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EXPERIMENTAL STUDY OF SURFACE QUALITY AT VIBRO-SHOCK DRILLING

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Abstract The paper presents the experimental results of using vibro-shock in drilling operations of OFHC copper, which is a high plasticity material and has a very low machinability. during the experiments, the influence of vibro-shocks on the surface roughness of the machined surface, on the deformation of machined layer and also on the chip fragmentation has been analyzed.

1. INTRODUCTION.

The use of vibration and vibro – percution can be a method to enhance machining of high plasticity materials machining like stainless steels, low carbon rate steels (ARMCO, CARBONIL), or other metals like pure copper (OFHC), aluminum and aluminum alloys, titanium, and so on [3], [8], [9], [10]. Usually these materials which are giving long chips and which, in general, are turned around the tools producing damage to the tools and the machined surfaces.

Adaptation of vibro-percution methods to must take into account the adaptation of devices and machines, which has to withstand higher impact forces and vibrations [5]. Speed discontinuities are characteristic for these kind of machining [4], [5] and are helping in chip fragmentation phenomena. The application of this method is made using specially designed devices [3], [7], [8], [10]. Such cutting of metals is made at high speeds when deformation leads to material hardening, decrease of mechanical work and radiated heat. In this condition the material build up on the tool edge is decreased.

Up to date cutting procedures are using high speed machining (HSM), multiple tool machining and automation [11], [12]. Large scale development of these methods had brought in scene issues related to vibrations born during the cutting process [2], [6]. The goal of the analysis of vibrations is on one hand to eliminate the vibrations which has a negative role on the process and on the other hand to use controlled vibrations in chip fragmentation purposes, which is useful in automated cutting where the chips has to be removed from the process area [12].

Chip fragmentation can also contribute to increase surface quality by:

a) – avoiding long chips to scratch the processed surface;

b) – avoiding material buildup on the tool edge.

Experiments on using vibro – percutions in metal cutting and the yielded surface quality had been made with different cutting parameters on OFHC copper probes, in drilling operations on CP20UO CNC machine tool.

2. EXPERIMENTAL VIBRO – PERCUTION DEVICE.

In this paper the authors had studied the influence of vibro - percutions on drilling operations on surface quality, deformed layer structure and chip fragmentation. In order to make the need experiments there had been designed and made an experimental setup shown in figure 1.

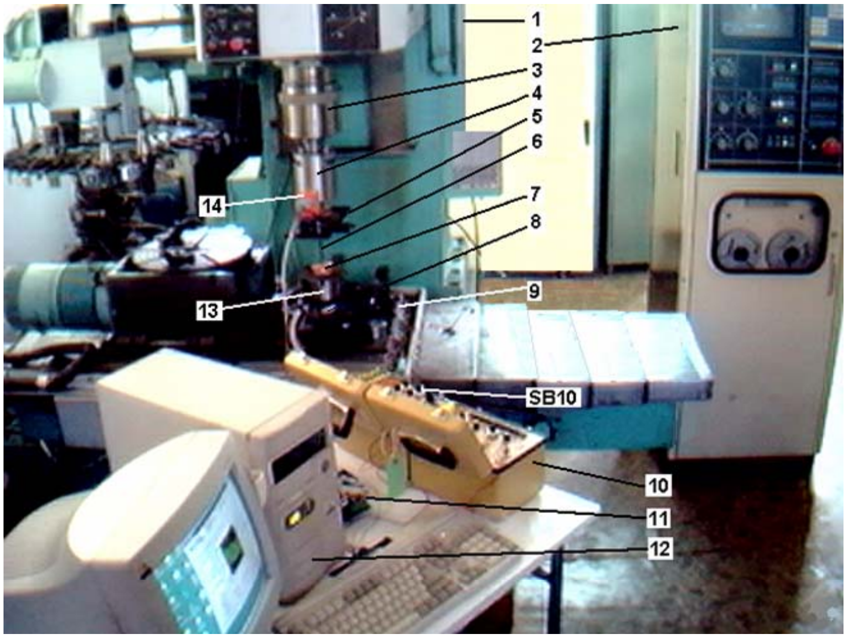
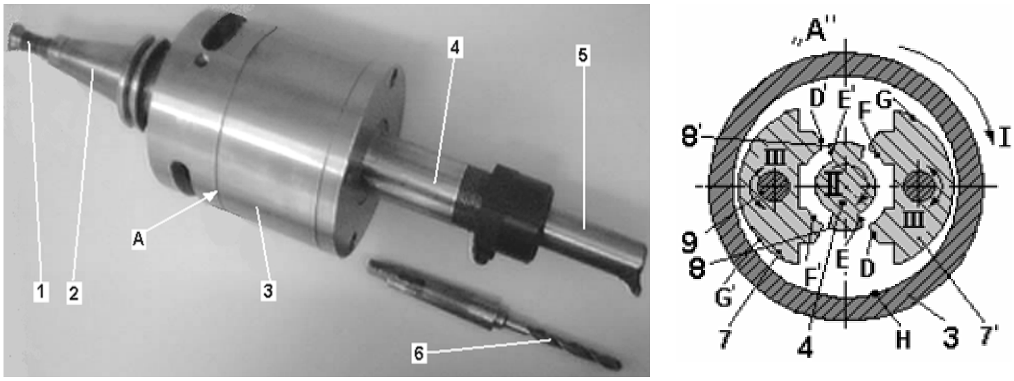


Fig. 1. Experimental equipment setup.

The experimental equipment is composed by a CNC machine tool (1), the vibro – percution device (4), a support (5), mounted on the percution device shaft, a tensometric table (8), linked to a tensometric bridge (10) type P_3500 (Vishay Measurements Group), with a 10 channel connection port SB10, a TIRO type incremental rotary transducer (14), accelerometer B&K15 type KD45, data acquisition card PCI 1200 (National Instruments), computer (12) type Pentium III and connection block (11) The drilling tool (6) is ∅8[mm], STAS SR 575-1993.

The percution device is shown in figure 2, and it can be stored in the machine tool by means of ISO taper (2) and tirret (1) and also in the machines main shaft. The rotation is transmitted from the machine's main shaft to the body (3) In this body there are axial fixtures of percution elements (7) and ($7^{'}$) which can rotate on the bolts (9). On the device shaft (4) (section A) there are the cams (8) and (8'). At the end of the shaft the drill (6) is placed.



a) ***b)***

Fig. 2.Vibro – percution device.

The vibro – percution device described above can operate in two different ways (fig. 2b):

a) – after the first impact between the percution knobs, due to some unconformities of D and D' surfaces or to dimensional mismatch, the percution knobs can remain blocked and the cutting will be a continuous one;

b) – after the first impact between the percution knobs surfaces D' with E', the percution knobs will be moved counterclockwise with reaching surface H, and the device shaft 4 will make the rotation movement II with the angle φ_{rot}, in the same time the device body 3 will make the movement I;

c) – after the first impact between the percution knobs the percution knobs will not contact the device shaft and the cutting will not occur.

Selection of cutting parameters (tab. 1) had been made considering the percution device design and also the machinability of OFHC copper [9]. Actual feed rates had been selected smaller than in literature [14].

Table 1. Cutting parameters.

Speed [m/min]	19,3773					17,8849					15,5571					14,0492					11,6364				
RPM [rot/min]	771					686					619					559					463				
Feedrate [mm/min]	1	2	4	6	8	1	2	4	6	8	1	2	4	6	8	1	2	4	6	8	1	2	4	6	8

Probe cutting had been made in normal and percution case, for comparison purposes. Normal cutting can be achieved by blocking the screws (1) in figure 3. Impact increasing is possible by additional mass (2) which can move freely in channel “C”.

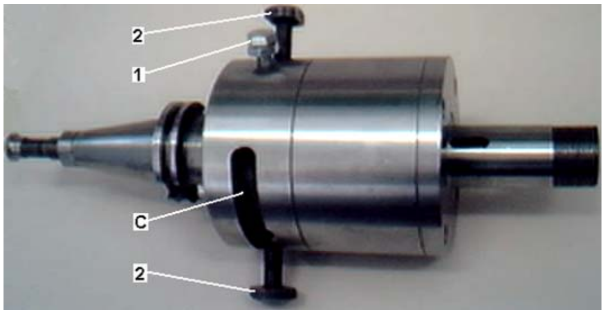


Fig.3. Percution device adjustment elements.

The OFHC copper probes (fig 4) had been fixed in the clutch and drilled. Vibro – percution probes are shown in figure 4.a and normal cutting probes are presented in figure 4.b.

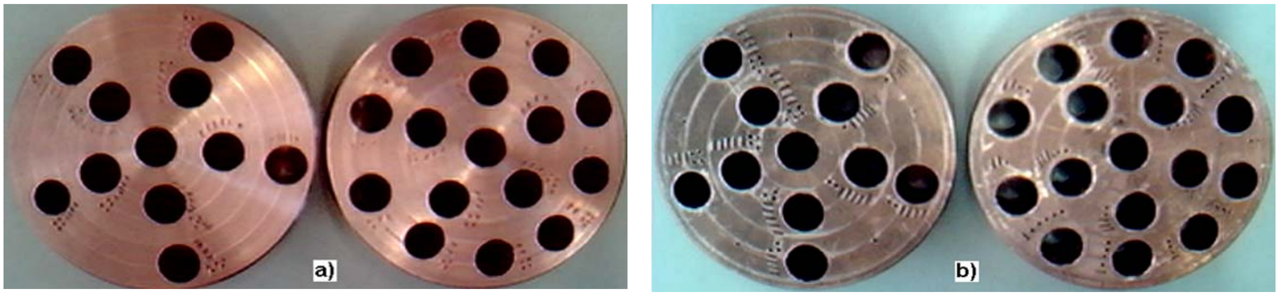


Fig. 4. OFHC copper probes used in experiments.

Impulse as function of shaft RPM can be computed with the relation:

$$H = (R+1) \cdot \frac{\pi \cdot n \cdot \cos\alpha}{30\left[\frac{r_2}{J_2} \cdot \cos^2\alpha + \frac{r_1^2}{J_1 \cdot r_2} \cdot \sin^2\varphi\right]} \qquad (1)$$

where:

R – restitution coefficient of percutor knobs versus shaft cam;
J_1 – inertia of percution knobs, [kg·m^2];
J_2 – inertia of device shaft, [kg·m^2]
r_1, r_2, α, φ – geometric elements of the device.

3. SURFACE QUALITY AT VIBRO – PERCUTION CUTTING

3.1. ROUGHNESS ANALYSIS

Surface roughness had been measured with a Taylor Hobson type Surtronic 2 equipment. Measured data is presented in table 2. The data is revealing that federate has a major influence on surface roughness [1, 10].

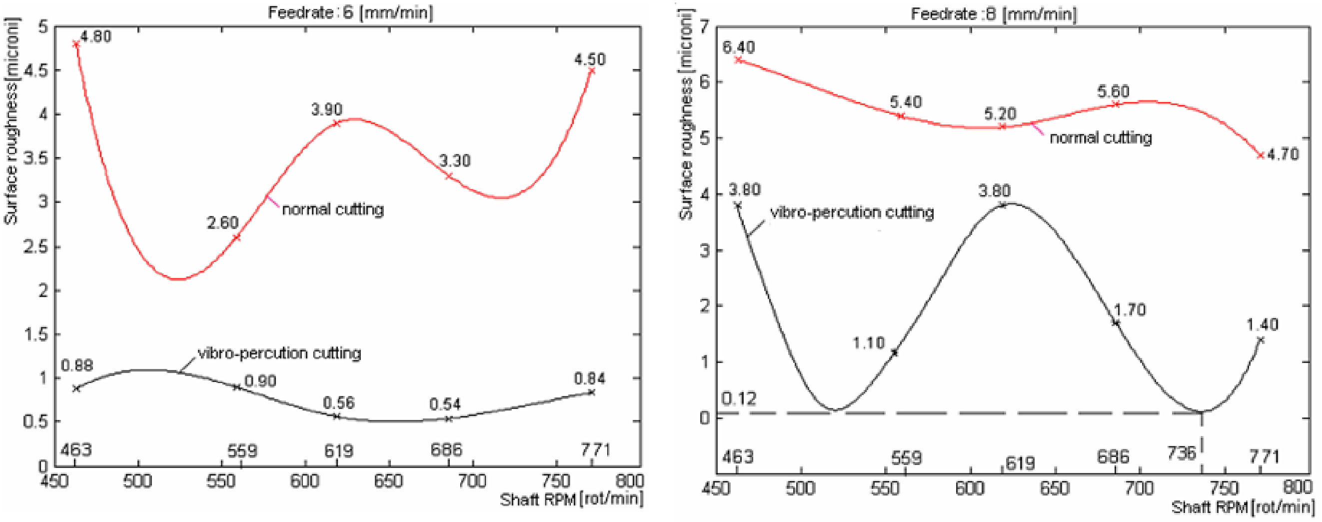
Table 2. Measured surface roughness values (courtesy to S.C. „STIMIN” S.A.)

Nr. crt.	**Shaft RPM n [rot/min]**	**Feedrate v_s [m/min]**	**Normal cutting roughness R_a [μm]**	**Vibro-percution roughness R_a [μm]**
1.	**463**	**1**	**2,7**	**0,9**
		2	4,6	2,4
		4	3,8	2,6
		6	**4,8**	**0,88**
		8	**6,4**	**3,8**
2.	**559**	1	6,2	1,1
		2	3,9	1,2
		4	3,4	1,8
		6	**2,6**	**0,9**
		8	**5,4**	**1,1**
3.	**619**	1	1,4	1,2
		2	2,2	0,98
		4	**3,8**	**0,26**
		6	**3,9**	**0,56**
		8	5,2	3,8
4.	**686**	1	1,8	1,1
		2	2,78	0,86
		4	3,8	1,3
		6	**3,3**	**0,54**
		8	5,6	1,7
5.	**771**	1	4,4	1,6
		2	4,6	1,3
		4	**4,1**	**0,74**
		6	**4,5**	**0,84**
		8	4,7	1,4

Analyzing the measured data we can observe that at normal cutting the surface roughness variation is somehow random but slightly decreasing with federate.

Regarding the percution cutting is hard to evaluate the influence because the cutting speed is variable yielding variable surface roughness. An overall conclusion would be that the surface roughness is smaller in the case of percution cutting.

In order to better visualize the measured data the authors developed a MATLAB program. Resulted diagrams are shown in figure 5, for federate of 6 (fig.5.a) and for a feed rate of 8 [m/min] (fig. 5.b). It can be seen that the highest roughness values are yielded at the lowest RPM and are decreasing with shaft rotation.



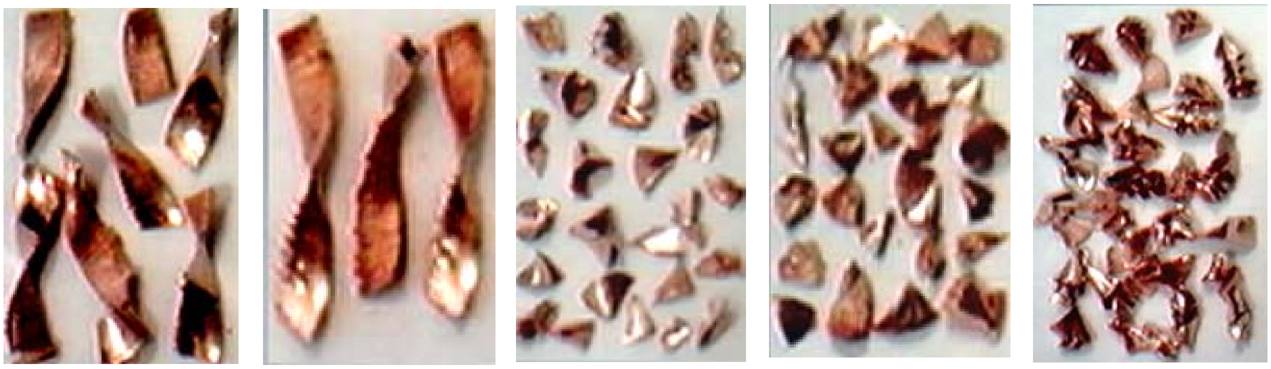
a) *b)*

Fig. 5. Surface roughness diagrams a. federate 6 m/min; b. federate 8 m/min.

Observations regarding surface roughness shows that in case of vibro-percution cutting the roughness values are smaller regardless the used federate or shaft RPM.

3.2. CHIP ANALYSIS.

The visual chip analysis had been made at collecting samples of chips for different cutting parameters. It can be seen that as the cutting speed grows the material will be more fragile and the chips will be more fragmented.



a) *b)* *c)* *d)* *e)*

Fig.6. Types of chips obtained at vibro-percution drilling of OFHC copper at a federate of 6[mm/min] and RPM of: a) n=430, b) n=559, c) n=619, d) n=686 şi e) n=771 [rot/min].

Comparing the chips obtained at vibro-percution cutting and normal cutting we can conclude that the best fragmentation of chips is obtained by vibro-percution cutting. It also can be demonstrated that the best parameters of cutting are rotation of 686 RPM and a federate of 6 mm/min.

3.3. ANALYSIS OF THE MANUFACTURED LAYER

Stress and deformation of the materials can influence the materials parameters and between them electric rezistivity.

Metallography analysis had been made for the manufactured layer in order to establish the degree of it's deformation. The probes had been prepared for each tested cutting parameter. The analysis had been made using a Neophot 21 microscope (1) with attached camera (4) with a special device (3), linked to a computer (5).

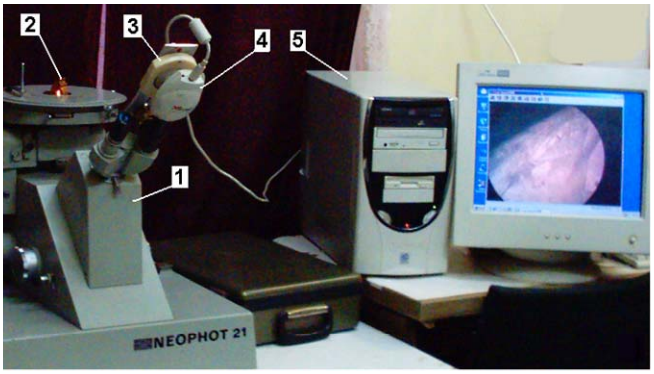


Fig. 7. Metallography equipment for microscopic analysis.

The main goal was to compare the deformed layer thickness in both cases, normal and percution cutting.

The images had been made at a scale of 500x and had been saved as bitmap files to the computer. Vibro-percution probes are presented in figures 8 and 9 marked with the letter "a" and normal probes are marked with "b". The base, undeformed layer is formed by large crystals, and the deformed layer by smaller elongated ones.

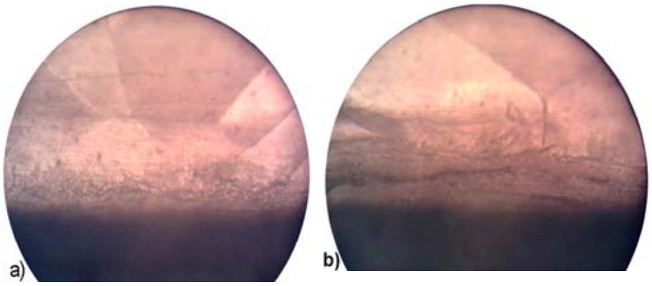


Fig.8.Microstructure of probes: cut with: n=771[rot/min]; v_s= 8[mm/min]. (Scale 500x).

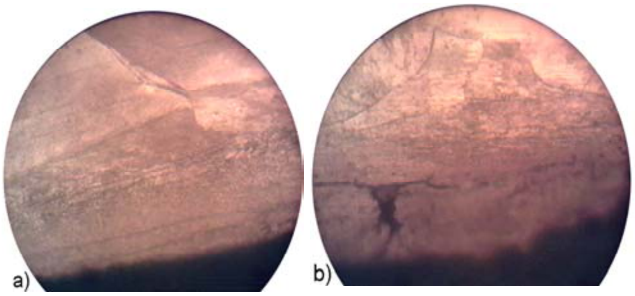


Fig. 9. Microstructure of probes: cut with: n=686 [rot/min]; v_s=8[mm/min (Scale 500x).

This study reveals that good results are obtained at higher cutting speed and higher federates (RPM = 771÷686 rot/min şi federate =6÷8mm/rot).

Correlating the roughness with the deformed layer thickness we will see that the optimal values are obtained at speed about 771-686 rot/min.

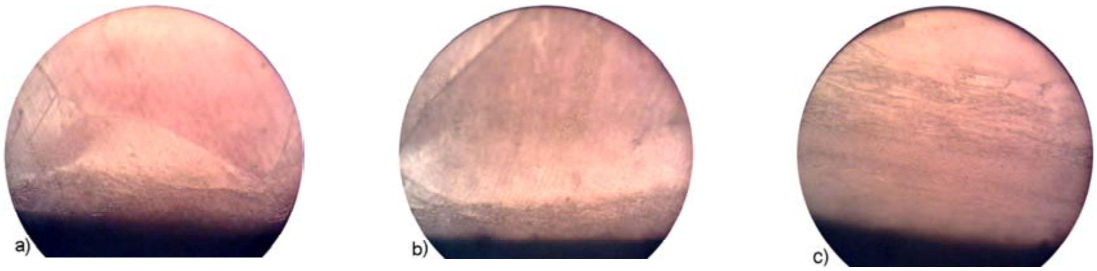


Fig. 10. Deformed layer thickness: a) RPM=771[rot/min], feed rate=6[mm/rot]; b) RPM=686[rot/min], feed rate=6[mm/rot];c) RPM=559[rot/min], feed rate=8[mm/rot]. (Scale 500x).

The largest deformations at vibro-percution cutting are obtained at RPM = 559 rot/min and a federate of 8 mm/rot presented in figure 10.c.

4. CONCLUSIONS

Analysis of vibro-percution and normal cutting had revealed the followings:

a) – obtained results had been possible to analyze only by using advanced techniques and computerized data processing along with adequate software in MATLAB language;

c) – the surface roughness obtained of vibro-percution cutting is better than the normal cutting surfaces when the same cutting parameters are used;

d) – deformation of material is complex following a specific pattern: at first the material is deformed after the thin layer model and then after the thick layer model;

e) – microstructure analysis of the deformed layer can offer the possibility of selection of cutting parameters which can give the minimal thickness of th deformed layer and surface roughness.

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