CHIP FORMATION DURING MILLING OF STAINLESS STEELS

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Abstract

Milling of stainless steels is one of the most challenging machining processes. General aim is to achieve high productivity required surface finish and minimize costs. The main prerequisite for the successful management of these criteria is the perfect knowledge of milling technology. Each type of material has different properties, for example chemical, mechanical, thermal, or other, and it is therefore necessary to choose the correct parameters for the production efficiency.

The market has found plenty of companies engaged in the development of machine tools and for these companies may be the issue of testing chip formation in milling stainless steel interesting topic. Most of these companies also deals with the development of inserts. The aim of the research was to obtain knowledge about the properties of stainless steel in face milling. To determine these properties were used practical tests on selected stainless steels. Part of this work is the testing inserts of selected companies and on the results are proposed recommendations on selection of inserts for milling stainless steels with regard to the effective geometry of the inserts.

Keywords: Milling, Stainless Steel, Insert

1. INTRODUCTION

Experience has shown that the machining of stainless steel is more difficult than normal machining of structural steels. At machining of tough materials exists a lot of difficulties, mainly because their machinability is adversely affected by their high tendency to work hardening of cold, low thermal conductivity and good toughness. This fact was the reason for the research experiment whose objective was to determine which tool is suitable for machining stainless steels.

2. STAINLESS STEEL

Stainless steel belongs to a group of alloy steel, which is warranted exact chemical composition, the specific conditions of production and specific test conditions. These steels contain a minimum of 10,5 % chromium and in comparison with unalloyed steels exhibit a significantly better corrosion resistance. Higher contents of chromium and other portions of alloying elements such as nickel and molybdenum, the corrosion resistance increase. Furthermore, it is possible alloying by other elements, which positively affect other properties, such as:

- Niobium, Titanium - resistance to intergranular corrosion
- Nitrogen - strength, corrosion resistance,
- Sulfur - machinability.

In the use of stainless steel are increasing demands on their property and that there are two main routes:

- stainless steel development on the basis of new or changed chemical composition,
- the introduction progressive production technology and existing stainless steel and their processing.

In recent years in improving the properties of stainless steels typically pursue new technology, especially metallurgical processes aimed at increasing the purity and high quality stainless steel structure. In some cases, stainless steel developed for a specific manufacturing process technology. Each type of stainless steel has its own specific properties and corrosion resistance in specific environments. [5]

2.1 An overview the most using stainless steel on the Czech market

Stainless steels are numerous. The aim was to identify the most commonly used steel in the Czech market. It was contact many suppliers of metallurgical materials, which stainless steels are the most demanded and sold, or in what quantities. Thanks the provided information can be build a table the most widely used stainless steel on the Czech market.

For the practical tests have been selected three types of stainless steels. By marking CSN 10088-1 is a steel 1.4301, 1.4541 and 1.4404.

3. DESCRIPTION AND CHARACTERISTICS OF TOOLS FOR CUTTING STAINLESS STEEL

For the experiments were selected for face milling cutter from Seco Tools Swedish Company, the type of R220.43-0063-05-6A. Inserts, which will be subjected to experimental tests, were selected from the two companies, which are deemed successful geometry market. It is a Swedish company inserts SECO TOOLS and Korean company TaeguTec. In the selection specific types of inserts into account the recommendations of the producers themselves inserts. Individual inserts have their structures, which are described below.

3.1 Tool from SECO Company

From SECO was chosen Cutter - designed for face milling R220.43-0063-05-6A (**Fig. 1, Fig 2**). It is generalist front cutter for various types of milling operations in all materials. It has beds and a small pitch. Specifications are listed in **Table 1**:

- dextrorotary,
- attaching with a mandrel,
- insert size 5 mm (length of the cutting edge)
- with openings for internal cooling. [3]

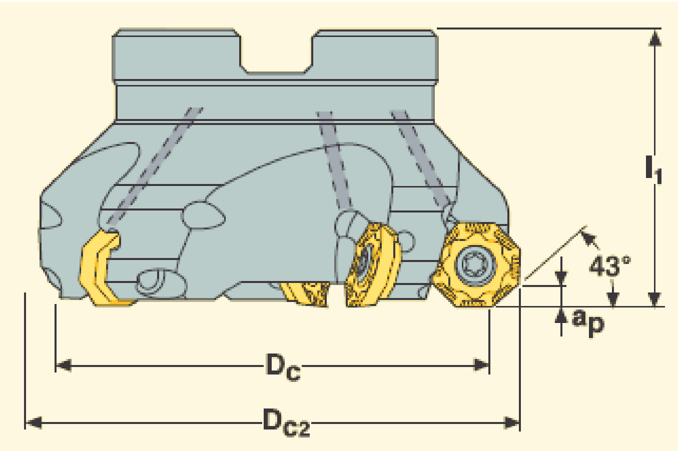

Fig. 1 Dimensions of tools [3]

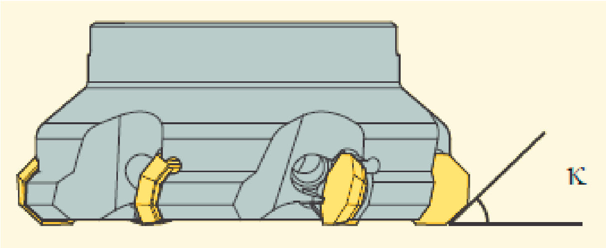

Fig. 2 The angle of the cutting edge [3]

Table 1 Technical parameters SECO cutter [3]

Dimensions (mm)				Dimensions (°)				Tooth no. (-)	Mass (kg)
D_{C2}	D_C	l_1	a_p	γ_o	γ_p	γ_f	κ	z	m
63	72	40	3.5	+15°	+15°	+5°	+43°	6	0.5

Into tool were fixed inserts with two different geometries and two different materials:

- OFEX05T305TN-ME07; F40M (PVD) a T350M (CVD) - inserts suitable for machining of materials from M group according to ISO 513. Insert is peripheral grinding and it has grinded contact of inserts. Insert is made of carbide that is doped tungsten, cobalt, chromium and carbon. See in **Fig. 3**.
- OFMT050405TR-M14; F40M (PVD) a T350M (CVD) - inserts suitable for machining of materials from M group according to ISO 513. Insert is not peripheral grinding but it has grinded contact of inserts. Insert is made of carbide that is doped tungsten, cobalt, chromium and carbon. Inserts are PVD and CVD coating. See in **Fig. 4**. [3]

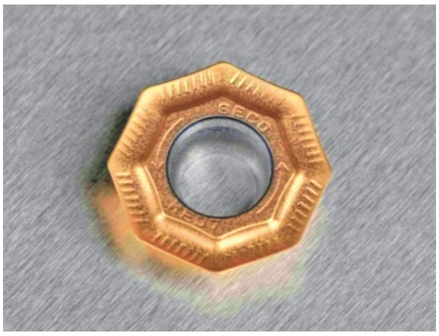

Fig. 3 OFEX05T305TN-ME07; F40M [3]

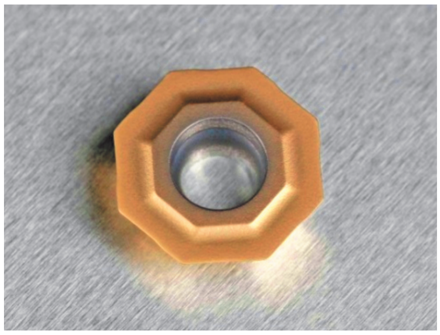

Fig. 4 OFMT050405TR-M14; F40M [3]

3.2 Tools from TaeguTec Company

From the Korean manufacturer of cutting tools were selected two geometry inserts:

- OFMT05T3TN-ML; TT9080 (TT7800) - inserts again suitable for machining of materials from M group according to ISO 513. Grinded is only the bearing surface of inserts. Inserts is made from carbide with PVD coating and it is alloyed with titanium, aluminum and nitrogen (see in **Fig .5**). Inserts CVD is marked as TT7800.
- OFCT05T3TN-EM; TT9080 (TT7800) - inserts again suitable for machining of materials from M group according to ISO 513. Grinded is only the bearing surface of inserts. Inserts is made from carbide with PVD coating labeled TT9800 (see in **Fig 6**). Inserts CVD is labeled as TT7800. [4]

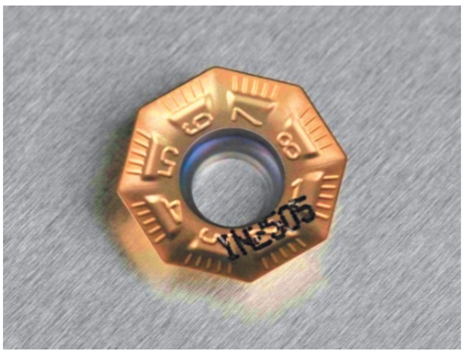

Fig. 5 OFMT05T3TN-ML; TT9080 [4]

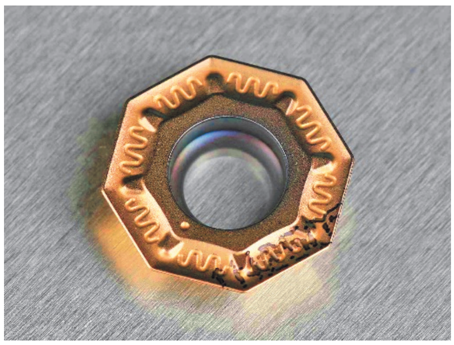

Fig. 6 OFCT05T3TN-EM; TT9080 [4]

4. CHIP FORMATION TESTING

Experimental machining tests were carried out in the laboratory of Pramet machining tools. Before machining testing, the inserts were measured. Measurement is focused on the actual size of the insert and to:

- measuring the curvature of the cutting edge
- dimensions of the facets.

Practical tests focused on the chip formation are carried out on a milling machine type FCV SCA 63 (**Fig. 7**).

Fig. 7 Milling machine FCV 63 SCA

4.1 The choice of cutting parameters

At choosing cutting conditions take account of the recommendations of the inserts manufacturer and experience of the Pramet Tools Company. Cutting parameters are listed in **Table 2**.

Table 2 The selected cutting parameters

Title	Value	
Depth of cut a_p	1 a 2.5 mm	
Cutting width a_e	50 mm	
Cutting speed v_c	150 m · min^{-1}	
Rotation n	758 min^{-1}	
Feed per tooth f_z	0.09 mm · tooth^{-1}	0.18 mm · tooth^{-1}
Feed *f*	409 mm · min^{-1}	819 mm · min^{-1}

4.2 Testing procedures

In practical tests was clamped first machined stainless steel. Subsequently, was made samples of 4 chips. Then to the milling tool were mounted another type of inserts. After the substitution of all four types of CVD-coated inserts (2 SECO geometry and 2 TaeguTec geometry) was replaced first stainless steel for following and continued in the same order. Milling was carried out with full fitting of inserts in the milling cutter. Before the start of machining there was an alignment of surface. This is a test to obtain a block plane and to ensure a constant depth of cut.

During the test chip formation was also measured roughness of the machined surface. Measuring of machined surface roughness was carried out after each change of cutting conditions, so after every working tool travel. The roughness was measured by surface roughness indicator Jenoptik Hommel - Etamic W5. [1]

During functional testing was also measured hardness of each stainless steel. Measurements were performed on machined surface by hardness tester EQUOTIP.

4.3 Evaluation of results

At analyzing of chips we characterize the chip shape, its thickness and other parameters. General aim is to get the most heat generated during machining walked away with the chip and chip temperature did not affect machined surface and the tool itself. It is important that chip flow was smooth and not damage the machined surface and tool.

The most characteristics of the chip affecting:

- depth of cut a_p,
- cutting speed v_c,
- feed per tooth f_z,
- chipbreaker. [6]

An important feature of the chip is that there is a regular breaking of a chip formation. For the most part the chip shape is affected of by the chipbreaker molded on the face insert. Best chip formation went at Inserts from Seco Tools, specifically OFEX05T305TN-ME07, T350M, and it was for all cutting conditions. The other three types of Inserts also satisfactorily shaped chips, but with some changes the cutting parameters occurred bending of chips. It is because of a difficult chip removal, which can affect the quality of the machined surface. [2]

Table 3 Achievements shapes of chips and measured values Ra and Rz

a_e = 50 mm a_p (mm)	**Insert: OFEXO5T305TNME07; T350M**	**Material: CSN 17 248.4, DIN 1.4541 120 HB; v_c=150 m·min^{-1}, n=758 min^{-1}**
1		
Ra (µm) / Rz (µm)	0.26 / 2.4	0.30 / 2.12
2.5		
Ra (µm) / Rz (µm)	0.40 / 2.54	0.48 / 3.90
Feed per tooth f_z (mm·tooth^{-1})	0.09	0.18
Feed f (min^{-1})	409	819

For each type of inserts a chip in the vast majority of retained its regular shape. It is a spiral shape, as the size of chips corresponding to the cutting depth a_p and feed per tooth f_z. The identified and measured data table was created with pictures of all chips and measured values of roughness. Because of the breadth of it cannot be the whole state in the paper, therefore, in **Table 3** there are only sample of data for the insert, which was evaluated as the best of all tested.

CONCLUSION

The object of the research was to face milling of stainless steels. Included was acquainting with stainless steels and conduct market research, in order to establish the most widely used steel on the Czech market. For this purpose was contacted many suppliers of metallurgical materials and then it was built table of most widely used stainless steel, and for experiments were choose 3 most widely used stainless steel. Before starting the practical test was necessary to determine the properties and practical application of selected steels. Subsequently, inserts was measured. This gave values of curvature of the cutting edges and the width of the facets.

Practical tests were focused on chip formation in milling. In all these types of inserts, except for minor deviations, showed similar chip formation. The best led inserts from SECO geometry ME07 (marking plates OFEX05T305TN-ME07). The results of surface roughness measured (**Table 3**) showed the best values of roughness were obtained using inserts from type OFEXO5T305TN SECO-ME07, T350M (**Fig. 3**), and both the depth of cut a_p = 1 mm, and in depth of cut a_p = 2,5 mm at both tested the feed per tooth f_z. This success certainly helped by the fact that this type of insert is the only peripheral grinding.

Conversely, tool geometry from TaeguTec EM proved completely unsuitable for machining of stainless steels, although the manufacturer recommended for this area. It would be interesting to examine this geometry, how would when cutting low alloy steels.

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