

## ANALYSIS OF FORMED CHIPS IN THE CASE OF TURNING DIFFERENT POLYMER MATERIALS

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In this paper, turning input parameters were defined for 12 different polymer materials that can be used in technical practices. Our goal was to determine turning input parameters where chip formation is favourable or continuous chips do not cause any problems. Our tests included the examination of detached chips and the values of the average surface roughness of the machined surfaces.

**Keywords:** chip formation, polymer materials, turning

### 1. Introduction

Nowadays, in addition to the 3D printing of polymers, the machining of polymer and polymer composite materials still plays an important role. Turning is one of the most productive machining technologies used to make cylindrical products. Polymers that exhibit good levels of machinability favour the development of chip formation. However, technical practices often use polymer materials that exhibit favourable properties (hardness, toughness, flexibility) but are difficult to machine. The most common problem is continuously flowing chips. In this case, rather than the chip being moved away from the material, it is pushed in front of the tool. As a result, the heat cannot dissipate from the chips and the detached chips are in constant contact with the tool, which generates additional heat. Since polymers tend to withstand high temperatures less than metals, their machined surfaces melt and their surface roughness becomes unacceptable.

Researchers have already studied the shape of detached chips. The literature is mainly concerned with the study of types of chips generated during the machining of metallic materials such as C45 [1, 2], Al/SiCp [3] and AISI D2 tool steel [4]. Kharlevich and Venuvinod analysed the formation of 3D chips in general as a result of metal cutting [5, 6], while others have researched methods of chip breaking for machining tools [7, 8].

Although chip detachment and formation are very important aspects in machining, in the case of polymers, this area has not yet been investigated.

### 2. Experimental methods

12 different polymer materials were tested, namely PA6 G-H, PA66 GF30, PET TF, PET, POM-C, POM-GF25, POM-H, PP,

PTFE, PVC, textile bakelite and UHMWPE. According to a manufacturer of polymer materials, the aforementioned materials are the most commonly used, excluding the so-called high-performance ones.

In this research, turning tests were performed to determine input parameters that can be used in practice to avoid such problems, e.g. melted surfaces, caused by continuously flowing chips. The turning tests were run on an E 400 conventional lathe machine and an NCT EUROturn-12B CNC lathe machine. Both devices are located in the workshop of the Institute of Technology. In all the experiments, a SCLCR 20.20 K09 tool shank and a CCGT 09T304-AS IC20 polished turning insert were used. After each test, a close-up photo of the surface was taken and the average surface roughness measured. For surface measurements, a Mitutoyo SurfTest SJ-201P surface roughness tester was used. Furthermore, the formed chips were collected before being analysed.

The input parameters of all the tests are shown in [Table 1](#). In the case of roughing, the depth of cut was 3 mm, while a depth of cut of 0.25 mm was used for finishing.

The air-cooled solution was mainly suitable for blowing off the detached chips. At first, all the experiments were tried without implementing any cooling methods. However, in the case of certain materials, flowing chips were formed in all cases, so chip blowing was used for these materials.

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Table 1: Input parameters of all tests

<b>Input parameters for roughing on a CNC lathe machine (NCT EUROturn-12B)</b>						
	PA6 G-H	PA66 GF30	PET TF	PET	POM C	POM GF25
vc (m/min)	250	250	250	250	250	250
f (mm/rot.)	0.2	0.2	0.15	0.15	0.2	0.2
Cooling	-	-	-	-	-	-
	POM H	PP	PTFE	PVC	Textile bakelite	UHMW-PE
vc (m/min)	250	250	250	250	250	250
f (mm/rot.)	0.2	0.2	0.2	0.1	0.2	0.15
Cooling	-	-	-	-	-	-
<b>Input parameters for finishing on a CNC lathe machine (NCT EUROturn-12B)</b>						
	PA-6 G-H	PA-66 GF-30	PET TF	PET	POM C	POM GF-25
vc (m/min)	300	300	300	300	300	300
f (mm/rot.)	0.1	0.1	0.1	0.1	0.1	0.1
Cooling	air	air	air	air	air	air
	POM H	PP	PTFE	PVC	Textile bakelite	UHMW-PE
vc (m/min)	300	300	300	300	300	300
f (mm/rot.)	0.1	0.1	0.1	0.1	0.08	0.1
Cooling	air	air	air	air	-	air
<b>Input parameters for roughing on a conventional lathe machine (E 400)</b>						
	PA-6 G-H	PA-66 GF-30	PET TF	PET	POM C	POM GF-25
vc (m/min)	61	52	59	75	58	52
f (mm/rot.)	0.75	0.75	0.4	0.4	0.6	0.6
Cooling	-	-	-	-	-	-
	POM H	PP	PTFE	PVC	Textile bakelite	UHMW-PE
vc (m/min)	66	76	58	58	59	58
f (mm/rot.)	0.6	0.75	0.6	0.2	0.75	0.4
Cooling	-	-	-	-	-	-
<b>Input parameters for finishing on a conventional lathe machine (E 400)</b>						
	PA-6 G-H	PA-66 GF-30	PET TF	PET	POM C	POM GF-25
vc (m/min)	65	62	63	79	62	62
f (mm/rot.)	0.1	0.1	0.1	0.1	0.1	0.1
Cooling	-	air	air	air	-	air
	POM H	PP	PTFE	PVC	Textile bakelite	UHMW-PE
vc (m/min)	71	80	57	63	63	62
f (mm/rot.)	0.1	0.1	0.1	0.1	0.1	0.1
Cooling	-	air	air	air	-	air

### 3. Results

The input parameters shown in Table 1 can also be considered as results. These parameters were determined experimentally.

In other aspects, however, the main results are the average surface roughness of the machined surfaces and the properties of the detached chips.

Table 2 shows the results of the average surface roughness measurements.

Although other setups can be used, by applying the parameters described above, safe and productive machining can be achieved by avoiding problems caused by con-

tinuously flowing chips.

The detached chips were examined subjectively rather than by making specific measurements. However, the results obtained in this way can be used in practice and provide a suitable point of reference.

Photos of the detached chips in all cases are presented in Fig. 1, while the properties of these chips are shown in Table 3.

### 4. Conclusions

In general, the turning of tough polymeric materials results in the formation of continuous chips. Due to the big

Table 2: Average surface roughness values

Material	Average surface roughness ( $\mu\text{m}$ )			
	NCT EUROturn-12B		E 400	
	Roughing	Finishing	Roughing	Finishing
PA6 G-H	4.06	1.18	12.95	1.58
PA66 GF30	3.12	1.27	12.32	1.55
PET TF	1.73	0.95	5.24	1.47
PET	1.75	0.9	5.18	1.13
POM-C	3.48	0.66	8.62	1.14
POM-GF25	3.75	1.2	8.56	1.43
POM-H	3.44	0.68	8.72	1.14
PP	3.38	0.89	12.72	1.45
PTFE	5.01	1.77	18.44	1.93
PVC	1.01	0.78	2.35	0.87
Textile bakelite	6.81	3.15	10.30	1.59
UHMWPE	2.53	1.81	11.27	1.67

Table 3: Properties of the detached chips

	Properties of the detached chips			
	NCT EUROturn-12B		E 400	
	Roughing	Finishing	Roughing	Finishing
PA6 G-H	5, 6, 7, 8	5, 6, 9	5, 6, 8	3, 4, 7
PA66 GF30	3, 4	4, 5	3, 4	3, 4
PET TF	4, 5	4, 5	3, 10	4, 5
PET	4, 5	4, 5	5, 10	4, 5
POM-C	1, 2	3, 4	1, 2	3, 4
POM-GF25	1, 2	1, 2	1, 2	3, 4
POM-H	1, 2	3, 4	1, 2	3, 4
PP	4, 5, 6	4, 5	3, 8	4, 5
PTFE	3, 4	3, 4	3, 4	3, 4
PVC	4, 5	4, 5	4, 5	3, 4
Textile bakelite	4, 11	11	1, 4, 11	11
UHMWPE	3, 6, 7, 10	3, 6, 9	3, 6, 7, 8	3, 6, 7

1: elemental, 2: rigid, 3: curved, continuously flowing, 4: easy to tear, 5: straight, continuously flowing, 6: tough, 7: stretches, 8: does not tear, 9: tears after being stretched, 10: hard to tear, 11: dust-like

cross-section of chips during the roughing operation, the mass of individual detached chips influences in which direction they start to flow. This is less of a problem because the ventilation effect of the chuck does not adversely affect the cooling of the chips.

In the case of the finishing operation, the cooling of the chips is critical. It is recommended to use air cooling, although not specifically for the purpose of cooling, in order to blow chips away from the workpiece and tool. Even though the quality of the machined surfaces can be improved by tools with bigger radius, chips can still

cause problems. During the experiments, chip blowing was worthwhile in all cases, especially during smoothing operations.

Future research can be conducted by precisely defining the air-cooling method, applying other tools and investigating high-performance polymeric materials. In the case of chip blowing, the distance between the workpiece and the chuck, the weight of the detached chips as well as the ventilation effect of the chuck must be taken into account. The direction and velocity of the air is also significant. It was found that a strong airflow is not always the

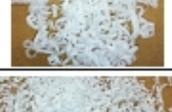
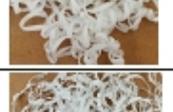
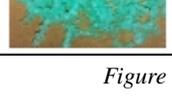
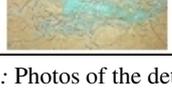
	Photos of the detached chips			
	NCT EUROturn 12-B		E 400	
	Roughing	Finishing	Roughing	Finishing
PA 6 G-H				
PA 66 GF 30				
PET TF				
PET				
POM C				
POM GF 25				
POM H				
PP				
PTFE				
PVC				
Textile bakelite				
UHMW PE				

Figure 1: Photos of the detached chips

most desirable. The distance between the nozzle and the tool is limited by the geometries of the machine as well as the workpiece. By precisely defining these parameters, more practical information can be provided.

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### Nomenclature

$v_c$	cutting speed (m/min)
$f$	feed rate (mm/rotation)
$R_a$	average surface roughness ( $\mu\text{m}$ )
PA6 G-H	cast polyamide 6, Hungarian version
PA66 GF30	polyamide 66 with 30 m/m% glass fiber
PET TF	polyethylene terephthalate with the addition of PTFE

PTFE	polytetrafluoroethylene
PET	polyethylene terephthalate
POM-GF25	polyoxymethylene with 25 m/m% glass fiber
POM-C	polyoxymethylene copolymer
POM-H	polyoxymethylene homopolymer
PP	polypropylene
PVC	polyvinyl chloride
UHMWPE	ultra-high molecular weight polyethylene

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