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Initial Flank Wear in the First Seconds of Coated Carbide Tools in Turning Operations

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Abstract:- Metal cutting processes have an important place among traditional manufacturing methods. The most important parameters in this type of manufacturing are the cutting tools used in manufacturing. Tool wear, which is the most important parameter affecting the performance of cutting tools, is of vital importance in terms of tool life. The present study sought to find the parameters that affect the position of the initial wear. The evaluation was conducted during the first spreading effect of tool wear (0-10 s). The experimental results showed that significant flank wear was the predominant failure mode affecting the tool life. The workpiece material was AISI 1050 steel, and three different types of DNMG 150608 carbide inserts, having the same geometry and substrate but different coating layers, were employed. Flank wear measurements were taken after the first few revolutions and the experimental results clearly showed that wear occurring at the beginning of the cutting process was very slight (0.04 mm). However, in industry, tool life criteria have been established as 0.3 mm flank wear for the coated tools used in the study. Thus, about 16% of the total flank wear had occurred in the first 1-10 seconds. This is vitally important information which can facilitate the assessment of tool life.

Keywords:- *Initial, Ttool Life, Coating, Machining, Flank Wear****.***

I. INTRODUCTION

Metal cutting processes have an important place among traditional manufacturing methods. The most important parameters in this type of manufacturing are the cutting tools used in manufacturing. In metal cutting processes, cutting tools constitute 30% of the production cost. For this reason, cutting tool selection and the life of the tools used are of great importance in metal cutting processes. It is undesirable for the cutting tool edge to become completely unusable due to wear and breakage during machining operations. As a result, tooling costs increase significantly. Finding the best tool life for machining is very important for economical machining [1]. Tool life is important in terms of surface quality, shape position and size tolerance as well as machining performance. New material types used in cutting tool manufacturing and developments in coating methods have played an important role in increasing tool life and tool performance. Tool life is always limited. Factors affecting tool wear are parameters related to the cutting process. Breakage of the cutting tool depends on the wear on the rake surface and free surface, and tool life criteria are mostly determined according to tool wear.

Tool wear has a great impact on the efficiency of the machining process. Information about wear mechanisms and determining tool life in the light of this information are extremely necessary for machining. Tool wear, which is the most important parameter affecting the performance of cutting tools, is of vital importance in terms of tool life [2, 3]. Mathematical models and theoretical calculations are not sufficient in determining tool life. Information on tool life is entirely based on analysis of information obtained from experimental data [4].

Among the different wear types on cutting tools, the wear types that are most effective on tool life are; flank wear and crater wear. However, cutting tools mostly end their life due to flank wear. Flank wear, which is most effective on tool life, starts from the beginning of the cutting process. In the research conducted on this subject, it is seen that flank wear of 0.04-0.06 mm occurs when the cutting tool starts the cutting process, in a very short period of time, for example, in lathe operations, when the cutting tool makes a few revolutions around the workpiece. Considering that 0.3 mm flank wear is used in the tool life criteria, 16% of the total tool life occurs in less than a second at the beginning of the cutting process [5]. Although the reason for this is not known exactly, the majority of opinions suggest that it may be due to the fact that the area involved in the cutting in the cutting tool is too small at the beginning of the cutting process.

The flank wear curve occurs over three separate periods throughout tool life. The first part usually ends in a few seconds and the following wear behavior creates an exponential curve. After a rapid initial increase, flank wear continues to rise at a constant rate. The period of the second part is linearly related to the tool life. In this segment, the curve usually contains the most important information related to tool performance. The third and last section of the wear curve depends on many factors such as the workpiece and tool material and the type of cutting. Set against the cutting parameters, the wear curve increases again, and the tool is rapidly broken [6].

The life and cost of cutting tools used in machining are of great importance both in terms of the quality of the parts produced and the total production cost. One of the most important issues in the field of machining is determining the most appropriate cutting parameters for the most economical

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manufacturing and the most ideal tool life. Many experimental studies have been conducted by researchers on the optimization of cutting parameters and modeling of tool wear mechanisms in metal cutting processes. Tool wear depends on the tension and temperature between the workpiece and the tool. However, understanding the tool wear mechanism is a difficult and complex problem. Mathematical models and visuals developed to understand the tool wear mechanism are sufficient [7, 8].

In recent years, TiN-based coatings have been used extensively in industry for cutting tool protection. Of these, the most commonly discussed by many researchers are TiAIN and TiAICrN. Some relevant recent works which report research results in this field can be found in [9-12].

The present study sought to find the parameters that affect the position of the initial wear. The evaluation was conducted during the first spreading effect of tool wear (0-10 s). The experimental results showed that significant flank wear was the predominant failure mode affecting the tool life. Furthermore, the rate of flank wear and the relation between the tool life and flank wear were also examined.

II. MATERIALS AND METHODS

➢ *Flank Wear*

In measuring flank wear according to ANSI/ASME B94.55M-1985 Standard [13, 14], wear height was measured vertically with a microscope. Measurements were made from three different points to increase measurement sensitivity and the average of the measurements was taken. In Figure 1 shows the characteristic structure of flank wear.

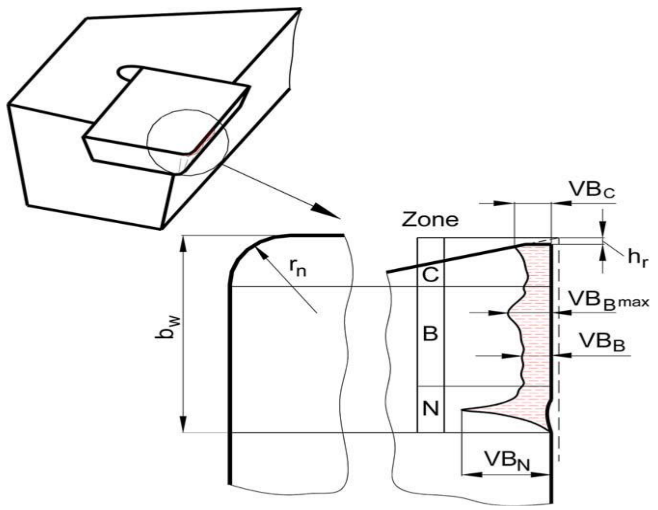

Fig. 1 Characteristic structure of flank wear ANSI/ASME B94.55M-1985 standard [13]

➢ *Experimental Procedure*

Tests were carried out to analyze the development of tool wear in the first period in turning operations. The tests carried out to experimentally examine the development of flank wear on the lathe in metal cutting operations were carried out on the TOSS lathe. machine power 5.5 KW, speed range 90-2500 rpm. and the feed rate range is 0.03-0.25 mm/rev. No coolant was used in the tests performed on the classical lathe. Optimum cutting parameters were selected for the experimental design. Low, medium and high cutting parameters were used for the experiments. For the tests, the values were applied as L27 (3x3x3) in the Taguchi experimental design. Experimental parameters are shown in Table 1. and in Figure 2 Flank wear vs. cutting time curves and the three characteristic stages

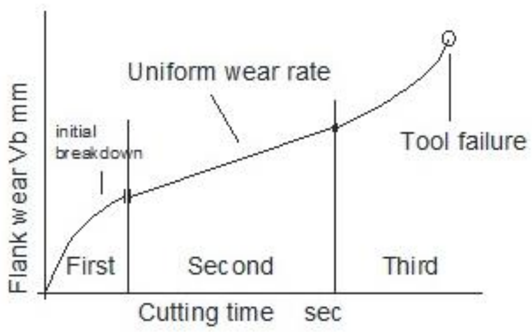

Fig. 2 Flank wear vs. cutting time curves and the three characteristic stages

Table 1. Machining parameters and their levels

Parameters	Levels		
	1	**2**	**3**
Cutting speed *V*, (m/min)	160	250	330
Feed rate *f*, (mm/rev)	0.08	0.12	0.18
Depth of cut *a*, (mm)	0.5	1.0	1.5

The experiments were carried out in accordance with the rules specified in ISO 3685. Test for single-point turning tools. The tests were carried out in a dry environment with coated carbide cutting tools. In Figure 3 shows the position of the tool and workpiece on the lathe visually. The flank wear used as the tool life criterion was applied as VB = 0.3 mm. flank wear measured with a Nikon 104 microscope at x10 magnification. The development values of flank wear at the beginning of cutting were measured four times for the first 10 seconds. Then, throughout the tool life, wear values were measured with a microscope by disassembling the tool every 60 mm. These measurements were continued up to the end of the tool life.

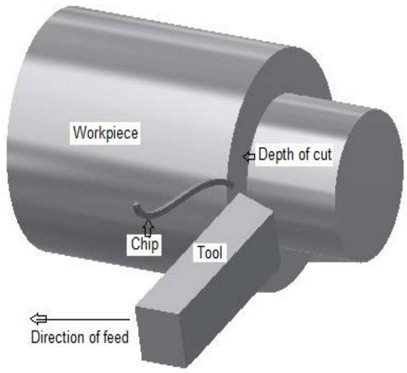

Fig. 3 The position of the tool and workpiece on the lathe visually

Three different coated carbide tools were used in the experiments. these teams; CVD coated TiC+TiCN+Tin and Tic+Al2O3+TiN and PVD coated TiAIN. The low heat

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conduction coefficient of Al2O3 used as the coating material in the TiAIN tool, which is a PVD coated tool, and its high wear resistance ensured that the tool life was longer than other tools. The properties of the CVD coatings are shown in Table 2.

Table 2. Properties of the CVD coatings

Coating material characteristics	TiN	TiC	TiCN
Coating design	5 layer	3 layer	1 layer
Hardness 25 °C (HV^{10})	2200	2110	2300
Thermal cond. 727 oC (W/mK)	25	28	31
Thermal exp. (10^{-6}/K)	9.35	8.85	8.65
Melting point (°C)	2950	3000	3070
Density (g/cm^3)	3.44	3.65	4.18

III. RESULTS AND DISCUSSION

In metal cutting processes, the wear process begins as soon as the cutting tool and the workpiece come into contact. It is not possible to prevent tool wear from the very beginning, but this process can be slowed down by determining optimum parameters. Effect of cutting parameters on initial flank wear. Three groups of experiments were scheduled for the investigation of the impact of the coated tool materials on machinability. The performance data of the different coating materials were analyzed in terms of tool life, initial flank wear, rate of flank wear, and the relation between the tool life and flank wear.

From the first cut, immediately upon contact with the workpiece, the cutting tool showed the beginnings of flank wear. After the first few revolutions, flank wear measurements were between 0.04 to 0.06 mm. The amount of flank wear depends on the cutting tool geometry, type of coating and cutting parameters, which vary according to factors such as dry or refrigerated cutting conditions.

However, in all cutting processes, at least 0.04 mm flank wear appeared within the first 1-10 s. Most likely, the surface friction and cutting tool wear occurred immediately upon the first contact of the cutting tool with the workpiece. The roughness of the contact was focused on the small contact area of the tool-workpiece interface. The stress and heat concentrated the roughness and the roughness caused by the partial removal of burrs could be observed in breakage or melting. At the first contact of the cutting tool with the workpiece surface, the resulting surface roughness caused stress, and small cracks were formed from the effect of heat from the workpiece surface. As a result, the surface contact area was enlarged and abrasive wear occurred in this region. The wear started from the moment of the first cutting and very rapid wear continued until it reached a critical value. The tool wear continued at a certain fixed rate and then accelerated again before the end of the tool life and continued until the tool life was completed. The wear occurring at the beginning of the cutting process (0.04 mm) can be considered as slight; however, in industry, the flank wear tool life criteria is 0.3 mm for the coated tools used in this study. Thus, 15% of the total flank wear had occurred in the first 1-10 s. When investigating tool life, this is vitally important information.

The 27 experiments were carried out to evaluate the effects of different cutting speeds, feed rates and depths of the cut. The machining processes were analyzed, and in particular, the effects on initial flank wear during the period of the first ten seconds. It was clearly shown that the cutting speed was the most effective parameter. The other cutting parameters were shown to be of secondary importance. The effects of cutting parameters on initial flank wear are shown in Figures 4, Figure 5 and Figure 6.

The machining was paused at 60 mm intervals of cutting length and the width of the flank wear was measured. This process was continued until the end of the tool life was reached. In Figure 7: Initial wear characteristics during the first 10 seconds. The experiments were repeated three times to ensure the reliability of the values obtained.

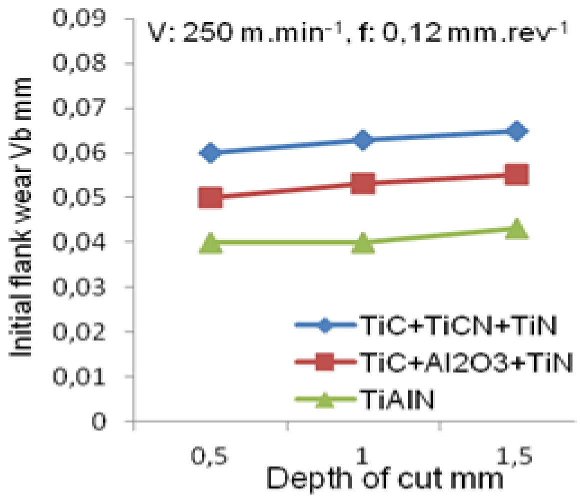

Fig. 4 Initial wear characteristics during the first 10 seconds in depth of cut

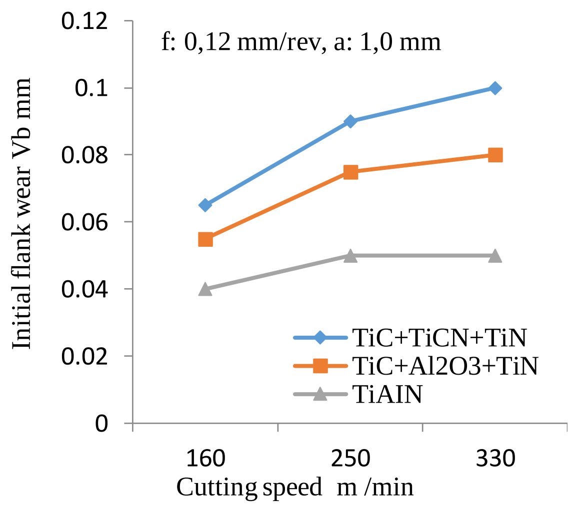

Fig. 5 Initial wear characteristics during the first 10 seconds in cutting speed

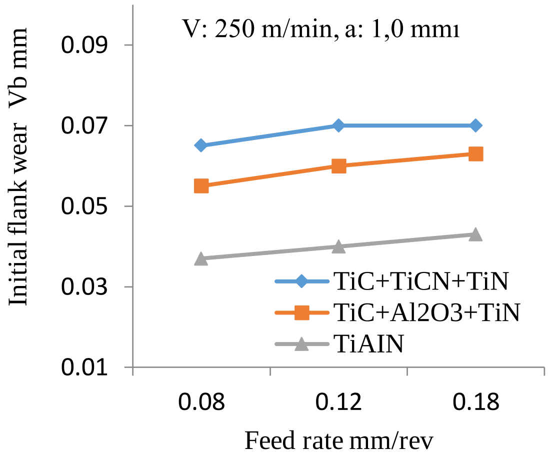

Fig. 6 Initial wear characteristics during the first 10 seconds in cutting speed

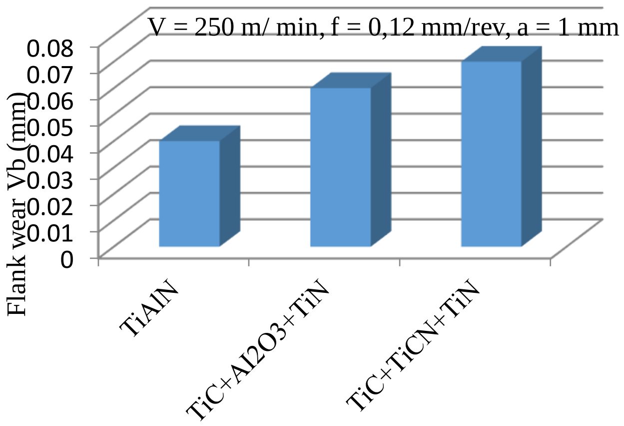

Fig. 7 Initial wear characteristics during the first 10 seconds

IV. CONCLUSION

The current study aimed to determine the parameters that affect the position of the initial wear, tool life, the rate of flank wear and the relation between the tool life and flank wear. The results obtained from this work can be summarized as follows:

- The wear process begins as soon as the cutting tool and the workpiece come into contact. It is not possible to prevent tool wear from the very beginning, but this process can be slowed down by determining optimum parameters
- The experimental results clearly showed that at the beginning of the cutting process, the wear occurring (0.04 mm) can be considered as very slight; however, in industry, the tool life criteria for these tools is 0.3 mm for flank wear. Thus, 16% of the total flank wear had occurred in the first 1-10 s. This information is vitally important for tool life evaluation.
- It was clearly shown that cutting speed was the most effective parameter and the other cutting parameters were of secondary importance.
- When the flank wear of coated tools is examined in the cutting process, first a rapid wear is observed, then a slow and in the last stage, a rapid flank wear again.
- In metal cutting operations, no matter how high quality the cutting tools are, it is not possible to prevent flank wear of 0.04-0.06 mm at the first cutting moment.

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