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THE INFLUENCE OF NUMBER OF INSERTS AND CUTTING PARAMETERS ON SURFACE ROUGHNESS IN FACE MILLING

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Abstract

In this study, AISI 1050 steel workpiece materials were subjected to face milling operations using coated cemented carbide cutting tools. Face milling operations were carried out at five different cutting speeds (60, 90, 120, 150 and 180 m/min), three different feed rates (0.05, 0.1 and 0,15 mm/tooth) and two different depth of cut (1 and 2 mm) without using coolant. The tests were performed by mounting various numbers of inserts (1, 2 and 3) to the face milling cutter. The influence of cutting parameters, number of inserts and cutting length on face milled surface roughness was investigated. Increasing number of inserts and cutting length were found to increase the surface roughness significantly.

Key Words: Face milling, Number of Insert, Cutting Length, Surface Roughness

1. Introduction

The required surface roughness values can not be obtained if a good combination between the cutting parameters is not formed during machining. There are so many factors like cutting tool geometry, cutting tool mounting on the machine tool, cutting speed, feed rate, depth of cut, workpiece microstructure and machine tool rigidity which have influence on the resulting surface roughness. Although all the conditions required for a good machining are met, some unexpected surface quality problems arise due to inadequately defined machining problems [1-4]. In milling which is an economical method to produce prismatic parts and which can be both a finishing process and a pre-machining for further processes like grinding, cutting parameters like cutting speed, feed rate and depth of cut should be defined suitably. In order to define the cutting parameters suitably, relationship among the cutting tool geometry, cutting tool materials, cutting parameters and workpiece materials should be defined using experimental data. This is primarily necessary for the widely used materials in manufacturing industry. Work to date has shown that definition of classical machining parameters is not enough. Therefore, definition of optimum parameters is also important. Based on the researches, these parameters are generally defined according to some criteria. These criteria are cutting speed, feed rate and depth of cut which are taken into consideration by the researchers based on the minimum cost and maximum production [5].

In order to improve cutting tool performance, coating is applied to saws for which cutting speeds and feed rates are taken relatively high when compared to high speed steel milling cutters [6-8]. However, the related work shows coating of multi-teeth cutter is questionable from the point of commercial quality and cost. Generally, some production defects in the cutter teeth were detected. These defects were examined under scanning electron microscope (SEM) and their harmful effects on the wear resistance and performance were evidenced by the tests. It was concluded from the researches that sub-layer preparation together with correct coating lead to improvements in application of coating for cutting edge geometry enhancement. For a beneficial surface coating technology, production applications should be improved and be uniform [8-10].

The uncontrolled vibration in machining operations leads to deterioration in surface quality, poor workpiece dimensional accuracy, short tool life and tool breakage, damaging effects to the machine tool components

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and high noise. Work to data has shown that vibration occurring during machining is in a complex manner. This vibration is divided into two group: forced vibration and self-excited vibration [11].

Orhan et al. investigated the relationship between cutting tool wear and vibration when machining with indexable milling cutters [12]. Lee et al. investigated the cutting forces and vibration developed during high speed milling. The researchers stated that examination of the cutting forces developed at normal cutting speed and of the cutting parameters is not enough. It was also stated that the vibration has big influence on geometric accuracy of the parts and surface quality when high speed machining conditions and that the vibration should also be taken into consideration when machining at these conditions for simulation. Cutting tool axis deflection is stated to be one of the most important reasons of the vibration occurring during machining [13]. Machining operations through turning and milling are the most investigated machining modes while tool wear, vibration, tool breakage, chip formation and type together with tool geometry are the most widely investigated subjects. In the analyses regarding the above mentioned subjects, cutting forces, acoustic emission and acceleration measurement are the most preferred methods [14].

In this study, face milling tests were carried out on AISI 1050 steel workpiece using coated cemented carbide cutting tools. Number of cutting tools mounted to the face milling cutter was varied. The milled surface roughness values were measured. The influence of cutting parameters, number of cutting tools and number of pass on surface roughness was examined.

2. Experimental procedure

2.1. Workpiece, cutting tool and machine tool

AISI 1050 steel was used as the workpiece materials for the tests. Dimensions of the workpiece materials are given in Fig. 1.

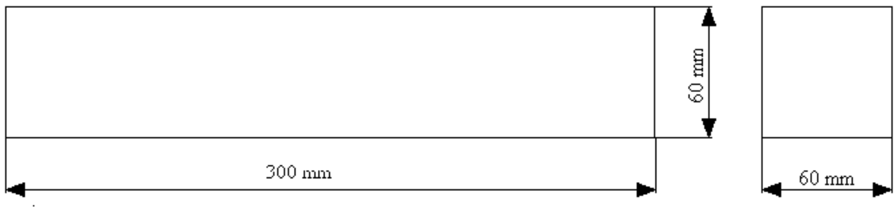

Fig. 1. Workpiece dimensions

The cutting tools used were commercial grade PVD coated cemented carbide inserts produced by Kennametal with the geometry of APKT1604PDR. These inserts are recommended for machining steel, stainless steel and ductile iron by Kennametal and had KC725M Kennametal designation. These inserts had good thermal shock resistance and can be used with and without coolant in difficult cutting conditions. These inserts were clamped mechanically on a rigid face milling cutter.

The milling tests were carried out on a Taksan TMC500-OM CNC vertical machining centre with a Fanuc control unit (Fig. 2).

Fig. 2. Taksan TMC500-OM CNC vertical machining centre

2.2. Surface roughness measurement device

Face milled surface roughness measurement was carried out using a Mahr Marsurf PS1 type portable instrument. Surface roughness measurements parallel to the workpiece axis were performed on three different places for each milling conditions. The arithmetic average of the three surface roughness measurements (Ra) was taken. The surface roughness values were measured as Ra1 and Ra2. The places where Ra1 and Ra2 values were determined are shown in Fig. 3. Passing of the face milling cutter by removing chip on the workpiece (250 mm) was called a pass.

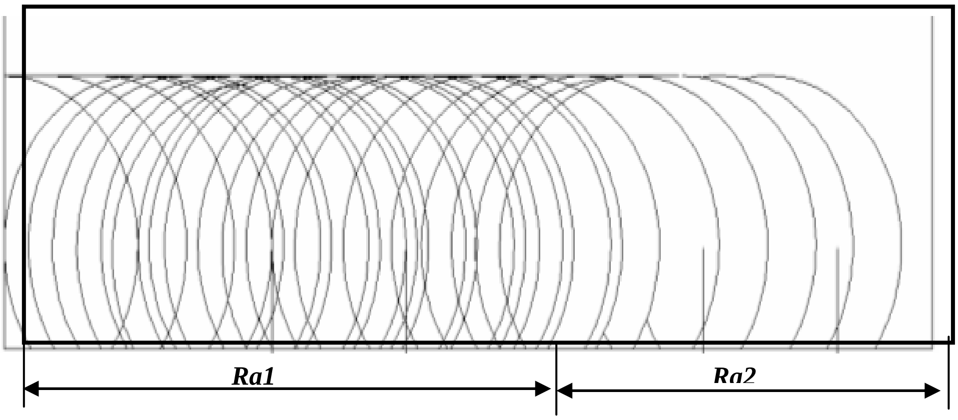

Fig. 3. Places of Ra1 and Ra2 values

3. Experimental results and discussions

3.1. The influence of cutting speed on surface roughness

In order to examine the influence of cutting speed on surface roughness, face milling tests were carried out at various cutting speed (60, 90, 120 150 and 180 m/min), 2 mm depth of cut and 0.1 mm/tooth feed rate. The resulting surface roughness values are given in Table 1. The surface roughness cutting speed relations is given in Fig. 4.

Table 1. Surface roughness values depending on the cutting speed

a=2 mm		s=0,1 mm/dişr
V(m/dak)	Ra1 µm	Ra2 µm
60	1,859	2,111
90	1,700	1,614
120	1,371	1,173
150	0,905	0,916
180	0,766	1,043

It is seen from the results that increasing cutting speed decreases the surface roughness values of the face milled surfaces. The lowest surface roughness value (Ra1=0.766 µm) was obtained from the surface face milled at 180 m/min cutting speed. While, the highest surface roughness value (Ra1=1.859 µm) was obtained from the surface face milled at 60 m/min cutting speed. The face milling test results show that the highest surface roughness values were obtained at the lowest cutting speed (60 m/min) employed. High surface roughness values at low cutting speeds can be attributed to built-up edge (BUE) formation [15].

Ra2 surface roughness values were found to be higher than Ra1surface roughness values. The face milling operation produced smooth surfaces. However, the cutting edges deteriorate the face milled surface as they cut the workpiece. For this reason, Ra2 surface roughness values become high.

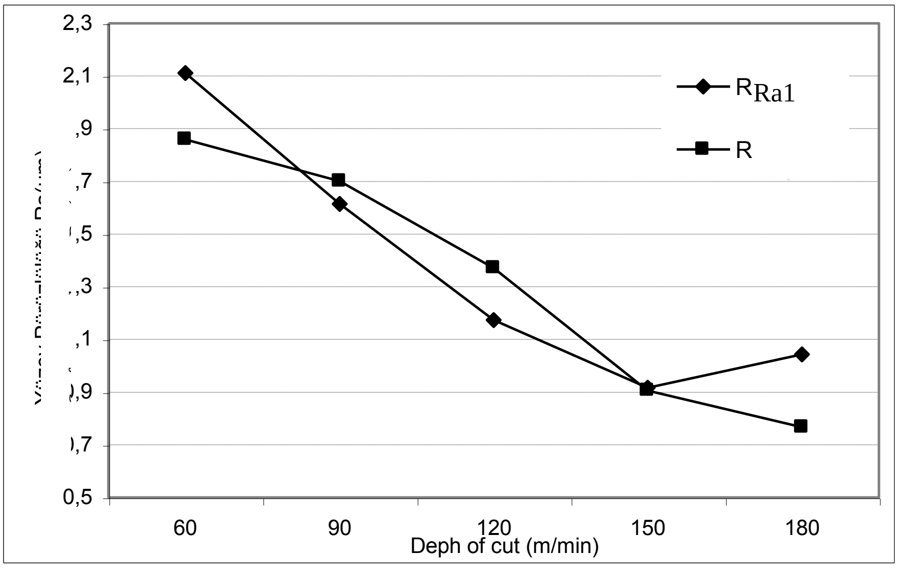

Fig. 4. The influence of cutting speed on surface roughness (number of teeth=2, feed rate=0.1 mm/tooth and depth of cut=2 mm)

3.2. The influence of number of teeth on surface roughness

In order to examine the influence of number of teeth on surface roughness, face milling tests were carried out by mounting 1, 2 and 3 inserts to the face milling cutter. The tests were performed at three different feed rates (0.05, 0.1 and 0.15 mm/tooth), 120 m/min cutting speed and 2 mm depth of cut. The obtained surface roughness values are given in Fig. 5.

It was observed that number of teeth had an important influence on surface roughness. At the same feed per tooth, increasing number of inserts increased the surface roughness. The surface roughness value obtained at 0.05 mm/tooth feed rate and with one insert was found to be 0.72 µm. On the other hand, it was found to be 1.08 µm with 2 inserts. This means a 50 % increase. When three inserts were used, the surface roughness increased to 1.504 µm. This means a 100 % increase when compared to one obtained with one insert. At 0.1 and 0.15 mm/tooth feed rate, similar increases in surface roughness values were observed with increasing number of inserts. In order to determine the reason for this increase, the vibration of cutting tool and workpiece occurring during face milling were tried to be measured. However, the machine tool induced vibration and also cutting tool and workpiece vibrations could not be measured reliably as they affect each other.

As chip volume for per tooth is equal, increasing number of inserts increases the chip volume to be removed from the workpiece. It is considered that increasing chip volume increases the cutting forces and this, in turn, increase the vibration and resulting surface roughness.

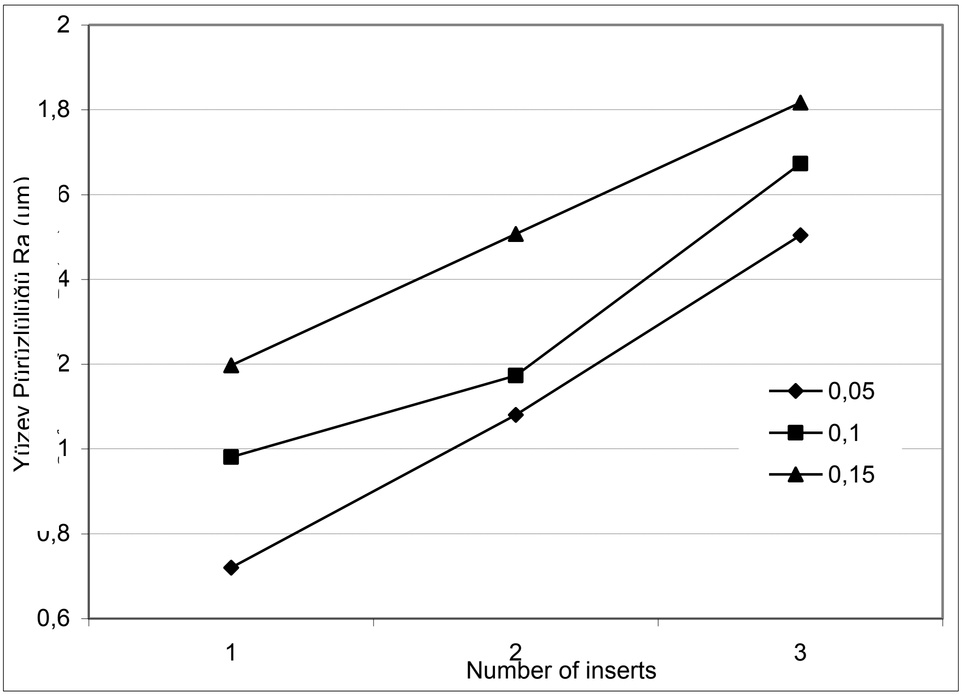

Fig. 5. The influence of number of inserts and feed rate on surface roughness (depth of cut=2 mm and cutting speed=120 m/min)

The resulting surface roughness values reveal that feed rate has big influence on surface roughness (Fig. 5). Increasing feed rate increased the surface roughness values. The lowest surface roughness values were obtained at the lowest feed rate (0.05 mm/tooth) for all the tests. On the other hand, the highest surface roughness values were obtained at the highest feed rate (0.15 mm/tooth). Number of inserts and feed rate were found to increase the surface roughness values significantly.

3.3. The influence of number of pass on surface roughness

Face milling tests were carried out at 120 m/min cutting speed, 1 mm depth of cut and 0.1 mm/tooth feed rate using one insert in order to determine the influence of number of pass on surface roughness. Passing of the face milling cutter by removing chip on the workpiece (250 mm) was called a pass. At the end of each pass, surface roughness measurements were performed on three different places of the face milled surface and the average of the three measurements was regarded as the surface roughness value of that pass. Fig. 6 gives the surface roughness values.

The experimental results show that number of pass has big influence on surface roughness values. Increasing pass number increased the face milled surface roughness values (Fig. 6). Increasing surface roughness values with increasing pass number can be explained by cutting tool wear.

Ra1 values increased quickly with increasing pass number up to first 5 passes. Further increase in pass number up to 30 passes had less influence on surface roughness values when compared to the first 5 passes.

Ra2 values did not vary much up to 8 passes. However, increasing pass number increased the surface roughness values significantly. The surface roughness value reached a maximum at 20th pass and then decreased sharply with increasing passes. This can be explained by the tool wear. Ra2 values increased depending on the tool wear and then decreased as the cutting tool lost its cutting ability with further tool wear. When the cutting tool loses its cutting ability, it makes scratching and rubbing and this, in turn, decreases surface roughness values. It was observed during the tests that the machine tool was forced much and the chips were burned after the 20th pass.

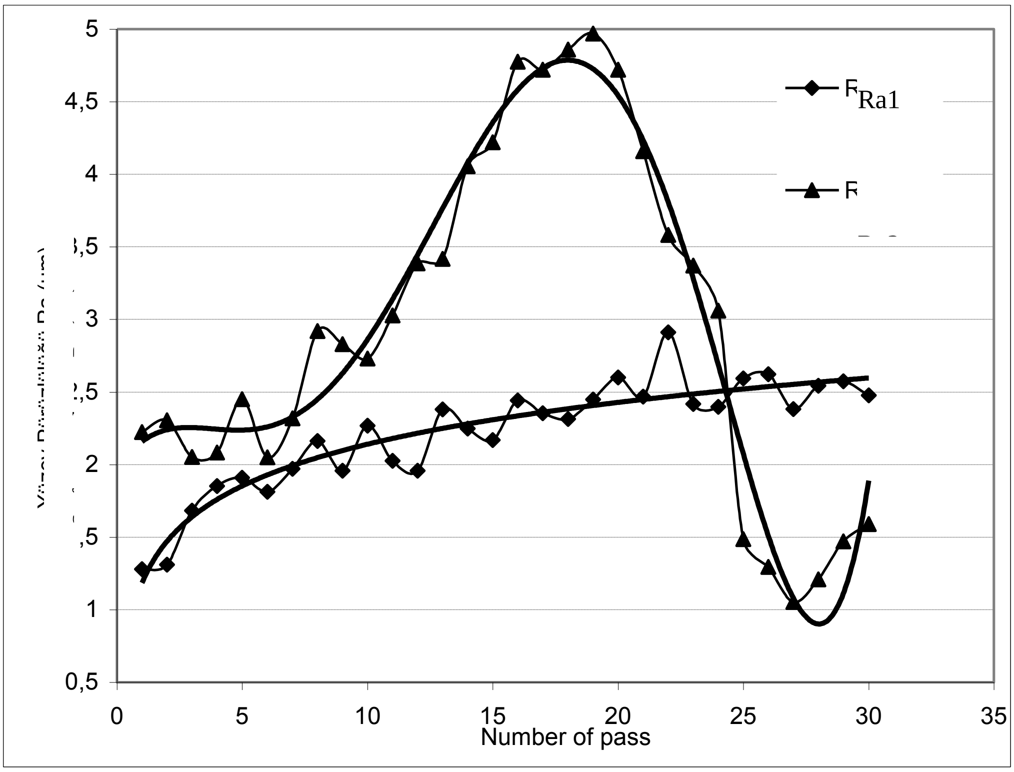

Fig.6. The influence of number of pass on surface roughness (depth of cut=1 mm and cutting speed=120 m/min and feed rate=0.1 mm/tooth)

Ra2 surface roughness values were found to be higher than Ra1 surface roughness values (Fig. 6). At 20th pass, Ra1 was measured to be 2.3 µm while Ra2 was doubled at the same pass and measured to be 4.97 µm. Rubbing of the cutting edge to the machined surface in face milling operation influences the surface roughness values either positively or negatively. The high surface roughness values obtained almost up to 20th pass can be reduced to very low values. In machining operations, Ra1 values are taken into consideration if the machine tool spindle or workpiece are not tilted.

4. Conclusions

In this study, AISI 1050 steel workpiece materials were subjected to face milling tests using coated cemented carbide cutting tools. The face milling tests were carried out at five different cutting speeds, three different feed rates and two different depths of cut without using coolant. In addition, the tests were carried out using various numbers of cutting tools (insert) clamped to the face milling cutter. The influences of cutting parameters, number of inserts and cutting length on face milled surface roughness values were investigated. The following conclusions can be drawn from this present study:

- Surface roughness values were found to decrease depending on increasing cutting speed in face milling at various cutting speeds.
- Number of inserts was found to have significant influence on surface roughness values. At the same feed per tooth, increasing number of inserts increased the surface roughness.
- Milling with three inserts increased the surface roughness significantly in comparison to one insert.

- Feed rate was found to have significant influence on surface roughness values. Increasing feed rate increased the surface roughness values.
- Number of pass had big influence on surface roughness values. Increasing pass number increased the face milled surface roughness values.

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