Internal Turning of the Polytetrafluoroethylene (Teflon) at High Feed

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Abstract. Experiments were made for the internal turning of Teflon at high feeds, collecting the resulting chips. There were studied the chips and the machined surfaces using a magnifying glass and a microscope. The shapes and dimensions of these chips were analyzed, explaining their correlation with the feed and with the deformation of the chips sections. The cutting process was evaluated by correlating the shapes of the chips with the plastic deformation phenomena occurred in the cutting area. The sections of the chips were measured and their deformability was determined using the cutting relationships. From the analysis of the shapes of the chips, conclusions can be drawn regarding the deformation of the part material in the cutting area, meaning an appreciation of the machinability of the material. All these considerations, as well as the final table regarding the deformation of the chip during processing, show how Teflon behaves during internal turning with high feeds. The measurements carried out during this research showed that significant plastic deformations occur in the cutting area at the internal turning with high feeds of this type of non-metallic material.

Keywords: internal turning · Polytetrafluoroethylene (PTFE · Teflon) · chip section

1 Introduction

An extraordinary versatile material, polytetrafluoroethylene, abbreviated PTFE, was discovered by coincidence, by a young chemist Roy Plunkett at the DuPont Company's Jackson Laboratory in 1938, while making experiments with cooling gases. PTFE (also known as Teflon) is a soft fluorocarbon polymer and has the lowest co-efficient of friction of any solid material. It is greatly effective operating at extreme temperatures, is non-stick and has a fantastic chemical resistance and excellent electrical insulation properties. It is non-melting and is also self-extinguishing [1].

It is widely used in machine building for gaskets and bearings, being resistant to corrosive chemicals. Semi-finished products are made in the form of sheets, rods and pipes. It is used in medical devices, aviation, marine, machine building, and electronics [2]. Teflon is suited for the most demanding environments in commercial, industrial, and aerospace applications due to its exceptional properties [3].

Recommendations for machining Teflon are presented in [4]. Unfilled or virgin PTFE can usually be machined using high-speed steel or high polished carbide tooling without

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Fig. 1. The cutting tool used during experiments

coolants; particularly if the cutting tools are sharp. Filled PTFE, however, is usually abrasive and requires carbide tooling. Machining guidelines for turning PTFE including recommendations for cutting tools geometry, cutting speeds and feed rates and are given by [5, 6]. For designers and users, the unusual versatility of this special plastic material is shown in [7], where design criteria and PTFE processing techniques are presented, including case studies and engineering solutions for industrial applications.

Despite the applicability of polytetrafluoroethylene (PTFE) in various industrial applications, there are relatively few studies on its processing [8]. Research about Teflon machining are a few, like [9], which provide an insight into selecting the optimum machining parameters for machining of PTFE using Genetic algorithm in order to achieve minimum surface roughness. Minimum surface roughness and good surface finish were the primary objectives of turning process on Teflon (PTFE) cylindrical rods. The paper [10] presents the single response optimization of CNC turning parameters using TAGUCHI DESIGN and ANOVA method.

Manufacturers of PTFE machined parts publish recommendations from their experience related to fabrication with correct working feeds, surface finishes, parts measuring or safe handling [11].The study of the shapes of the turning resulting chips and their correlation with the phenomena in the cutting area were made especially for the processing of steel and other metallic materials, such as in [12].

2 Experimental Data

A Teflon bushing with an outer diameter of 58 mm and an inner diameter of 32 mm was machined by internal turning on a normal lathe. The hardness of the used Teflon was 6.2 HV. The turning parameters were as follows: v = 50.24 m / min, the cutting depth $a_p = 0.5$ mm, and the feeds were: f = 0.416; f = 0.5; f = 0.584 mm/rot. No cutting fluid was used. The cutting tool made of High-Speed Steel, with round section of 13.24 mm in diameter, is shown in Fig. 1.The cutting tool geometry: a channel 11.46 x 3.36 with 3.5 mm depth, tool cutting-edge angle $\kappa_r = 110°$, end cutting-edge angle $\kappa_r' = 4°$, tool relief angle $\alpha_n = 18°$; tool rake angle $\gamma_n = 30°$.

3 The Shapes of the Resulting Chips

There were obtained white chips (Fig. 2) and the evaluation of the phenomena in the cutting area was aimed. The resulting chips were continuous, sliding slightly on the

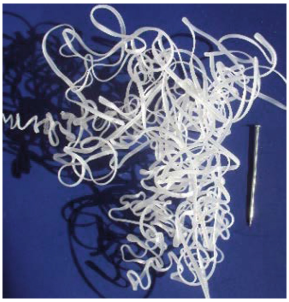

Fig. 2. The resulting chips shape for f = 0.416 mm/rev

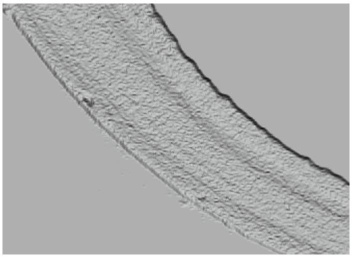

Fig. 3. The width of the chip for f = 0.416 mm/rev

rake face and on the channel made on the tool due to the low coefficient of friction between the Teflon and the tool material High-Speed Steel. When leaving the cutting area, the chips tend to take the form of a ribbon, then bend into a tight roll due to the low strength of their transversal sections. The images of the chips show that in length they are not smooth and have successive shapes of sinusoidal curves, in different planes, with variable steps and amplitudes. The images below also show a pin, considered as scale standard (the images change their size when typing); the pin has a length of 28 mm and a diameter of 0.76 mm.

3.1 Feed F = 0.416 mm/rev

The images obtained for this value of the feed are given in Fig. 2, 3, 4. Here, the chips being thick, there are more areas with less deformed shapes, so with less bends, the chips being more agglomerated.

The width of the chip shows some wrinkles on one edge, a sign of deformation of the chip elements, which come out unevenly from the cutting area and slide against each other (Fig. 3).

Quite uniform traces appear on the surface of the part, but small agglomerations of chips appear too, a sign of uneven plastic deformation (Fig. 4). There are also traces of the corner of the cutting tool.

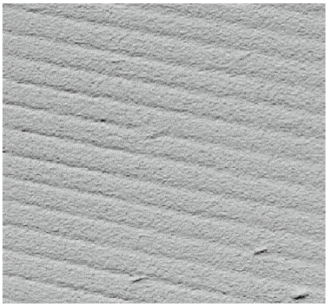

Fig. 4. Processed surface for f = 0.416 mm/rev

Fig. 5. The resulting chips shape for f = 0.5 mm/rev

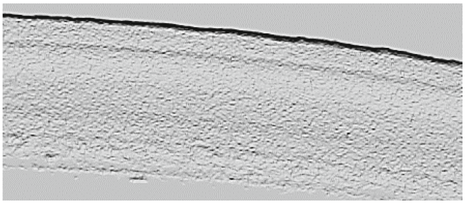

Fig. 6. The width of the chip for f = 0.5 mm/rev

3.2 Feed F = 0.5 mm/rev

For this value of feed, the images presented by Fig. 5, 6, 7 were obtained. The chips are piled up, without areas with large lengths. The shapes were initially circular, then deformed, the explanation being their higher thickness.

Traces of the cutting edge can be seen on the width of the resulting chip, as well as certain cogs or indents, as traces of plastic deformation in the cutting area.

On the surface of the machined part there were noticed traces characterized by a large step, corresponding to the high feed, deeper than those from the previous tests.

Fig. 7. Processed surface for f = 0.5 mm/rev

Fig. 8. The resulting chips shape for f = 0.548 mm/rev

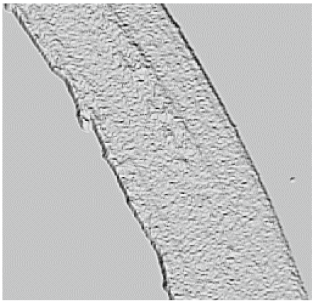

Fig. 9. The width of the chip for f = 0.548 mm/rev

3.3 Feed F = 0.548 mm/rev

The resulting chips are shown in Fig. 8.

Figure 9 shows the variation of the chip width. Analyzing the width of the chip, irregular shapes are found on one of the edges, towards which the elements of the chip have slipped during their forming process.

The machined surface is shown in Fig. 10. On the surface of the piece the channels are difficult to be identified, a sign of tearing out of the chips with high thickness; there are also several traces of deformation during chips removal.

Fig. 10. Processed surface for f = 0.548 mm/rev

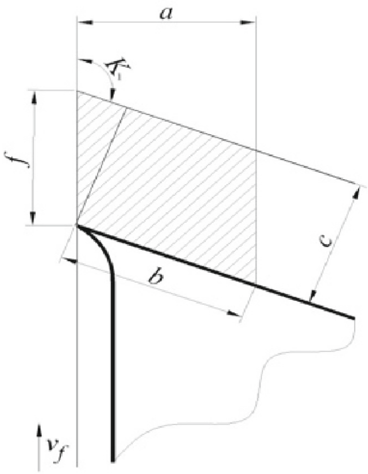

Fig. 11. The theoretical chip section

4 The Dimensions of the Chips

The theoretical section of the resulting chip for this operation is given in Fig. 11. The section of the real resulting chip is given by a1 x b1, dimensions which were measured on the chips. Having a = 0.5 mm and $k_r = 110°$, the result is b = 0.532 mm = constant.

The thickness and width of the resulting chips were measured (a1 and b1), the results being given in Table 1. The table also shows the workability indicators which are the coefficients of chip thickness, k_a, and the coefficients of chip width, k_b, calculated with the following relationships:

$$k_a = a_1/c \tag{1}$$

$$k_b = b1/b \tag{2}$$

Also, in the Fig. 12 the dependencies of the workability indicators, presented in Table 11, versus the high feed values are shown.

Table 1. Results about chip section

f	c	a_1	b_1	k_a	k_b
0.416	0.390912	0.27	0.93	0.6906926	1.74812
0.5	0.4698462	0.37	1.31	0.7874919	2.462406
0.584	0.5487803	0.55	1.33	1.002223	2.5

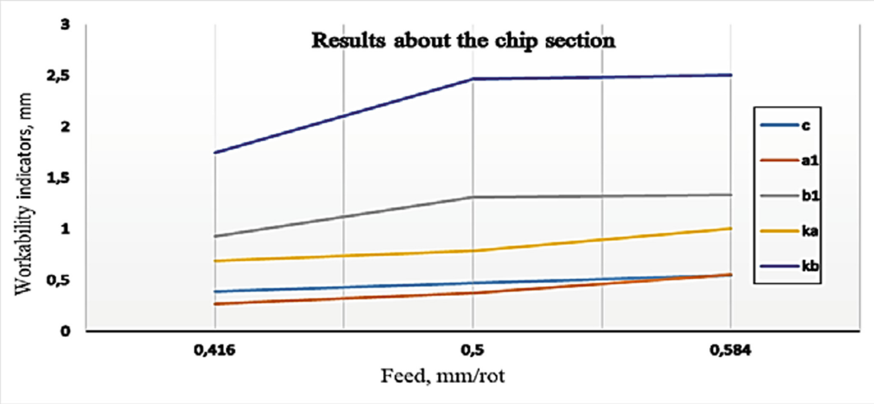

Fig. 12. The variation of the workability indicators relative to feed value

It was found that the resulting chips were thinner than the theoretical ones, so their sections were compressed when feed was f = 0.416 mm/rev. And f = 0.5 mm/rev. The theoretical chips were thinner at feed f = 0.584 mm/rev than the resulting real chips because the feed was increased and the plastic deformation couldn't be high. The coefficients of chip thickness k_a increased, as it was normal. The width of the chip increased with the increase of the feed, the values being higher for the real resulting chips than for the theoretical chips, so the phenomena in the cutting area determined the increase of the chip width and, implicitly, of the values of the coefficients of chip width, k_b.

5 Conclusions

The shape and size of the resulting chips were studied for internal turning of a part made of Teflon, with high feed. Thus, it has been seen how the property of this material to have a low coefficient of friction in relative motion relative to other materials influences the cutting, ensuring the smooth flow of the chips on the face of the cutting tool. Continuous chips were obtained, long, coiled, with large sections. Being resistant, therefore, they no longer formed straight ribbons, but curled in the form of circular arches or sinusoids positioned in space. If this curl is not mechanically guided away from the work, it may wrap around it forcing the work away from the tool. The thickness of the chips was uneven, but the width was quite uniform, with some irregularities on one edge. Traces of the corner of the cutting tool were clearly seen on the machined surfaces, but also rare accumulations of chip elements. Measurements showed that the chips became thicker and wider as the feed increased.

All this proves that in the cutting process of this material there are remarkable plastic deformations in the cutting area as in the case of steel turning.

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