The Effect of Tool Geometry of Hole Towards Tool Life in Hard Material Holes

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Abstract. This study studied the characteristics of machining hard material milling by using carbide Endmill tool with variation machining and carried out without using cooling water. The method used in this study was experimental by providing machining variables (rotation = 191 rpm, 398 rpm, 764 rpm and 1,082 rpm; feeding speed (Vf) = 0.1; 0.18 and 0.26 mm / min). After machining, a tool wear is measured using a digital microscope with magnification 1,000 times. The results of Endmill tool wear measurements show that maximum wear at Vf = 0.1 mm / min = 0.42 mm; Vf = 0.18 mm / min = 0.428 mm and Vf = 0.26 mm / min = 0.4325 mm / min, the greater the feeding speed, the fewer the number of holes produced. While the effect on roughness is that the speed of feed is more influential on roughness compared to changes in workpiece rotation and the rake angle. The roughness data obtained ranged from 0.495 μm to 2.095 μm, this means that the surface roughness value is still in the standard area (Ni ÷ N9 = 0.025 ÷ 6.3 µm) or it can be said that the selected machining variable can be used as the machining variable perforating hard material

1. Introduction
The latest development of machining currently consists of two types, namely: high speed machining and hard machining. The machining of hard material milling has many problems, including tool that are used too quickly to wear out so that production costs rise. High speed machining is triggered by increasing demand to increase productivity with low production costs because this type of machining can increase high cuts, the volume of material release from parent material will increase so that significant savings in machining time will be obtained. In addition, high speed machining is capable of producing smoother products and more precise sizes. Whereas hard machining is carried out on workpieces that have a hardness greater than 40 HRC. The hard milling process can be performed on various types of metals such as alloy steel (alloy steel), steel for bearings (steel), hot and cold steel working tools, high speed steel, die steel, and hardened cast steel [1]. To support the latest machining, the cutting tool used must be reliable and have good material properties, wear resistance and high temperature. One of the development of cutting tools is the use of hard material (hard metal).

Hard material cutting tool is a cutting tool that can minimize lag time because this type of tool is easily replaced when worn. The use of hard metal cutting tool has resulted in maximum productivity that will increase tool change time, precision products, reduce production time and production costs so that product selling prices will be affordable and will ultimately strengthen the company's ability to compete with competitors. The hard metal cutting tool consists of two main parts, the tool handle and
the insert tool holder. Tool handles are rectangular or cylindrical rods where one end is clamped to the machine part (lathe or milling) while the other end is used to peel the material (insert tool) which can be replaced.

Studies on the use of tools in milling machineries have been carried out by several researchers, such as those investigated [1] using hard materials AISI 440 C martensitic stainless steel and SCM 440 alloy steel, variations in cutting rates, feeds, and medium cutting depth. The results of his research concluded that the cutting speed and the combination of feeds in the cutting process will increase the working stress of the cutting tool and consequently the cutting tool will blunt rapidly. With blunt cutting tools, product quality and productivity decline. Ghani [1], using a carbide tool coated with Titanium alloy, using various cutting rates, feeding rates and cutting depth levels. And concluded that at the level of simple cutting tool wear is determined by the friction between the tool and the workpiece.

Some researchers have conducted research on the use of carving inserts in the machining process, especially for hard machining. Various methods have been used in the machining process to determine cutting parameters, cutting tool types, measured quantities and analytical methods. All methods used lead to the optimization of machining, which is to get a low cutting force and a small surface roughness. In addition, the development of metal cutting processes with machine tools is also directed at tool endurance, low production costs and product accuracy. One solution is to use a carbide insert tool.

Venkatesan [2] conducted a study of the effect of cutting parameters of Ni-Cr, Inconel 625 alloy, using a tool coated carbide inserts (AlTiN PVD) and using a dry machining process. In this study measurements of cutting force and surface roughness were measured. This is intended to analyze the effectiveness of the temporary machine to search for cutting optimization and to analyze the effect of cutting parameters. Signal-to-noise (S/N) comparison analysis, variance analysis (ANOVA), and regression analysis are performed. This analysis was carried out to obtain lower cutting forces and good surface quality in dry cutting conditions.

Wet machining is machining which in the process is carried out with a cooler. The main function of the cooler is to reduce the cutting temperature by reducing the frictional force and as a heat carrier medium from the cutting area, it also functions as a furious carrier. When the cutting temperature decreases, the tool life will increase. This will be different in the dry machining process where in the dry machining process there is a large friction force so that the cutting temperature becomes very high. This high cutting temperature will reach the melting point of the tool material and can change the micro structure of the tool tip. Because the tool tip is soft and subjected to pressure as a result of cutting parameters which causes the tool’s strength to decrease. This will affect machining products.

Based on the description above, a more in-depth study of the use of inserts is required in the dry machining process of hard materials under conditions of cutting parameters (feeding, cutting depth, cutting speed). In this study, it is expected to show a picture of the quality of milling machining products and their relationship with the surface roughness of dry machining products on hard materials.

2. Machinery Theory
Cutting material with machine tools is an industrial activity that aims to form machine components or other equipment. To facilitate human work and to produce products quickly, effectively and economically, is the basis for the development of chisels and machine tools.

The turning process is the process of changing the shape of the product using a cutting tool and a milling machine. In the process of changing shape, all energy is converted into heat, where heat is caused by friction between growls and chisels and between chisels and workpieces. High pressure due to cutting forces and high temperatures results in a great material release process. This is the impact of the friction force on the tool’s friction surface with the workpiece. At very high temperatures can
damage the tool and will affect the quality of production, also to some extent can affect the work of milling machines.

The quality of machining products is also influenced by the cutting parameters and cutting temperature \((T_p)\). Cutting parameters, namely: cutting speed \((V_c)\), cutting depth \((d)\) and feeding \((f)\). In the machining process it is important to know the values: the cutting force \((F)\), the cutting temperature \((T_p)\), the rate of furious formation \((Z)\) and the cutting time \((t)\) [3, 4].

The cutting speed is very influential on the quality of the machining product where the determination of the speed value is very important to know and the cutting speed is directly proportional to the rotation of the workpiece. The relationship between cutting speed and rotation is shown by the following equation [5]:

\[
V_c = \frac{\pi \cdot d \cdot n}{1,000} \text{ [mm/min]}
\]  

(1)

The following equation is used to determine the characteristics of machining, namely:

- Feeding speed,
  \[
  V_f = f \cdot n \text{ [mm/min]}
  \]  
  (2)

- Cutting time,
  \[
  T_c = \frac{t}{V_f} \text{ [mm/min]}
  \]  
  (3)

- Chips formation speed
  \[
  Z = A \cdot V_c \text{ [mm}^3/\text{min]}
  \]  
  (4)

3. Research Methods

In this study the workpiece material ST 60 is used, the dimensions are 100 x 50 x 10 mm, with a tensile strength of 194.56 kg/mm\(^2\) while the hole means using End Mill Two Flute Carbide. The machining process used is milling and without cooling water. Engine variables selected: rotation = 191 rpm, 398 rpm, 764 rpm, 1,082 rpm; feeding speed = 0.1 mm/min, 0.18 mm/min, 0.26 mm/min and tool geometry changes are made at the rake angle of 2º and 3º.

Figure 1 shows the End mill two flute tool used. Cutter Diameter \((d)\) = 8 mm and Shank diameter \((D)\) = 8 mm. Figure 2 shows the End Mill tool geometry, while Figure 3 shows the Digital Microscope which is used to view the tool type.

![Figure 1. Two flute end mill](image-url)
The machining process is carried out with 1 set of treatments (cutting angle, rotation, feeding and rake angle), then the tool wear and product surface roughness is measured. Furthermore, the measurement results are illustrated in graphical relation to the machining variables.

The machining of perforation using a milling machine on ST 60 material is carried out to a depth of 10 mm with variations in cutting angle, rotation and feeding speed. The perforation is done first by adjusting the rotation and feed speed then changing the rake angle of rotation and the feeding speed does not change. After that, the rotation changes are carried out as much as 4 times the variation. After completing the punching process, measurements of tool wear and surface roughness are carried out every 1 data set. In this case roughness is done 12 times (data set = 12). While tool wear measurements are carried out every 3 (three) minutes of use until wear reaches 0.38 mm. Surface roughness measurements are carried out using Mitutoyo Surftest Surface Tester 301, while cutting tool wear measurements use a digital microscope.

4. Result

Roughness measurement results are made in the form of a graph of the relationship between rotation and surface roughness at variations in feed speed and cutting angle. The results are shown in Figure 4. While the tool wear results are made in the form of graphs of the relationship of wear to the time of hollowing and are shown in Figure 5.

Figure 4 shows that the higher the round perforation, the roughness value decreases and the variable that is very influential is into the cut. When compared with the cut angle (rake angle), the roughness value at 2° rake angle is lower than the roughness value at 3° rake angle, but the decrease in the roughness value at 3° rake angle is smaller than the roughness value at 2° rake angle. At the 2° rake angle the smallest roughness value was obtained 0.58 µm and the largest roughness value was 2.08 µm. Whereas at the rake angle of 3° the smallest roughness value was obtained 0.495 µm and the largest roughness value was 2.095 µm.

While the tool wear measurement results are made in the form of a graph of the rotation relationship with tool wear on variations in feed speed and cutting angle. The results are shown in Figure 5.
In Figure 5, it appears that the greater the speed of feed, the greater the level of tool wear, as well as the shorter use time of the tool. The greater the cut angle (rake angle), the greater the tool wear while the tool use time has the same value.

At rake angle of 3° and perforation time of 36 minutes there was a decrease in wear especially at the feeding speed \( V_f = 0.1 \) mm/min and \( V_f = 0.18 \) mm/min. Whereas at 2° rake angle, this did not happen. Perforated tool wear increases with increasing time for drilling.

Figure 4. Graph of the relationship of rotation with surface roughness at various variations in cutting depth and rotation, (a) Cutting angle 2° and (b) cutting angle 3°
Figure 5. Graph of the relationship of rotation with tool wear on various variations of feed and rotation, (a) Cutting angle 2° and (b) cutting angle 3°

5. Conclusion
The results showed that the higher the turning hole of the hole, the smaller the surface roughness, while at a large rake angle, the surface roughness was also greater. The variable which is very influential on roughness is the feeding speed (Vf). The greater the value of Vf, the greater the resulting roughness perforation. The smallest surface roughness values were obtained at rake angle of 3°, feeding speed of 0.1 mm/min and rotation of the chisel hole 1082 rpm. While the greatest surface roughness value was also obtained at rake angle of 3°, feeding speed of 0.25 mm/min and turning hole of turning tool 191 rpm.
Surface roughness values obtained in this study were between 0.495 µm to 2.095 µm. This shows that the surface roughness value is still in the standard standard area (Ni ÷ N9 = 0.025 ÷ 6.3 µm) or it can be said that the chosen research variable can be used as a variable of hard material milling machining.

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