piece and tool–chip interfaces[2]. Increasing the temperature causing the vapour blanket over the cutting area, moreover the chip flaw was provided during cutting process. Both of this condition influence the penetrating of coolant on the cutting process.

More than 100 years ago, water used as coolant due to its high thermal capacity. In other side water is a poor lubricant and cause problems of corrosion to components or machine tool. Improvement of cutting technology has been developed the cutting fluids to lubricate and cool the work piece during cutting process. Nowadays cutting fluids are divided into four main groups : *neat oils, soluble oils, semi-synthetic fluids* and *synthetic fluids*[3]. Besides cooling, cutting fluids also aid the cutting process by lubricating the interface between the tool's cutting edge and the chip. By preventing friction at this interface, some of the heat generation is prevented. This lubrication also helps prevent the chip from being welded onto the tool, which interferes with subsequent cutting. The efficiency of metal cutting process depends on the cooling/lubrication provided. A flood of fluid directed over the back of the chip is the most common method of applying the cutting fluid. Kovacevic et all reported that the welding of hot chip to the cutting edge which is a common problem in the cutting was eliminated due to increasing the efficiency of cooling. Thus the surface quality and tool life was improved[4].

Polymerization is one of the study to enhance the properties of the plastic. Generally blending the additives as plasticizing or co polymer will change the properties. Generally the characteristic of hard plastic has a high impact and tensile strength, but low in flat loading (flatting weight). At least about 20 million tons existence all over the world of general purpose Poly Vinyl Chloride (PVC) resin. It was dividing into hard and soft depending on the plasticizer composition. The plasticizer is composed by 62.5%wt of chlorine and a large proportion of the flame-retardant. PVC used in many purpose, for example the water pipes, window frames, coating for wires, industrial toys, wallpaper, flooring, packaging films. PVC has a advantages that low in pricing, excellent chemical resistance, good toughness, and electrical insulation. More than 60% of construction materials widely using the PVC material. The PVC paste resin has 750 to 1800 degree of polymerization. More than 90% the particle size below 20㎛. Basically, the physical properties of PVC is depending on the processing properties.[5,6].

In this study is try to figure out and observe the characteristic of PVC material in the mechanical machining process. The two condition of machining are decided, those in wet condition or using cutting fluid and in dry condition or non cutting fluid machining. The result has been reported and discussed.

2. Experiment Details

2.1 Material and Specimen

Figure 1 shows the PVC specimens which is used in this study. And Table 1 shows the Test condition. There was 200mm for length, 100mm for width and 20mm for thickness.

Table 1 Test condition

Parameters	Condition
Material	PVC
end mill(tool)	Φ10, Φ8, Φ6.5, Φ4.7
Depth of cut	10mm,15mm,20mm
RPM	5～70
Cutting Fluids	dry / wet
Temperature	Room temperature

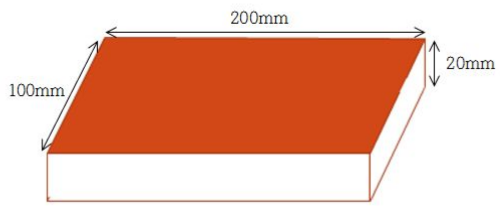

Fig. 1 Schematic of PVC specimen

2.2 Tools

The HSS (High Speed Steel) drill bits has been used in this experiment. Four drill bits which the diameter are 10 mm, 8 mm, 6.5 mm and 4.7 mm respectively.

The drilling machine was shown in the Figure 3. On this machine was equipped with servo motor where the RPM is controled by instrument panel. The cutting speed (RPM of drilling) and the depth of drilling is possible to be set precisely.

Fig. 2 Drill Bits

Fig. 3 Precisely Drilling Machine

2.3 Experimental Method

In this study two treatment was applied in the experiment. During PVC drilling process was the water as coolant and fluid cutting. The second treatment is no coolant or fluid cutting during the process. The surface temperature after drilling and burr diameter size are the parameter for comparing the result of drilling process in the same cutting speed or RPM.

Chips were analyzed to compare the cutting characteristic on variation of speed (RPM) and the roughness of bore were tested by roughness meter (styluss) as the parameter.

2.3.1 Dry/Wet Condition Drilling Test

In the first experiment on dry or the non cutting fluid condition was used four kinds of drill bits. There are 10 mm, 8 mm , 6.5 mm and 4.7 mm of diameter. The surface temperature was measured by infrared gun thermometer before drilling test. The same way was applied in the wet drilling test, which the process is involving the cutting fluid as coolant.

After finished the process, the temperature is measured immediately. Based on the timer display the drilling time was recorded. Entire experiments were using the same cutting speed. The RPM of servo motor has been adjusted on the control panel as the same way as to set the down press load force.

The bore has been created by the end of the drilling process. The burr was occurring on the opposite PVC surface. Characteristic of the burr is observed by measuring the inner and outer diameter using a vernier calliper. Based on the shape, the burr was determined and classified.

2.3.2 Correlation RPM And Roughness in Various Drilling Depth

In this section of experiment was using an 10 mm diameter of drill bit to prevent surface temperature change non-uniformly caused by different diameter size . This drill bit used to make bore in various depth, that was 10 mm, 15 mm and 20 mm of depth respectively.

Variation of cutting speed ranged from 5 RPM to 70 RPM and devided into 14 section. In another word the RPM is increasing step by step by 5 RPM in every section drilling test. There will be provided 42 of drilling tests. An stylus type of roughness meter was used to measure the inner surface of created bore and plotted the result in the graph.

3. Result And Discussion

3.1 Dry/Wet Condition Drilling Test

Table 1 given the result of each experiment. The comparison between two treatment, non and with fluid drilling test. In this experiment there was a difference the burr diameter size in dry and wet drilling condition. For example, the 10 mm of drill bit diameter provides the inner burr diameter size 10,2 mm and 12,4 outer diameter in dry drilling condition. Meanwhile, if the lubricant was used in the process the 10 mm of drill bit provided 10.1 mm of inner burr diameter size and 12.1 mm of outer burr diameter size.

Many factors are influencing the burr form in drilling process, such cutting speed, lubricating, and cutting force. In this experiment the cutting speed (RPM) and cutting force (down load force) to be set in the same condition. Then assuming only the surface condition, dry or wet affecting for the drilling process. On dry condition means the drilling without cutting fluid, and wet condition means using the water as cutting fluid in the drilling process

The temperature increase as the effect of drill bit lip penetrating the work piece. Non fluid cutting process provides higher temperature than wet drilling process, meanwhile in the wet dry condition provides cutting time faster than wet condition.

The dry condition provides the burr diameter size larger than the wet condition. Inner diameter on the wet condition occurred better than dry condition. From Table 2 can be seen the small difference than original drill bit diameter. As like as the inner burr diameter size, the outer burr diameter size is also have smaller size than outer burr in the dry condition drilling process. The result of burr diameter size has been shown in the Figure 4 and Figure 5.

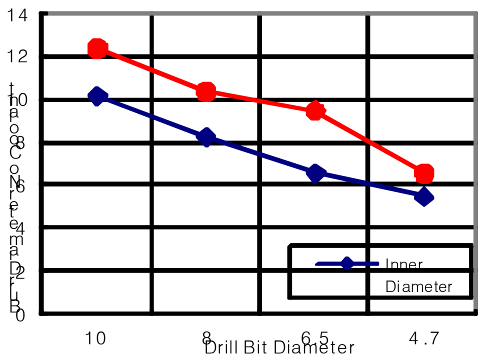

Fig. 4 Burr Diameter Size Dry Condition

Table 2 Drilling Result on Several Condition

Drill Diameter (Φ mm)	Temperature (℃)		Burr Diameter size (mm)		Cutting Time (sec)	Coolant
	Before	After	Inner	Outer		
10	11	28	10.2	12.4	20	no
8	11	22	8.3	10.4	20	no
6.5	11	18	6.6	9.5	8.14	no
4.7	11	15	5.5	6.6	5.69	no
10	11	20	10.1	12.1	20	water
8	11	17	8	10.25	14.98	water
6.5	11	15	6.58	7.65	12.32	water
4.7	11	12.5	4.7	6.35	11.9	water

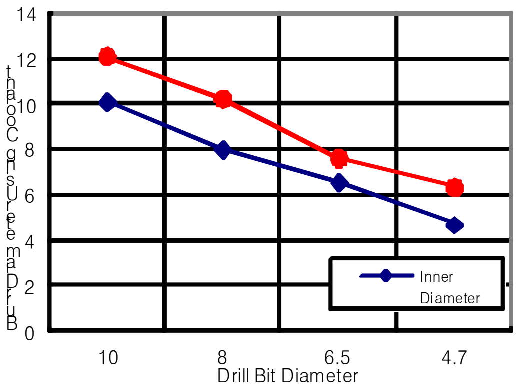

Fig. 5 Burr Diameter Size Wet Condition

The surface temperature in the end of drilling process measured by infrared thermometer. Figure 6 shows that surface temperature increment linearly with drill bit diameter, both on the drilling condition has the same trend line. On least square analysis the R^2 value are above 0.95.

The water was flooded over the work piece for minimizing the third body friction during the drilling process. Worn and small debris were flush away by water. Beside that, the water as a function of lubricant minimizing the torque of drill bits to the surface work piece [10], so in the wet condition drilling process the time cutting are more longer than dry condition drilling process.

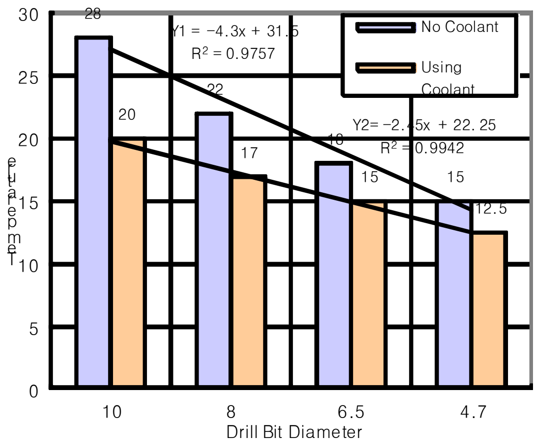

Fig. 7 Surface Temperature After Drilling

Chipping lip or wear drill bit is one factor that influencing in the burr formation. During the drilling process, the worn was occurred in the lip. Worn and small debris caused the third body friction in the drilling process, which potentially generating more heat and reduce of the surface roughness quality

The water act as lubricant and coolant in the wet condition drilling process. In this case, the cutting time for wet condition is higher than dry condition. This condition shown in Figure 7, where the same value of cutting force and cutting speed were giving the different result both on cutting time and burr diameter size.

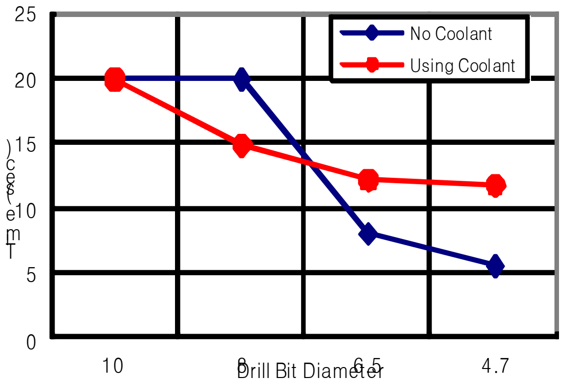

Fig. 6 Cutting Time

3.2 Correlation RPM And Roughness in Various Drilling Depth

This experiment is to figure out the correlation between cutting speed and roughness in various drilling depth. Three variation of drilling depth were applied, those are 10 mm, 15 mm and 20 mm respectively. The parameters to be analyzed in this experiment are drilling chips and the roughness in the bore of the drilling result.

The cutting force is set in the same value for each test and variation is given for the cutting speed from 5 to 70 RPM with increment 5 RPM for each drilling test. After drilling process finished, those are available 42 of bore to be tested.

The stylus roughness meter was using to measure the inner bore surface and the result plotted into the graph. Figure 8 shows the result of roughness measurement in 10 mm of bore depth, 15 mm in Figure 9 and 20 mm in Figure 10 respectively.

In each graph could be seen clearly that RPM affected the roughness of the bore surface. Based on the graph almost no significant roughness difference on the drilling process with variation of depth on the same cutting speed. Increasing the cutting speed in the constant cutting force provides the fine inner bore surface roughness until 45 RPM. The trend line has the similar tendency, where the finest surface roughness occurring at 45 RPM of cutting speed.

Motorcu et all [9] has been reported that the surface roughness values increased with the increasing of cutting speed and drill bit angle. Besides the roughness values increased with the increasing of feed rate. In this roughness test experiment, the same drill bit angle and constant cutting force were used, just only cutting speed variation is given.

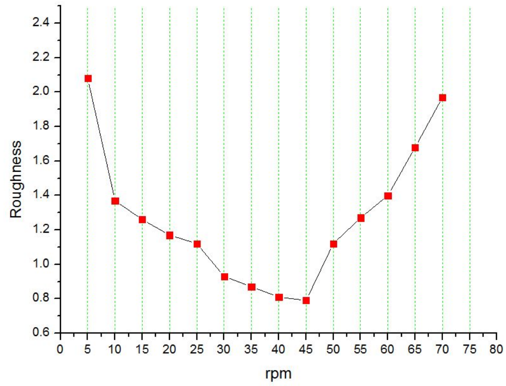

Fig. 8 Roughness as a Function of RPM - 10 mm of Depth

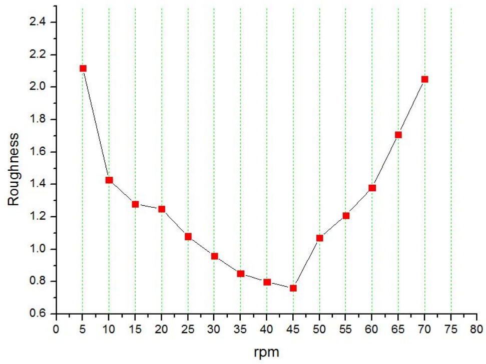

Fig. 9 Roughness as a Function of RPM - 15 mm of Depth

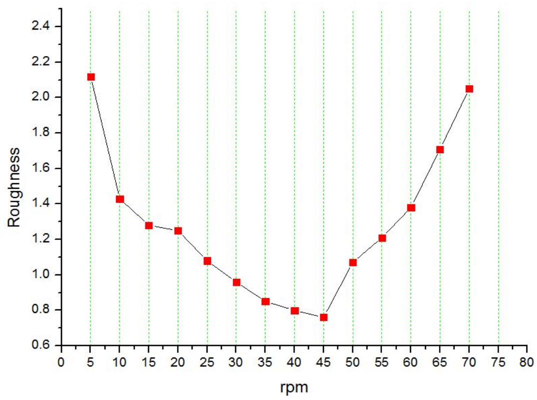

Fig. 10 Roughness as a Function of RPM - 20 mm of Depth

3.3 Chips Analysis

In the drilling processes, the formation of chip shapes are not uniform as the drilling depth increases. The first chips are spiral shaped chips, as the drilling depth increases chip rotation grows difficult and spiral chip is spoiled. Unwound spiral chip becomes string chip at the end.

At the chip tip, the color is darker. Figure 11 shows that the chips produced by drilling in the 10 mm of bore depth

Comparing to the Figure 12 and Figure 13, the chips formation in the Figure 10 has uniformity more better. Side by side with increment of the drilling depth, the non-uniform chips formation occurs increasingly.

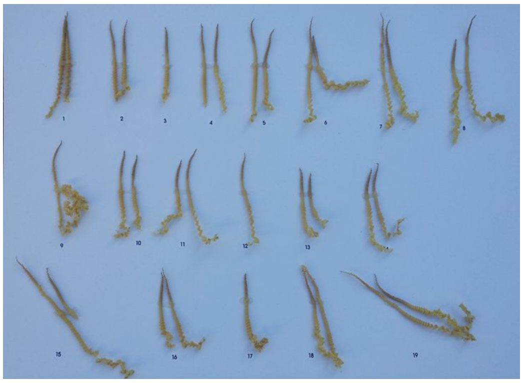

Fig. 11 Drill Chips at 10 mm of Depth

Fig. 12 Drill Chips at 15 mm of Depth

Fig. 13 Drill Chips at 20 mm of Depth

4. Conclusion

An drilling experimental test on the PVC surface has been investigated. Based on the findings, the following conclusions can be drawn :

1. Lubricant influencing the burr diameter size and minimizing the temperature occurred in the surface of work piece. In the wet condition drilling process, provides the smaller burr diameter size than dry condition.
2. Temperature has a linear correlation with the drill bit size, where in the least square analysis provides R^2 above than 0.95.
3. Wet condition requires more cutting time than dry condition. This condition caused by the water provides a lubrication effect. A thin layer between cutting edges and work piece surface is formed.
4. No correlation between drilling depth and bore roughness, but variation of cutting speed or RPM influence the roughness of the bore. The optimum cutting speed occurs ranged between 40 RPM to 45 RPM, when at the condition provides the finest roughness surface.

5. The drill chips formation increase into non-uniformly side by side with increment of drilling depth. The color changes darken in the tip of drilling chips.

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