

CHIP DEFORMATION AND ITS MORPHOLOGY IN ORTHOGONAL CUTTING OF HARDENED STEEL 42CrMo4

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ABSTRACT

The chip formation and morphology are definitely affected by tool geometry and cutting parameters such as cutting speed (v), feed rate (s), and depth of cutting (a). An experiment investigation was presented to study the influence of tool geometry on chip morphology and chip deformation in orthogonal turning. The experiment is realized with the lathe machine IK62. For data process is used a statistic method with five factors. The result obtained in this study showed that tool geometry affected the chip morphology significantly; cutting speed was the most contributively factor.

Keywords: Chip deformation, Cutting tool, Orthogonal Turning, hardened steel

1. INTRODUCTION

Orthogonal machining setups are used to model oblique machining processes. Processes such as turning, drilling, milling, and shaping are all three-force, or oblique, cutting methods. However, the orthogonal model shown in fig. 1. The cutting edge of the tool is perpendicular to the line of tool travel, tangential, longitudinal, and radial forces are in the same plane, and only a single, straight cutting edge is active [1,2,3].

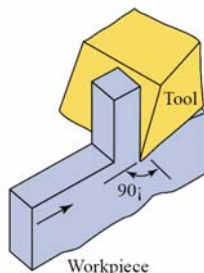


Figure 1. Orthogonal cutting

2. TYPES OF CHIPS AND CONDITIONS FOR FORMATION

Different types of chips of various shape, size, colour etc. are produced by machining depending upon

- type of cut, i.e., continuous (turning, boring etc.) or intermittent cut (milling)

- work material (brittle or ductile etc.)
- cutting tool geometry (rake, cutting angles etc.)
- levels of the cutting velocity and feed (low, medium or high)
- cutting fluid (type of fluid and method of application)

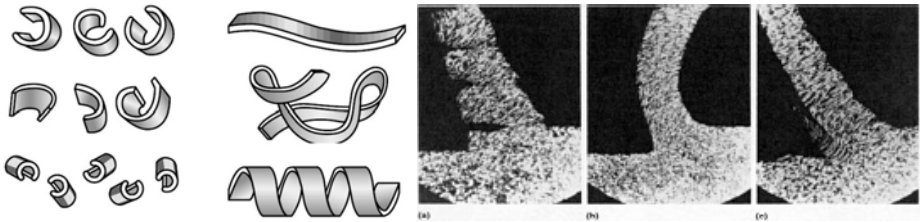


Figure 2 Characteristic types of chips.

The chip is enormously variable in shape and size in industrial machining operations. Figure 2 shows some of the forms [2]. The formation of all types of chips involves a shearing of the work material in the region of a plane extending from the tool edge to the position where the upper surface of the chip leaves the work surface. A very large amount of strain takes place in this region in a very short interval of time, and not all metals and alloys can withstand this strain without fracture. Gray cast iron chips, for example, are always fragmented, and the chips of more ductile materials may be produced as segments, particularly at very low cutting speed. This discontinuous chip is one of the principal classes of chip form, and has the practical advantage that it is easily cleared from the cutting area. Under a majority of cutting conditions, however, ductile metals and alloys do not fracture on the shear plane and a continuous chip is produced. Continuous chips may adopt many shapes - straight, tangled or with different types of helix. Often they have considerable strength, and control of chip shape is one of the problems confronting machinists and tool designers [4].

The cutting parameters also influence chip formation. Cutting parameters include tool materials, tool angles, edge geometries (which change due to wear, cutting speed, feed, and depth of cut), and the cutting environment (machine tool deflections, cutting fluids, and so on). Further complications result from the formation of the built-up edge on the cutting tool.

3. CHIP REDUCTION COEFFICIENT (K_s)

Chip reduction coefficient (K_s) is defined as the ratio of chip thickness (S₁) to the uncut chip thickness (S). This factor, K_s, is an index of the degree of deformation involved in chip formation process during which the thickness of layer increases and the length shrinks. The following figure 3 shows the formation of flat chips under orthogonal cutting conditions.

$$K_s = \frac{s_1}{s} > 1 \quad (1)$$

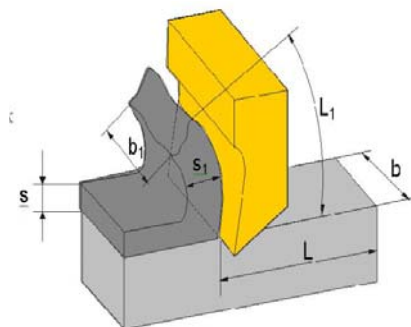


Figure 3. Chip formation

4. CONDITIONS DURING EXPERIMENTATION

For research there have been used cutting plates P30, produced by Sintal-ZAGREB, ISO SNMM120404, SNMM120408, and SNMM120412. Reinforcing have been done on the body of instrument with a sign ISO PSDNN2525P12, on a standard supporter with an outlet 25mm and cutting geometry: $\chi=60^{\circ}$, $\chi_1=45^{\circ}$, $\gamma=-6^{\circ}$, $\alpha=6^{\circ}$, $\lambda=-6^{\circ}$, $r_{\epsilon}=0.4\text{mm}$, $b_r=0.2\text{mm}$, $\gamma_r=-20^{\circ}$.

Researching material – Hardened Steel 42CrMo4 (cylindrical shape) with dimensions $\Phi 68 \times 750 / \Phi 48.5 \times 750\text{mm}$, and with strength $R_m=880 \text{ N/mm}^2 \div 1080 \text{ N/mm}^2$. Processing with cutting have been realized with horizontal late IK62: $P=10 \text{ kW}$, maximal working diameter 400 mm, $n = (12.5 \div 2000) \text{ rev/min}$, feed $s = (0.035 \div 2.08) \text{ mm/rev}$.

Processing with cutting have been realized with a holding of the processing piece, with new edge, without cooling equipment, with changing of parameters v , s , a , r & χ (table 1), with applying the experimental plan of five factors of a first order $y=2^k+N_0$.

Table.1. Conditions for experiment realization

Independent variables with levels and coding identification					
\sum	Note	Level Code	Maximal 1	Average 0	Minimal -1
1	v [m/min]	X_1	67.000	53.000	42.000
2	s [mm/rev]	X_2	0.042	0.038	0.035
3	a [mm]	X_3	1.000	0.707	0.500
4	r [mm]	X_4	1.200	0.800	0.400
5	χ [°]	X_5	60.000	51.000	45.000

Tab.2. Derived results during experiment realization

\sum	Design cutting condition					results	
	v [m/min]	s [mm/rev]	a [mm]	r [mm]	χ [°]	K	$Y=\ln K$
1	42	0.035	0.5	0.4	45	2.826	1.039
2	67	0.035	0.5	0.4	45	3.314	1.198
3	42	0.042	0.5	0.4	45	2.820	1.037
4	67	0.042	0.5	0.4	45	3.404	1.225
5	42	0.035	1.0	0.4	45	2.805	1.031
6	67	0.035	1.0	0.4	45	3.311	1.197
7	42	0.042	1.0	0.4	45	2.812	1.034
8	67	0.042	1.0	0.4	45	3.367	1.214
9	42	0.035	0.5	1.2	45	3.785	1.331
10	67	0.035	0.5	1.2	45	3.435	1.234
11	42	0.042	0.5	1.2	45	2.435	0.890
12	67	0.042	0.5	1.2	45	3.422	1.230
13	42	0.035	1.0	1.2	45	2.789	1.026
14	67	0.035	1.0	1.2	45	3.439	1.235
15	42	0.042	1.0	1.2	45	2.720	1.001
16	67	0.042	1.0	1.2	45	3.432	1.233
17	42	0.035	0.5	0.4	60	2.852	1.048
18	67	0.035	0.5	0.4	60	4.397	1.481
19	42	0.042	0.5	0.4	60	4.327	1.465
20	67	0.042	0.5	0.4	60	4.814	1.572
21	42	0.035	1.0	0.4	60	3.922	1.367
22	67	0.035	1.0	0.4	60	3.318	1.199
23	42	0.042	1.0	0.4	60	4.318	1.463
24	67	0.042	1.0	0.4	60	4.874	1.584
25	42	0.035	0.5	1.2	60	3.792	1.333
26	67	0.035	0.5	1.2	60	4.442	1.491
27	42	0.042	0.5	1.2	60	3.721	1.314
28	67	0.042	0.5	1.2	60	4.432	1.489
29	42	0.035	1.0	1.2	60	3.795	1.334
30	67	0.035	1.0	1.2	60	4.451	1.493
31	42	0.042	1.0	1.2	60	3.728	1.316
32	67	0.042	1.0	1.2	60	4.442	1.491
33	53	0.038	0.7	0.8	51	3.125	1.139
34	53	0.038	0.7	0.8	51	3.125	1.139
35	53	0.038	0.7	0.8	51	3.125	1.139
36	53	0.038	0.7	0.8	51	3.125	1.139
37	53	0.038	0.7	0.8	51	3.125	1.139
38	53	0.038	0.7	0.8	51	3.125	1.139

5. ANALIZING OF RESEARCH RESULTS

The level of plastic deformation of metals in the process of chip formation is quantitatively evaluated with the chip reduction. The coefficient of chip reduction is different for different materials, and to a greater extent depends on the cutting speed (v) and front angle of cutting wedge (γ).

During the research we have followed the change of chip reduction. For the description of this change there has been adopted the mathematical model (1):

$$K_s = 7.170 \cdot v^{-0.303} \cdot s^{-0.225} \cdot a^{0.22} \cdot r^{0.19} \cdot \chi^{-0.026} \quad (2)$$

Interpretation of mathematical model (2) is given in the fig.4

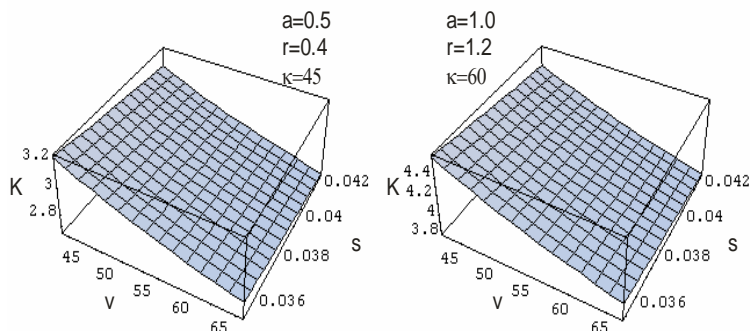


Figure 4. Graphical interpretation of the mathematical models (2)

4. CONCLUSION

Based on the analysis of the results acquired through experimental research, table 2, mathematical model (2) and its graphical interpretation, we may conclude that:

Change of the of chip reduction coefficient can be described with the function of exponential form; With the increase of cutting speed, cutting step and cutting angle, the chip reduction coefficient of is decreased.

Increase in radius of rounding the cutting blade and cutting depth have an impact on the increase of the chip reduction coefficient.

5. REFERENCE

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