The quality improvement of polymer-surface treatment due to optimal toolpath and cutting parameters

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Abstract. This article discusses the main directions of development in the sphere of polymer edge cutting machining. The authors proposed a special geometry of the cutting tool, as well as the technology for processing the case-shaped part, found on this study.

1. Analysis of information on this topic
Edge cutting machining of plastics materials is widespread. It is one of the most important operations in the general process of polymer-parts manufacturing. The need for such a processing requires studying both practical and theoretical issues of polymer edge cutting machining, and developing optimal designs of cutting tools and rational cutting conditions, as well as special high-performance equipment needed. During development of the machining procedure specification, it should be taken into account that the composition of the plastic besides polymer includes fillers, plasticizers, stabilizing additive, curatives, colourant and other additives, which, in addition to their direct purpose, also affect the processing characteristics of plastics. From this list of components the type of filler alongside the polymer itself has the greatest impact on the machinability of plastics and tool life.

Plastic machining processes have been studied by many scientists and practitioners: B.P. Shtuchny, V.I. Drozhzhin, A. Kobayashi, N.V. Vyrezub and others. Based on these and other works, recommendations were developed on the cutting parameters of various plastics and requirements for a cutting tool.

Recently emerging new types of plastics with special performance properties are difficult to attribute to the previously proposed groups of machinability by cutting. That reality requires additional research and development of new suggestion on their machinability. Nowadays a typical example of a capron-part from bulk polyamide-6 is the case presented in the Figure 1.

Capron is used as a structural, electrical insulating and anti-friction material in various industries for the manufacture of parts for a wide range of purposes.

Capron has high physical and mechanical properties, is resistant to alkalis, oils, hydrocarbons, alcohols, ethers and weak acids; It has a fairly high strength with a low specific gravity and it is six-seven times lighter than bronze or steel. In addition, the low coefficient of friction allows capron to work in friction units without lubrication.
Under normal conditions Caprolon is non-toxic and has no harmful effects on the human body. There is no decomposition of material and no harmful substances under Caprolon edge cutting machining. However, treatment should not be carried out at a temperature about 300°C or higher, since Caprolon decomposes with the release of ammonia, as well as carbon and nitrogen oxides.

Our recommendations for cutting parameters are shown in Table 1.

![Figure 1. Three-dimensional solid model of a Caprolon case-shaped part.](image)

Table 1. Recommended cutting parameters.

| Cutting point material                  | Milling speed, m min⁻¹ | Tool advance | Depth-of-cut, mm |
|----------------------------------------|-------------------------|--------------|-----------------|
| High-speed tool steel or carbides (for turning) | 150÷300                 | 0.1÷0.5 mm/rev. | 1÷5            |
| High-speed tool steel (for milling)     | 100÷200                  | 0.01÷0.03 mm per tooth | 2÷6            |
| Carbides (for milling)                  | 200÷300                  |              |                 |

2. Polymer processing methods

An analysis of the literature [1] shows that the currently used cutting parameters in the processing of polymeric materials are not effective enough, and the resulting surface has a high roughness and surface defects as burrs and overcuts. However, in order to increase the productivity of the polymer cutting process with high quality of the machined surface and dimensional accuracy of the parts, it is necessary to provide intensive cooling of both the cutting tool and the cutting region. It should be noted that the use of conventional cooling media in the processing of plastics is very limited, due to the increased moisture absorption of plastics with a change in the dimensions of the parts and with changes of the mechanical and physical properties of the processed material. In one of the sources [2], it was found that during Caprolon edge cutting machining for cooling the cutting tool and the processed plastics, pre-cooled compressed air could be used.

There have been recorded instances of the use of artificial cold or refrigeration in the implementation of various cutting processes [3]. As sources of cold can be used various refrigeration devices and installations. Previous experience shows that reversible (temporary) changes in mechanical properties during cooling of Caprolon increase its machinability with tool and cutter. This results in a high-quality surface.
Caprolon can be cooled by a low-temperature air flow directly in contact with refrigerant in a special container or in various refrigeration chambers and installations. The application of this method makes it possible to maintain optimal cooling temperatures throughout the processing time.

This is of particular importance when performing complex and time-consuming operations, for example, gear-milling, requiring a significant expenditure of machine time.

Another, no less effective method of cooling polymer materials during machining is to use a stream of compressed, pre-cooled air, in order to prevent thermomechanical destruction of the treated surface layer, while simultaneously improving the cutting parameters and the quality of the processed surface.

However, one should take into account the fact that the implementation of such methods of preliminary preparation of the polymeric materials surface is possible only in the presence of specialized expensive equipment and providing the corresponding conditions of process procedure. That necessitating the developing of new, more technological and economical methods of polymer parts processing.

Next, we considered the developing of an edge cutting machining technology for the case-shaped part, which made of bulk polyamide-6 (Caprolon), and compared the parts processed using traditional technology and the developed technology.

3. Designing a new method
In the NX program we set the necessary cutting tools, rational cutting parameters, a “along the part” cutting pattern with braking in the corners, which is carried out in order to avoid fusion of the workpiece. The program generates the necessary tool path (Figure 2), which by means of the postprocessor is interpreted in the G-code statement.

Processing of the case-shaped part according to the developed technology was carried out on the FADAL VMC 6030 machining center. A triple-fluted cutter for machining was made from P18 high-speed steel. It has 6 mm in diameter, a face sharpening angle of 20° and a back clearance angle of 8°. This cutter tooth profile has a double back formed by milling with an angular-milling cutter.

Figure 3 shows a photograph of the processed case-shaped part according to the old (traditional) technology. Figure 4 shows a new (developed) one. The advantages of the developed technology are the absence of overcuts and burrs on the part, the surface roughnesses after milling is Ra3.2.

Figure 2. The optimal NC cutterpath of the end-milling cutter during the Caprolon processing.
Figure 3. After processing by the old technology the case-shaped part has overcuts and burrs.

Figure 4. After processing with the new technology the case-shaped part is devoid of the above weaknesses.
Conclusions
After analyzing the foregoing, we can conclude that it is advisable to use this method of processing caprolon on CNC machines, with further experimental work with the task to correct the tool geometry and cutting parameters. This processing technology in the submission can be applied to other types of polymers, including polycarbonate.

References
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