CHIPS SHAPES AT END-MILLING OF OL37 STEEL

Pascu Cristina Ileana[1], Popescu Iulian[1]
[1]University of Craiova
i_pascu@yahoo.com, mediu06@yahoo.com

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Abstract: In this paper a study, based on a factorial experiment, microscopy and shapes chips resulted at milling steel cylinder front-OL37 is presented. Microscopic images and diagrams of the resulted surface and diagrams of obtained roughness are presented. Also, it is explained the phenomena that cause the resulted shapes chips.

1. INTRODUCTION

Milling with end-mills cutters was studied over time in different aspects. The resulted chips after milling have been studied, following such complex phenomena on the cutting area and from the contact surface tool-chip-piece. In [6] some aspects of milling with tools based on silicon carbide are studied, having in view the deposits on the cutting at different cutting regimes, measuring the forces and temperature. In [12] is simulated the milling process, step by step, establishing the forces, roughness and depositions on the cutting edge. In [13] characteristics of resulted surfaces of chips after a steel cutting with different materials and different geometries are studied.

In [7] appear details about formation and control of resulted chips for industrial applications, for this study contributing 60 researchers, in 40 scientific papers. He insisted on chip breaking procedures. Other aspects are given in [4, 5].

2. EXPERIMENTAL PROCEDURE

Factorial experiment was conducted with 15 samples, by executing end-millings on a piece of OL37. On the four-side piece milling areas were delineated (fig. 1). One channel on each area on one side has been milled, and then the piece has been rotated and has been milled areas on a new side and so on.

Fig. 1. Experimental procedure

Milling cutter passed on the part edge, milling being complete. Milling was done on a vertical milling machine.

Although milling was end-milling type, the front surface only interested, like the final surface, because the cylinder area turned into chips.

In some areas that were to be mill network and squares networks have been plotted and other surfaces were painted in different colors to be able to track the formation of chips and splinters, and for know the exterior surfaces of resulted chips.

Chip formation and flow was monitored using an image acquisition and analysis system- SIMI Motion, (SIMI Reality Motion Systems GmbH). The system consists of an ultra-fast camera Panasonic, and Acer - Aspire 3000 Series. The software allowed for the separation of each frame of one second of film.

The tool used was an end-milling cutter from high-speed steel, with D = 20 mm diameter, given in fig. 2.

Fig. 2. End-milling cutter used

The angles of adjustment were $\chi_r = 125^0$, $\chi_r' = 5^0$. Helix angle was 20^0, normal front rake was 12^0, and angle of clearance was 6^0.

Levels of variables are given in table 1.

In table 2 is presented the experimental program.

For cutting depth quotation a_p, the point at the maximum distance from the finished surface has been considered. The cutting feed v_t was in mm/min, speed n in rot/min, cutting depth a_p in mm and cutting speed in m/min.

Table 1.Levels of variables

Parameters		Levels				
Real	Encoded	-2	-1	0	1	2
n, rot/min	x_1	200	315	400	500	630
v_f, mm/min	x_2	10	12,5	16	20	25
a_p , mm	x_3	0,25	0,5	1	1,5	2

Table 2. Experimental program

Sample	Speed n, rot/min	Cutting feed v_f, mm/min	Cutting depth a_p , mm	Cutting speed v, m/min
1	315	12,5	0,5	20
2	500	12,5	0,5	31,4
3	315	20	0,5	20
4	500	20	0,5	31,4
5	315	12,5	1,5	20
6	500	12,5	1,5	31,4
7	315	20	1,5	20
8	500	20	1,5	31,4
9	200	16	1	12,5
10	630	16	1	40
11	400	10	1	25
12	400	25	1	25
13	400	16	0,25	25
14	400	16	2	25
15	400	16	1	25

3. SHAPES OF CHIPS

At the end-milling, at a time, there are two splinted surfaces, one in contact with the cylindrical cutter, and the other in contact with the front of the cutter.

Finite area important for our experiment was the front face, like final surface, so here was measured roughness.

Because of plastic deformation occurring at the cutting process, roughness is correlated with the plastic deformation, which also affects chip results forms and dimensions.

Therefore resulted chips were studied, and based on shooting process followed the formation and removal of chips.

Milled surfaces were studied under a microscope Handheld Digital model # 44300. Also, the aspect of each milled surface was studied.

All these investigations were made to obtain as much information about the milling cutting process.

Samples were made not in order present in table 2, but in order convenient for experiment, starting from the maximum depth of cut, so that adjustments from sample to sample be simpler.

Below gives the results obtained for samples of the experiment, but in order of their performance.

It also specifies that the resulted chips were collected with a magnet, which is why at the shooting and microscopy, they are stuck together. In reality they were independent elements, unrelated.

Sample numbers are given in table 2 so that knowledge can be cutting regime parameters and based on images captured during the experiment certain conclusions can be established taking into consideration the observed on the realized film.

Sample 14

The work area was painted in blue and on it were drawn squares. From the analysis of the obtained film the followings are established:

- milling cutter is initially tangent to the lower side of the rectangle of chips, then penetrate, generating circle with radius increasingly higher until describe a semicircle on the part, then forward;
- drawn squares sides maintain undistorted, and teeth generating clear circular arcs;
- chips crowd in the channels, where some of them are sticked, so the cutter is always surrounded by some chips, even in the area that is not in contact with the piece;
- chips are disposed on the tangential directions to the circle on which the cutter teeth found.

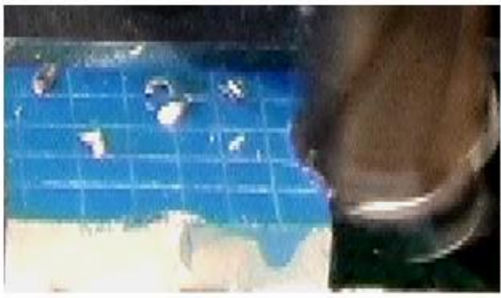
In fig. 3 a sequence of images of the working mill is shown. These images have been obtained by decomposing the film in all images in one second.

For reasons of space only some of these images are presented. Under each picture appears the appropriate time so that you can watch the development of the process in time, at very short intervals.

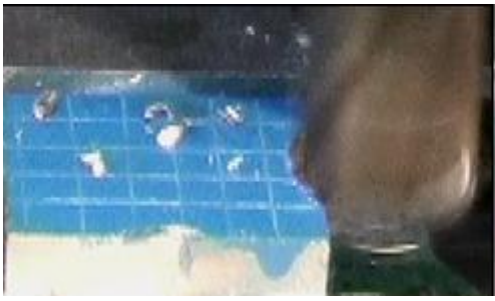
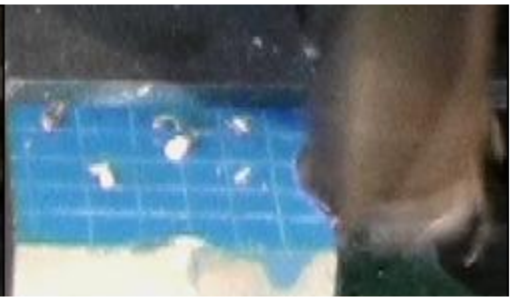
From the analysis of these images (fig.3) can be observed the cutting edge position which cut, appearance of some chips and their evolution.

Chips from this sample (fig. 4 and 5) have large widths and are wrapped, forming helical surfaces, placed approximately on one cylinder, but more to the front surface of the workpiece is reduced the propeller diameter, separation being difficult.


49,820 49,860




49,880 49,900

49,920 49,940

Fig.3. A sequence of images of the working mill at sample 14

Fig.4. Chips from sample 14

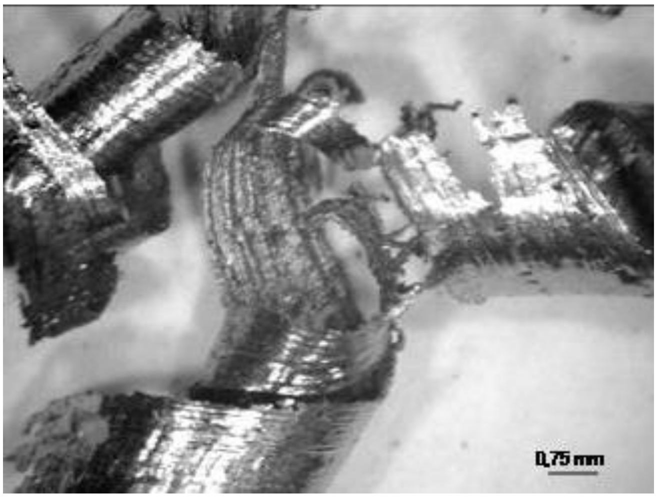


Fig.5. Chips resulted at end-mill of sample 14

From the fig.5 can be observed longitudinal specular flaws on the side that came in contact with the tool edge and longitudinal unpolished flaws on the opposite side.

This opposite side is actually a zone on the piece, machined on previous tooth. In this manner it can see the roughness of cylindrical surface machined on the previous tooth.

Sample 5

For the sample 5 the parameters have been decreased compared with previous sample, chips (fig. 6 and 7) are cylindrical helix by 2.5 turns, but there are some with one spire, that broke out before the edge split from the chip. And also appear longitudinal grooves on both sides of the chip.

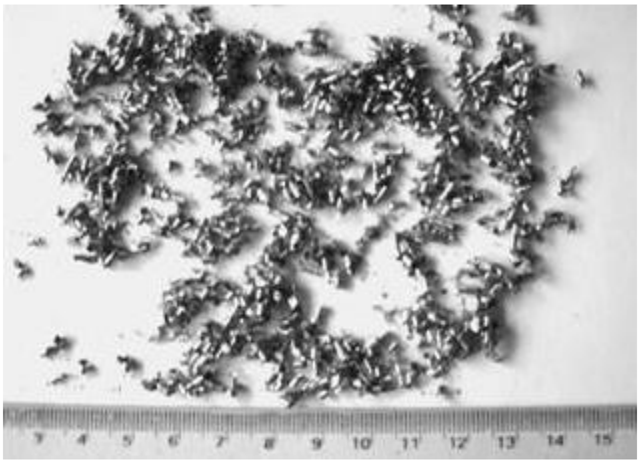


Fig.6. Chips from sample 5

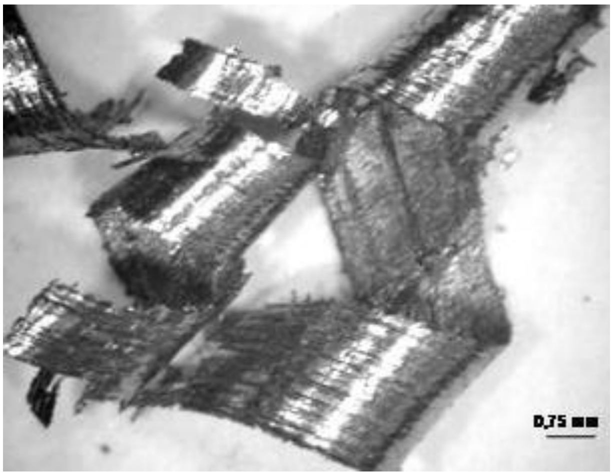


Fig.7. Chips resulted at end-mill of sample 5

Sample 6

For this sample only increased speed from the previous sample.

Chips (fig. 8, 9) are uneven, confusing. Chip width is less than sample 5, although they had same depth of cut. This shows that the chips were quickly broken due to higher speed. One can see that the chip thickness is uneven.

Fig.8. Chips from sample 6

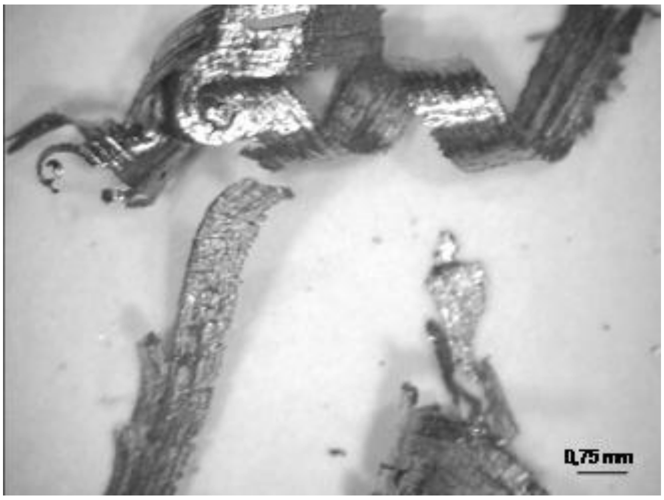


Fig.9. Chips resulted at end-mill of sample 6

Sample 7

Watching the film made, the following have been established:

- at mill cutter entry in the part, chips with small dimensions not observed since entering into the helical channels;
- further, the channels are filled, chips are taken from the channel in the inactive end of the mill cutter where, due to centrifugal forces, some chips are thrown out, others are outside of the mill, stuck to it; these chips are hit with piece that come into contact again and then fall.

Unlike sample 6 to sample 7 the speed decreased and increased the feed. By this, the chips (fig. 10) became thicker, less deformed, so that made propellers have two turns, one with a larger diameter and one with a smaller diameter. In this situation could see that the chip from the front surface is more broken, split identified by red paint on the outside of the sample (the originals are in color).

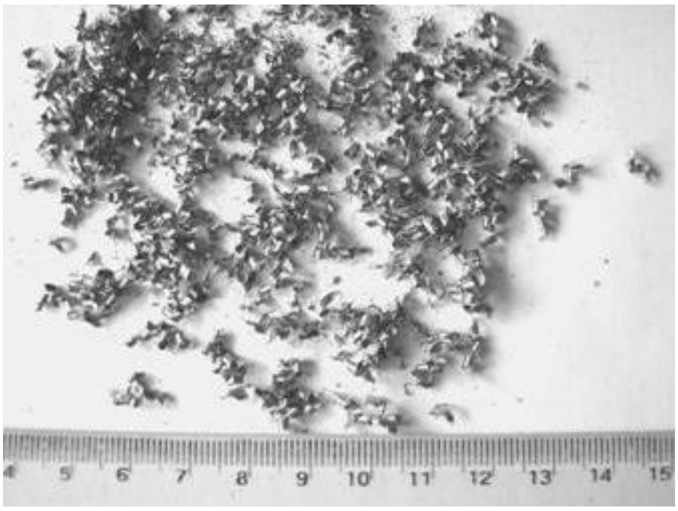


Fig.10. Chips resulted after mill-end of sample 7

Sample 8

Unlike the sample 7, for sample 8 only the speed has been increased. Resulted chips (fig. 11) were up maximum 1.5 turns, like propeller cone, being broken due to high cutting speed. Longitudinal grooves can be observed, with approximately constant step, on the surface that came in contact with the main cutting edge. On its opposite surface, formed scales observed in the evacuation of the chip material from the shear zone.

Fig.11. Chips resulted after mill-end of sample 8

Sample 9

For this sample the lowest cutting speed of the experiment has been used. From watching the film shows that at initial entry o mill cutter into piece, chips go on channels and jump in front, too. After a while around the cutter around a "ring" of chips is formed, speed is low, the centrifugal force is small and chips jump more difficult. Resulted chips (fig. 12) are conical helix with two turns, with few breaks, being fairly uniform.

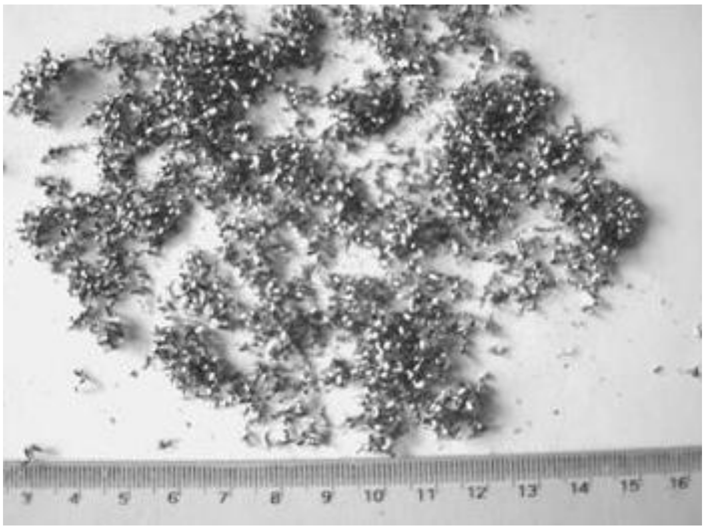


Fig.12. Chips resulted after mill-end of sample 9

Sample 10

Unlike the sample 9, this only speed has been increased. The film shows that first, chips rises channels and are thrown into the mill. Next, the chips are bonded to the channel reach on the area where it not split off and loose, and chips thrown forward and sideways. Fewer chips are thrown to "back" because speed is high, phase separation takes more and chips come forward. Also can be observed that some chips are above on the screw channel and are thrown "on different floors" so at different heights. Resulted chips (fig. 13) were broken, consist of two, three cylindrical helix small diameter, propeller fairly uniform.

Sample 11

For this sample, unlike sample 10, speed and feed have been decreased. Chips (fig. 14) are less broken, smooth. Some chips have two helical turns, but, appear smaller chips having a shape like Greek character ξ . Chips edges from the front surface of the piece have cogs. On the finished surface of the sample similar cogs have been remained, as forms of roughness.

Fig.13. Chips resulted after mill-end of sample 10

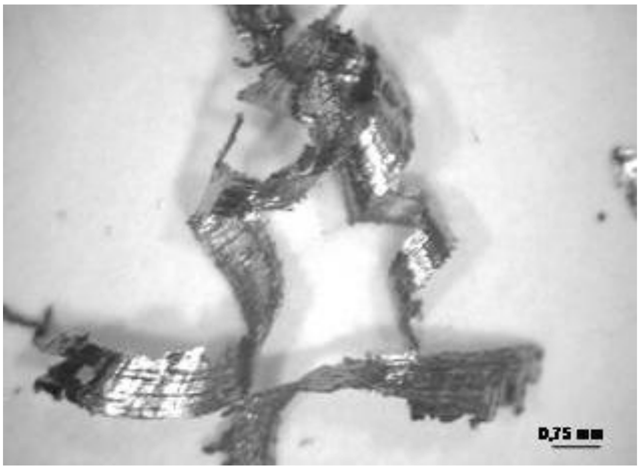


Fig.14. Chips resulted after mill-end of sample 11

It can be observed how the chip area, which came in contact with the edge tool, is specular. On the opposite zone scales can be seen due to compression chips elements resulted in the cutting chips.

Sample 12

Film (fig. 15) shows clearly how chips are formed with variable thickness. Chips fly in front and lateral, and very little on back side. They are strung on the channel, the above are discarded, while those below also include a rotation and then discarded.

Resulted chips (fig. 16) have larger thickness, so deforms hardly. Therefore they are cone-shaped propeller, comma-shaped, and some even like the Greek character ξ. Chip edges are smoother than in the previous case.

Fig.15. A sequence of images of the working mill for sample 12

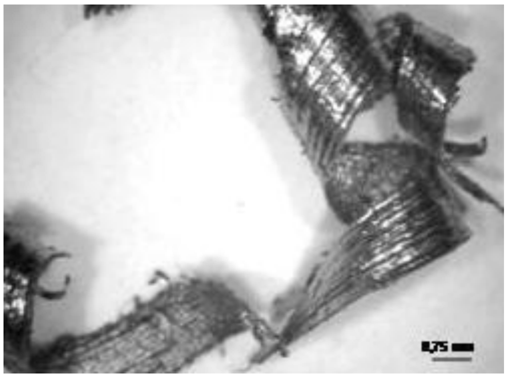


Fig.16. Chips resulted after mill-end of sample 12

Sample 15

For this sample, compared with previous sample 12 only the feed has been decreased. Resulted chips (fig. 17) have smaller thicknesses than the previous ones, so it deforms easily. Because of this, some shapes of chips in propeller cone, and others with bendings have been resulted. There are broken chips, comma-shaped.

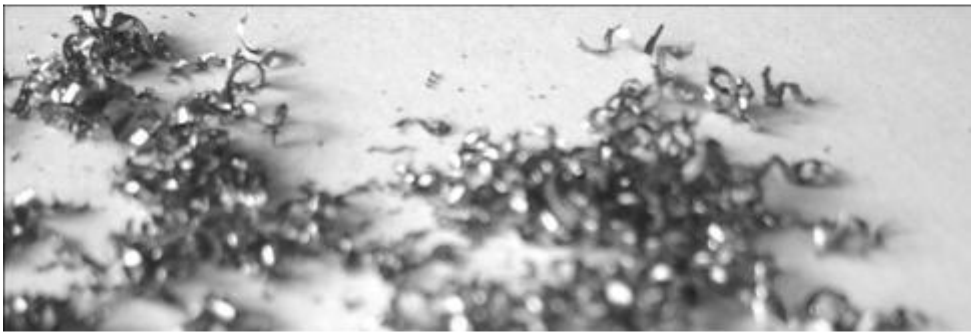


Fig.17. Chips resulted after mill-end of sample 15

Sample 1

For this sample were used finishing regimes. Resulted chips (fig. 18) are cylindrical helix with two turns, but appear broken chips, having shape of ξ Greek character . Widths are small and some unevenness.

Sample 2

The film shows how chips are long and stick to the top of the cylindrical milling area, forming a kind of waist thickened, but are then removed from following cutting edges, moulded other similar. For this sample, unlike the previous sample1 speed has been increased, which caused the chips (fig. 19) to be broken, in the form of commas. Chips appear in the form of a spiral propeller up.

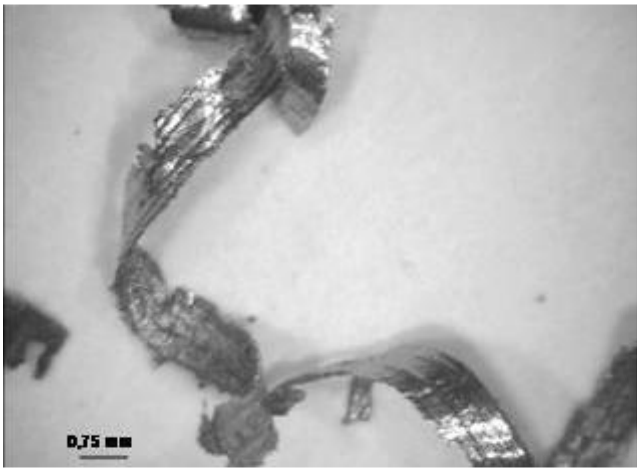


Fig.18. Chips resulted after mill-end of sample 1

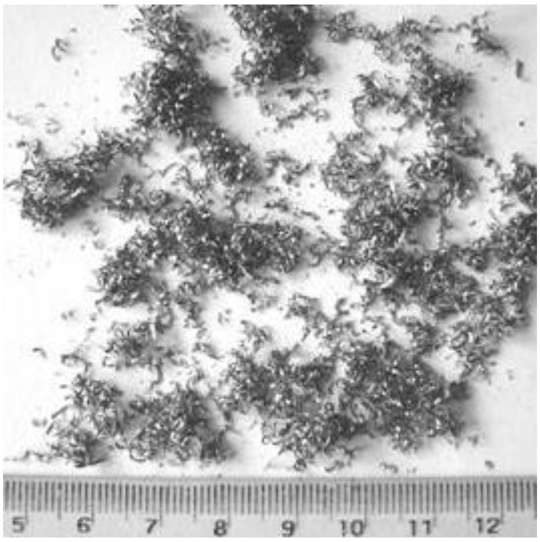


Fig.19. Chips resulted after mill-end of sample 2

Sample 3

For this sample, unlike the previous sample 2, speed has been decreased and feed has been increased. Obtained chips (fig. 20) have thicknesses greater than the previous ones, have the form of cylindrical helix with two turns, but appear chips with one spire. On some edge creases appear, but others are smooth.

Sample 4

For this sample, unlike sample 3, only speed has been increased. Showing he film can be noted that chips are long and stick on cylindrical chipped surface, at the top, forming an area full of chips. They are then removed at the next rotations, but others are formed. Chips resulted (fig. 21) more broken, comma-shaped and some are shaped like a spiral within each propeller. Their edges are fairly uniform, but clusters of particles appear piled on the front face.

Fig.20. Chips resulted after mill-end of sample 3

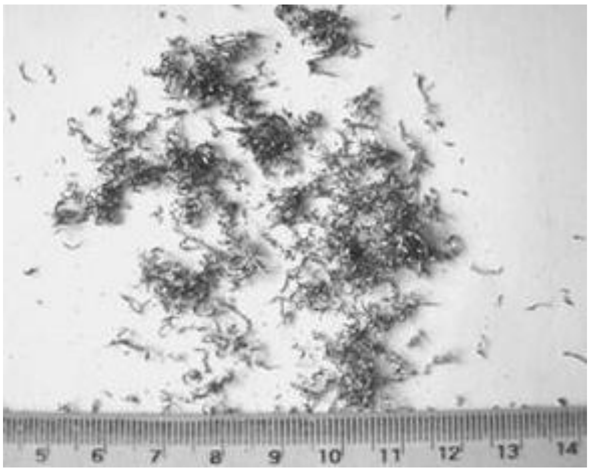


Fig.21. Chips resulted after mill-end of sample 4

Sample 13

This sample had the lowest depth of cut of the experiment. Chips (fig. 22) resulted in the form of propeller conical-shaped and ξ Greek character. Also, broken chips with lower section were obtained. Chip edges were fairly uniform.

Fig.22. Chips resulted after mill-end of sample 13

4. CONCLUSIONS

- Resulted chips are correlated, like shapes and sizes with cutting conditions and phenomena of plastic deformation and heat emanating from the cutting zone.
- Scales were found depending in size with cutting regime, on the chip that did not come in contact with the front face and with more clear surfaces, uniform, on the area that was in contact with the cutter.
- It can be observed the influence of cutting regime on chip forms.

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