EXPERIMENTAL RESEARCH REGARDING THE SHELL-MILL – PIECE METAL CUTTING TRIBOSYSTEM ON NUMERICALLY CONTROLLED MACHINES

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Abstract: *The paper approaches the outcome of some experimental researches regarding the shell-mill – piece metal cutting tribosystem, under the technological conditions of processing on numerically controlled machine-tools. The experiments were industry oriented, having been conducted under fabrication technological conditions. After presenting the experimental conditions, the paper brings out the scientific data of the experiments, those related to the variation of the tool wear compared to the length of metal cutting, as well as the variation of the absorbed power and of roughness, compared to wear.*
Keywords: *metal cutting tribosystem, tool wear, roughness, power in metal cutting.*

1. INTRODUCTION

Czihos [2] approached, in a structural and systematized manner, the issue of tribosystems, bringing a mathematical model that can be particularized for each metal cutting tribosystem. Kragelsky [3], in his famous work Tribology Handbook, approached a few tribology aspects, belonging to the processes of metal cutting. The temptation of a tribosystemical approach to the metal cutting process is significant. As a consequence, there appeared piece – tool, type – specialized, more complex approaches. The effects of tool transformation were no longer followed exclusively as observation results, but in systemic approach; there was made use of an actual research on the effects of tool wear on other parameters, like precision of the tool, roughness, power absorbed in the process etc. [1],[4],[5]. We could state that the tribosystemical approach has intersected other technological systems of processing, too: stamping, pressing, and forging.

The experiments were conducted at RAMIRA S.A., in Baia Mare, Romania, a currently local promoter company in the field of processing technologies.

Our goal was to perform an experimental study of observing the evolution of a shell-mill wear, under conditions of processing on numerically controlled machines, and of observing the evolution of the surface quality and absorbed power, as a result of the tool wear. Throughout the researches, other phenomena of technological and experimental interest were also noticed.

2. EXPERIMENTING CONDITIONS

The research was performed on a MICROCUT Challenger numerically controlled machine; model MCV-2416, presented in figure 1, with the technical data in table 1:

Fig. 1. MICROCUT Challenger machine

Table 1

Characteristic	**M.U.**	**Value**
Physical dimensions	mm	760 X 360
X Axis stroke	mm	610
Y Axis stroke	mm	305
Z Axis stroke	mm	510
Chuck cone		BT 40
Minimum/Maximum distance bench-chuck	mm	110/620
Tool storage capacity		16
Main engine axle power	kW	7
Main axle rotary speed	rot/min	10000-18000
Command software used		FANUC OiMC
Overall dimensions	mm	1850X1950X2490
Total installed power	kW	15

Table 2

Tool type	Dimensions [mm]				z_n
	D_c	dm_m	l_2	a_p	
J91100	10	10	75	25	4

The cutting tool used in the experiment is a type J91100, manufactured by Jabro Tools, a member of the Seco Tools group, and is presented in figure 2, with its characteristics outlined in table 2. The cutting conditions within the test were calculated according to the Technical Guide, edition 2006, edited by Seco Tools, the manufacturer of the cutting tool. The technological parameters calculated, and then used in the experiment were: vc =115 [m/min], ap=10 [mm], fz=0.07 [mm/tooth], n=3660 [rot/min], vf=256.2 [mm/min], Q=0.614 [cm3/min]. The material processed in this experiment was 42MoCr11.

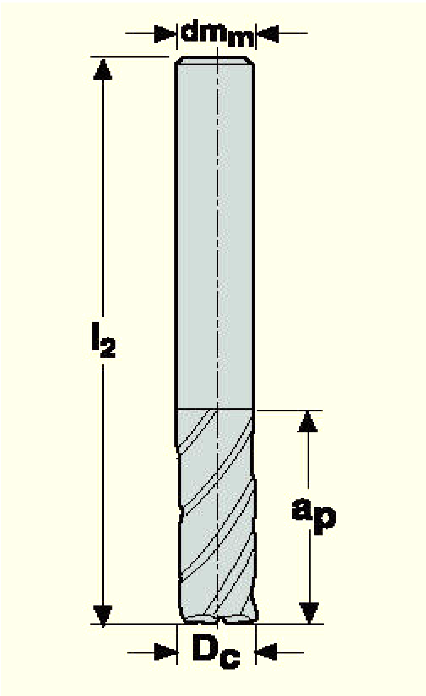

Fig. 2. Cutting tool

A 3D model of the piece was created, using the SolidWords design environment, and then this model was imported into PowerMill, a cutting simulation software. The data necessary to perform the experiment were entered: the turning speed of the main axle, the advance speed of the mill, the processing add-on, the type of the mill, as well as information about the cutting tool. The itinerary of the experiment was established, dividing the cutting process in 10 minute stages of actual cutting time, period in which the wear phenomena were developed, so that the wear of the tool measurement and the behaviour of the cutting edge in different stages and states of the process would be relevant.

In the semi-finished piece, two lateral channels were executed on, with the purpose of a better fixing and positioning on the bench of the machine tool. The cutting was performed in the opposite direction to the advance, using the emulsion cutting liquid.

The measurement of the mill wear face was realized using an optical microscope, with a 1 μm precision and with the possibility of measurement axes rotation, function to the inclination angle of the mill helix tooth.

The power absorbed by the tool machine was measured, too, both for the loaded and the unloaded running during cutting, with the help of a digital hook-on-meter. In order to observe as precisely as possible the rise of power consumption, each ten minute phase of the test was itself divided into three measurement stages, the reading of the consumption being executed at intervals of approximately three minutes, and the arithmetical mean of the measured values was calculated.

There was measured the roughness obtained as a result of the cutting process in each of the first five complete processing stages, in the sixth stage, the measurement being executed on a surface equal to 2/3 of the pre-established surface, as in this last stage the catastrophic wear of the mill occurred. The roughness was measured with portable multi-parameter surface roughness measuring instrument, Model 2222, manufactured by HARBIN MEASURING & CUTTING TOOL WORKS , People's Republic of China

After each cutting stage chip samples from the cutting zone were gathered, observing the changes in their shape along with the tool wear.

3. EXPERIMENTAL DATA

The data obtained are presented in table 3.

Table 3

	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6
Metal cutting distance on each test [m]	2888	2877	2871	2871	2735	2725
Total metal cutting distance till test point [m]	2888	5765	8636	11507	14242	16040
Wear [mm]	0,160	0,185	0,201	0,220	0,254	catastrophic wear
Power absorbed $P_{abs.}$ [W]	1120	1138.3	1180.7	1211.04	1404.8	1422.9
Roughness R_a [μm]	0.500	0.578	0.606	0.621	0.887	0.934

The power absorbed while functioning unloaded was of 1.089 [KW].

The results of the experiment are presented in the figures 3, 4 and 5. In tests 1 and 2, the initial wear was stronger on only one tooth of the mill, it presenting the wear face and pinches, and on all the other teeth there were noticed, when put under the microscope, stronger wears.

During test 6, after covering 2/3 of the planned cutting length for this test, due to the loss of cutting capacity, the cutting tool was physically destroyed.

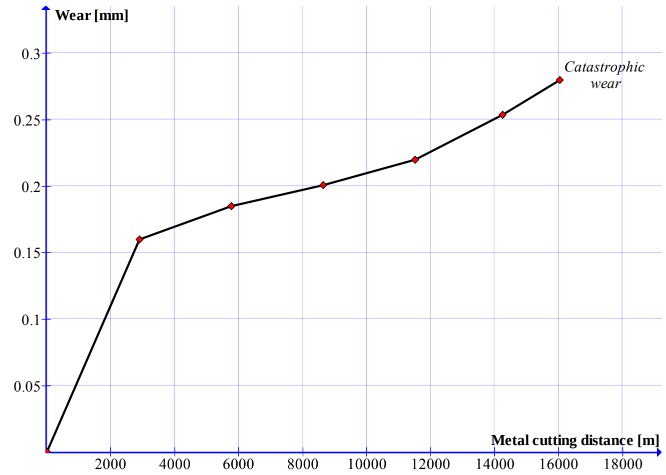

Fig. 3. The variation of the tool wear, function of the covered distance during cutting

The actual cutting time was of approximately 10 minutes per test, hence a durability of the cutting tool of approximately 56 minutes. The tooth on which the measurements were taken was the one completely destroyed (it had the strongest wear).

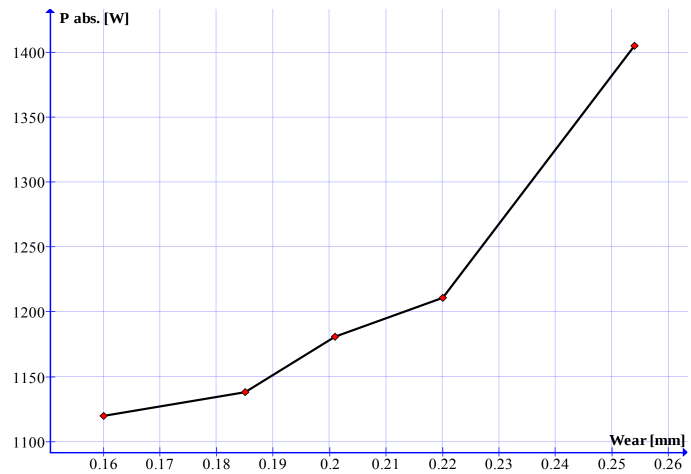

Fig. 4. The variation of the power absorbed, function of the wear

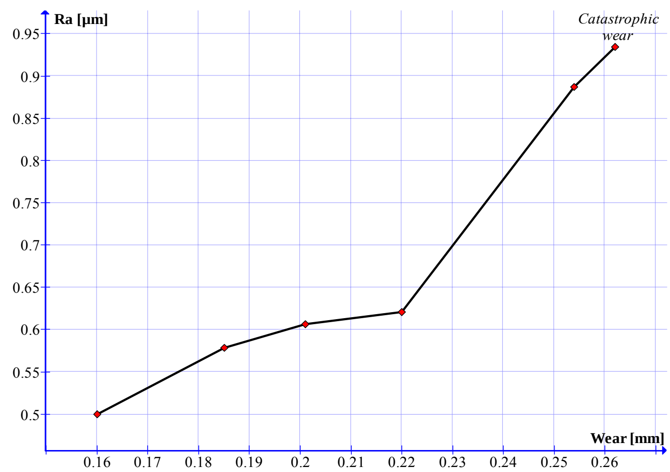

Fig. 5. The variation of the roughness, function of the wear

4. CONCLUSIONS

a) During the cutting process, the evolution of the tool wear basically follows the wear evolution pattern. But, as one can notice, there is a slight deviation from linearity. The phenomenon deserves a closer and more thorough study.

b) The variation of the power absorbed in proportion to the wear does not have a linear nature. A polynomial function of the type $a*x^2-b*x+c$ (in the case of the experiment $2.115*x^2-0.0156*x+1150.9$) can be associated with this variation.

c) The power absorbed during the actual cutting process is between 3-30%, function of the tool wear.

d) The rising of the power absorbed during the cutting process increases 11 times up to the loss of the cutting capacity, this being followed by the breaking of the tool.

e) The chips modify their shapes with the tool wear.

f) The roughness is basically influenced by the wear, at the level of cutting asperities, the rise starting from 0.5 to 0.95. The roughness study compared to the power absorbedand the tool wear can be developed, due to the fact that there exists a connection between the ways the chip is formed, the wear state of the tool, and the cutting power absorbed.

g) The researches have a great expansion area at industrial level.

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