BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi” din Iaşi
Tomul LXI (LXV), Fasc. 4, 2015
Secţia
CONSTRUCŢII DE MAŞINI

EXPERIMENTAL ANALYSIS OF CUTTING TOOL'S WEAR EVOLUTION

BY

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Received: August 17, 2015
Accepted for publication: September 5, 2015

Abstract. Predicting the wear of the cutting tools in machining processes has become a dominant requirement in the manufacturing industry. Flank wear especially affects the size and quality of the machined workpiece. In a preliminary study, we identified the main factors that cause the progressive degradation of the insert. Active factors are: the cutting speed, feed rate, depth of cut and the nature of machined materials. The quantities representative of the degradation which we used are: the state of cutting edges observed by a microscope and different types of wear. Furthermore, the cutting conditions are also parameters affecting the shape of the wear during the machining operations. The cutting parameters (cutting speed, cutting feed and depth of cut) are exploited and used as input data to determine the evolution of wear phenomenon. Analyses of wear have confirmed a rapidly increase in wear until the collapse of the active part of the tool, even if breaking didn't occur.

Key words: cutting tools, insert, wear, materials.

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1. Introduction

The tools made of hard metal, mainly for machining metals, are also used in other sectors such as mining, the timber or that of paper (Maushart, 2000). The global market for hard metal tool is so immense. Metal working concerns many sectors such as automotive, aerospace or aeronautics. To save time and therefore money, we try to increase cutting speeds and thicknesses removed in each pass without affect the accuracy or the surface condition (Poulanchon, 1999). The considerable financial stakes and guide research toward new, more efficient cutting tools to support tougher cutting conditions (Bagard, 1994).

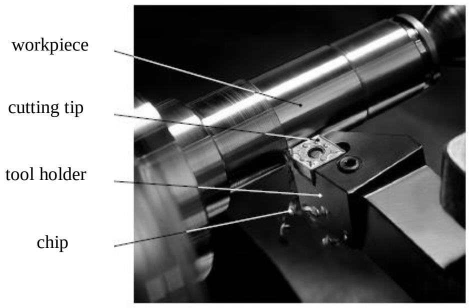

Fig. 1 − Main elements of machining process.

Unfortunately, these properties are generally not consistent and improving one of them is at the expense of others. The combination of these qualities in a single material is so hard to get. To increase the productivity of the machining there are several ways (Holleck&Kleycamp, 1981). One of the most effective is to increase feed through the use of cutting tips (inserts) (Fig. 1). This type of insert changes the machining habits of industry, in all types of materials and operations to the point of truly mark the beginning of a new era (Barlier&Poulet, 1999).

2. Working Methodology

The methodology used in this research is based on the metallic carbides inserts produced by a conventional powder metallurgy process. They are available as compact inserts of different geometries requiring a tool holder. A cutting tool must be tough to withstand the shocks encountered during machining. He must be hard to resist wear and must withstand the high temperatures during cutting operations.

Fig. 2 − Indexable inserts (*a*); Clamped-tip tool (*b*).

2.1. Tool's Geometry Influence on Wear

The geometrical characteristics of the active part of the cutting tool are defined by the orthogonal rake angle, the orthogonal wedge angle and the orthogonal clearance angle, as Fig. 3 shows.

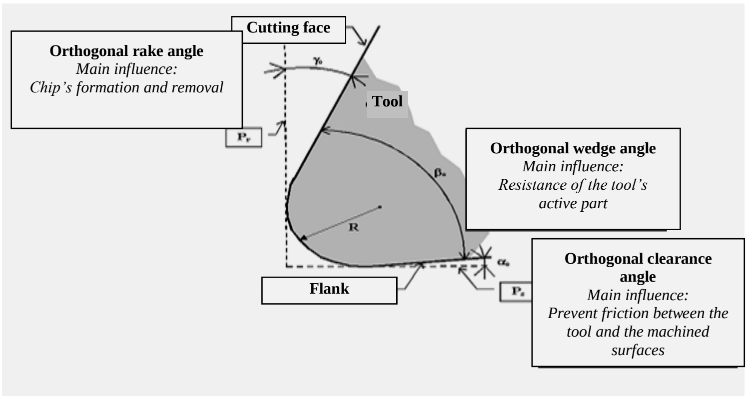

Fig. 3 − Geometry of the tool's active part.

There are coated and uncoated cutting tools. The chemical composition has a very important role in machining mechanical parts. The uncoated tools are characterized by rapid wear, since the coated ones have much longer tool life (Amri, 1987).

Among many factors that influence the wear of the tool the following are most important: cutting speed, ($v=\pi Dn$ [m/min]), feed rate ($v_f=nf$ [mm/min]) and depth of cut (d [mm]), see Fig. 4.

The wear is a result of various mechanisms, such as: abrasive wear, adhesive wear, wear diffusion by mechanical fatigue, wear by thermal fatigue. There are several forms of visible wear of the cutting tool as follows: wear notch, cracks of the cutting edge, insert's breaking, flank wear, plastic deformation or crater wear. Crater wear is due to the elevated temperatures in the area of chip / tool contact, causing a significant diffusion.

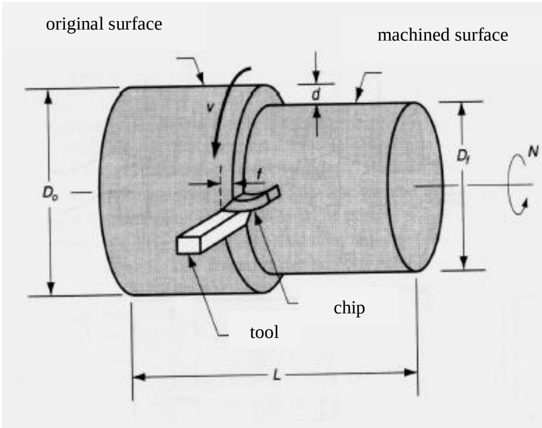

Fig. 4 − Cutting parameters.

Chip's formation, a complex mechanical process due to the pressure exerted by the tool on the piece during the machining, has as result different areas of friction and shear deformation at the contact between the tool and the machining surface.

2.2. Materials and Tools Used for Experiments

Machining operations during the experiments were performed on a lathe for turning and threading, type SN40C, from a Czech company, with a power on pin equal to 6.6 KW. The worked materials, shaped as cylindrical blanks with 65 mm diameter and 500 mm length, used during the experiments were:

- XC48 steel, semi-hard high quality steel, having the following chemical composition: 0.51%C, 0.25% Si, 0.72% Mn, 0.139% Cr, 0.007% S, 0.223% Cu, 0.011% Al, 0.017%Mo, 0.079% Ni, 0.013% P, 0.004% V.
- 100Cr6 steel, a very wear-resistant steel, with the chemical composition as follows: 1% C, 0.29% Si, 0.37% Mn, 1.5% Cr, 0.015% S, 0.204% Cu, 0.008% Al, 0.018% Mo, 0.09% Ni, 0.015% P, 0.008% V, 0.017% Co.

Table 1

Geometrical characteristics of the inserts

Insert	**Reference**	χ_r°	α°	γ°	λ°
Sandvik	SNMG 12.08.04	75	6	-6	15

Selected inserts are reversible square shaped metal carbide, Sandvik brand ref: 12-04-08 SNMG), shade (P30) with 8 cutting edges per insert. Their geometrical characteristics and chemical composition are presented in the Tables 1 and 2.

Table 2
Chemical composition of P30 insert

TiC %	Co%	WC%
5	10	85

The toolholder used was type PCLNR25X25. The evolution of the wear results on an optical microscope, used to measure the sizes of the tool's wear. After each work sequence we are using the Imagtech software and another optical microscope, in order to highlight the different types of wear on the plate and their values. The input parameters considered were the cutting speed, v, the feed per revolution, f and the depth of cut, d. The output parameter was the wear evolution.

2.3. Experimental Plan

Experimental test are planned according to the unifactorial method, an essential method when it comes to characterize the action of a single factor X on the parameter Y (Clement, 2000). This is done by giving a series of discrete values to the considered factor X, $[X_i \in \{X_{min}, X_{max}\}]$, while maintaining all other factors constant. For each $X = X_i$ there is provided an experimental test and the corresponding value Y_i $(i = 1 \div n)$ is measured. This method allow to study and optimize a technological process based on the resultant relationship $Y = f(X)$, where X is the only variable factor. The overall objective we are pursuing through this study is the deterioration of the cutting tool's active edge. Before choosing the working conditions of the tool, a series of preliminary tests were done, using XC48 steel and a tool coated with metal carbide. The cutting parameters are presented in Table 3, showing cutting speed, v, as a variable parameter, while the feed per revolution, f, and the depth of cut, d, are constant parameters.

Table 3
Cutting parameters for preliminary tests

Test	v [m/min]	f [mm/rev]	d [mm]
1	150	0.22	0.75
2	198	0.22	0.75
3	300	0.22	0.75
4	400	0.22	1

The insert's wear variation in time, determined after the preliminary tests, was illustrated in Figs. 5 – 8.

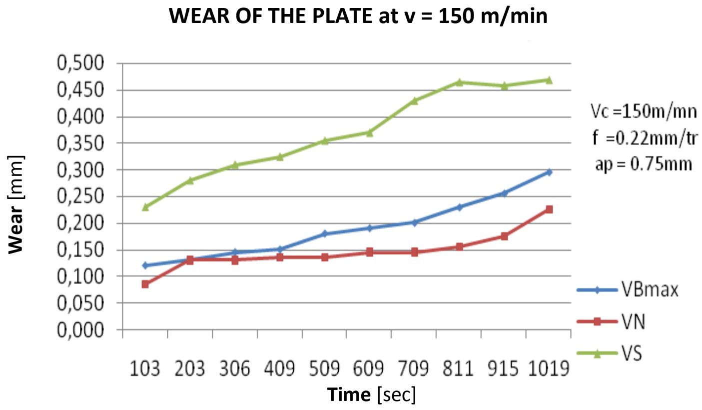

Fig. 5 − Wear variation after test 1.

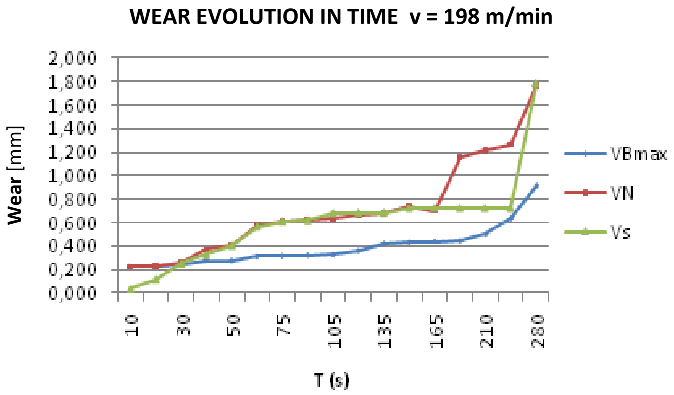

Fig. 6 − Wear variation after test 2.

The diagrams below show that different combinations of cutting parameters have a major influence on the wear, while observing that the shape of the wear strip is almost the same for all the tests. Generally, the resultant curves present similar stages of evolution for all the experiments and the plate breaking didn't occur. So, this led us to change the tool material initially chosen by uncoated metal carbide P30, having less cutting capacity and the workpiece material was replaced by 100Cr6.

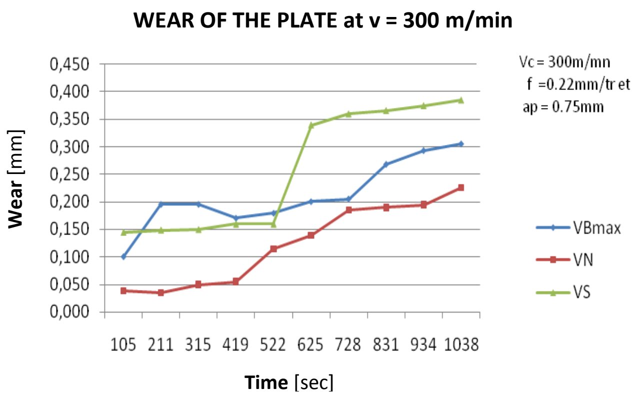

Fig. 7 – Wear variation after test 3.

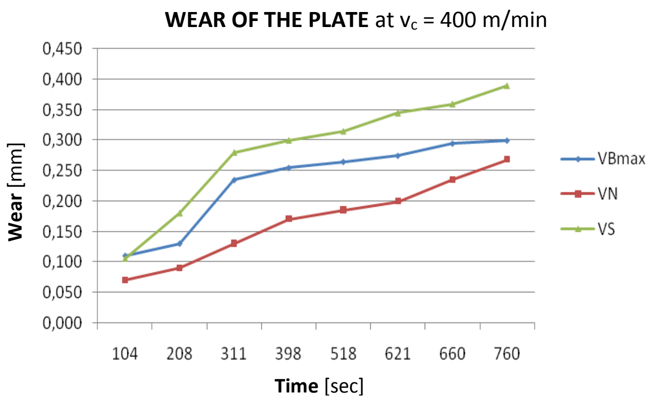

Fig. 8 – Wear variation after test 4.

Three experiments series were carried out, as follows: Series 1, including 9 tests, Series 2 with 4 tests and Series 3 with 3 tests.

For Series 1 experiments we were considering the cutting speed values v = 197; 233 and 305 m/min, with f = 0.22 mm/rev and d = 0.5 mm at constant values, each test being performed with a new cutting edge.

The results obtained for the wear size concluded that the wear types VB, VS and VN increase with time. Despite the theory saying that there are three areas of wear (premature, constant and growing), our testing has not complied with the existence of the first zone. It was noted that all the wear curves begin at an important wear point. It should be noted that the admissible standard wear is 0.3 mm, whereas in our case we pushed the test until the very high wear values in order to cause the breakdown of the active edge the tool.

The carbide tips wear observed by microscope are shown in Fig. 9.

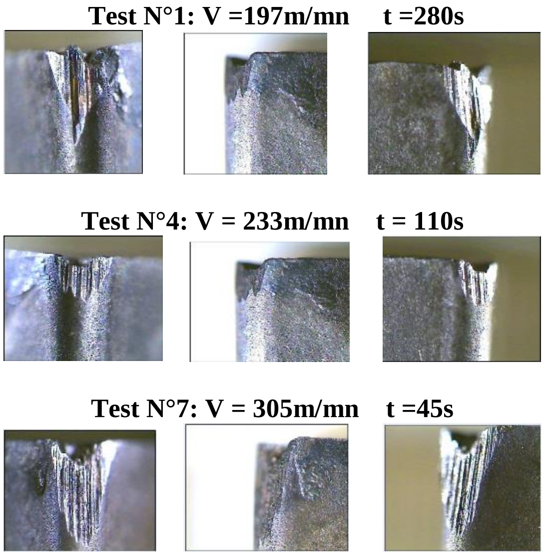

Fig. 9 − Carbide tips wear by microsope – series 1.

It is noted that the active part of the edge is subjected to a great damage, explained by the fact that when the cutting speed increases, the temperature in the cutting zone is increased (in particular on the contact surfaces between the chip and the rake face, as well as between the workpiece and the main flank surface), therefore different wear mechanisms of the tool occur, followed by hardness reduction. According to the first series of tests it is found that the wear values obtained are significant. The target in this case was not realized, so we changed the cutting conditions for the experiments of Series 2.

Four tests were developed during the Series 2 and we choose the one with cutting speed v = 280 m/min, the cutting feed f = 0.22 mm/rev and the depth of cut d = 1 mm. The aspect of tips wear is presented in Fig. 10 and the wear variation in time is shown in Fig. 11.

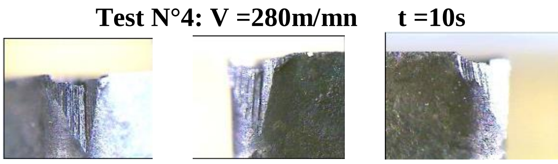

Fig. 10 − Tips wear at microsope – series 2.

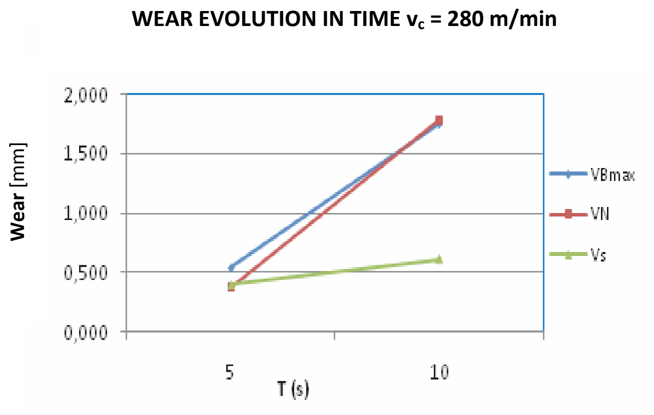

Fig. 11 – Wear evolution in time for the 4th test of Series 2.

It should be noted that, according to the admissible wear standard of 0.3 mm, in our case we pushed the test until the very high wear values in order to cause the breakdown of the active edge of the tool.

During Series 3 of experiments we selected the one for the cutting speed of v = 336 m/min, f = 0.22 mm/rev and depth of cut d = 2mm. The resulted tips wear is shown in Fig. 12.

Test N°3: V = 336m/mn t = 5s

Fig. 12 – Tips wear at microsope – series 3.

These images reveal the wear evolution on all the surfaces of the tool's edge, which correspond to the greater penetration of the edge into the worked material. Note that after five seconds the edge of the tool is completely erased and crater wear occurs much faster. The explanation consists in the fact that with the increase of the cutting parameters (cutting speed and depth of cut) the temperature in the cutting zone is increased, which accelerates the process of wear and therefore the machining time is reduced. For this test the machining time does not last more than five seconds. Also the three forms of wear occur, which makes cutting control and predicting failure more difficult.

3. Conclusions

1. The present work aimed to understand the role of cutting tools metal carbide inserts on the wear of the active part, until its deterioration. The resulting high temperatures around the edges of the cutting tool have a direct influence on control of the rate and the mechanism of wear, on the friction between the chip and the cutting tool, and also between the cutting tool and the new generated surface.
2. One of the objectives initially selected for the wear of cutting tools metal carbides, in the dry film, remains inadequately analyzed because the wear process is extremely fast. The phenomenon of wear occurs in the first pass for some tests. Monitoring the evolution of wear and statements dimensional parameters is performed by an optical microscope on the Laboratory of Mechanics of Materials and Industrial Maintenance (LR3MI).
3. We observed from this work the following aspects: 100Cr6 steel is very difficult to machine, hence the need for a cutting tool material with very high properties; analysis of monitoring wear shows that the shape of the wear curves obeys the universal law of wear of any mechanical part. Is also found that the life of uncoated P30 inserts is very short;
4. The increase in cutting speed improves the surface quality, but it accelerates the cutting tool's wear, so it's very important to optimize the cutting process;
5. When working with high cutting speed (over 300 m/min) the machining system is unstable, vibrations occurs after 5 minutes because the intensive wear mechanism, resulting a complete collapse of the tool's nose.

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ANALIZA EXPERIMENTALĂ A UZURII SCULELOR AŞCHIETOARE

(Rezumat)

Evaluarea uzurii sculei aşchietoare în procesele de aşchiere a devenit o cerință esențială a industriei prelucrătoare. În mod special uzura suprafeței de aşezare influențează în mod direct dimensiunile şi calitatea suprafeței prelucrate. Pe parcursul unui studiu preliminar, s-au identificat principalii factori care determină degradarea progresivă a plăcuței aşchietoare, dintre care trebuie menționați viteza principală de aşchiere, avansul şi adâncimea de aşchiere, precum şi natura materialului aşchiat. Caracterizarea nivelului de uzură a fost realizată prin observarea la microscop a aspectului plăcuței aşchietoare, cu evidențierea diferitelor tipuri de uzură. Parametrii regimului de aşchiere au fost utilizați pentru analiza evoluției fenomenului de uzură, constatându-se o creştere rapidă a intensității uzurii până la pierderea calităților aşchietoare, fără însă să se producă ruperea plăcuței.