16th International Research/Expert Conference
”Trends in the Development of Machinery and Associated Technology”
TMT 2012, Dubai, UAE, 10-12 September 2012

EXPERIMENTAL MILLING TESTS OF CUTTING TOOLS AT STAINLESS STEEL

Robert Cep, Adam Janasek, Lenka Cepova, Jana Petru, Ondrej Dupala
VŠB – Technical University of Ostrava
Faculty of Mechanical Engineering
17. listopadu 15
708 33 Ostrava – Poruba
Czech Republic

ABSTRACT
The article is focused on the issue of cutting tools for group of materials M, according to ISO 513, more specifically the area of stainless steel machining. The main objective is to do a practical comparison of selected milling cutters and their inserts at machining of the world's leading manufacturers as Pramet Tools, Mitsubishi, Sandvik and Seco. Experimental testing is focused on functional cutting tests at machining which aim is to test and check significant methods as technique of chip formation during cutting, trajectory of chips leaving, shape and size of chip, tool's operation in cut (noisiness, vibration) or tool's operation in cut at various axial depths of cut. Selected tests will be performed on the milling centre - Kovosvit MAS MCV 1270 Power, and stainless steel X2CrNiMo17-12-2 will be selected as machined material.
Keywords: Machining, Indexable Cutting Inserts, Stainless Steel, Functional Machining Test

1. INTRODUCTION

Engineering, especially automotive industry is one of the main sectors of the economy for each country. Around the world, there were about 806 million cars and light trucks on the road. The current production rate, high productivity and cost reduction at machining, not only stainless steels, requires a high demand for machine tools with indexable cutting inserts.

The article is focused on the issue of cutting tools for group of materials M, according to ISO 513, more specifically the area of stainless steel for machining. [1] In the current range Pramet Tools, s.r.o. Šumperk Company are milling tools, which are in terms of productivity labour at a lower level than competitive tools of new generation, thanks to its construction and use. Upgrading the existing product range is inevitable. All cutting tool makers must develop tools that can machine the new materials at the highest possible levels of productivity. The development process should be continuous and interactive.

The aim is to analyze the current range of Pramet milling tools and competition on the domestic market. In addition to identify and select three competitive solutions, tested these solutions and try out on laboratory.

2. FUNCTIONAL MACHINING TEST

Input cutting tests are carried out for initial verification of the tool's functionality. The main object is to test and check follows:

1. Trajectory of chip leaving from cutting process;
2. Chip's characteristics – shape and size of chip;
3. Operation of tool at machining process - noisiness, vibration, trembling effect;
4. Axial depth of cut $a_{p\,max}$ at different depths.

2.1. Machine Tool, Testing Material, Indexable Cutting Inserts

Machining tests are performed at Pramet laboratory. The laboratory is equipped with a CNC Milling Centre MCV 1270 Power, manufacturer Kovosvit MAS (Figure 1). [10] Function tests performed on stainless steel, grade 17 349.4 (*EN ISO: X2CrNiMo17-12 2, DIN: X2 CrNiMo 18 14 3*). The three main representatives were chosen from the list of competing manufacturers of milling tools for machining stainless steels. Selected manufacturers have a significant position in the domestic market. Mill concepts are among the most successful in planar milling.

Figure 1. Milling Center MCV 1270 Power set in the laboratory.

Table 1. Milling cutters: basic technical data of competitive milling tools. [2,3,4,5]

Manufacturer's Logo	Marking Milling Cutter	Tool Minor Cutting Edge Angle κ_r (°)	Geometry (γ_p / γ_f) (°)	Axial Depth of Cut $a_{p\ max}$ (mm)	Marking Indexable Cutting Insert (ISO 513)
MITSUBISHI	ASX445	45	+20 / -13	6.0	SEET 13T3AGEN-JL SEMT 13T3AGSN-JM SEMT 13T3AGSN-JH
SECO	220.53-12	45	+20 / -5	6.0	SEEX 1204AFTN-M14 SEEX 1204AFN-M10 SEMX 1204AFTN-M15
SANDVIK	345	45	not stated	6.0	345R-1305E-PL 345R-1305M-PL
PRAMET	S45SE12F-A	45	+18 / -6	6.5	SEET 1204AFSN SEEW 1204AFSN

2.2. Trajectory of Chip Leaving from Cutting Process

Analysis of the chip leaving trajectories is important for mapping out the chip leaving direction from the cut. The main requirement is placed on a smooth chip leaving from cutting process and eliminating potential damage of machined surfaces [8]. The chip direction is dependent on milling technique, meshing conditions, i.e. tool's position against the workpiece, insert's geometry and quality of machined material.

2.3. Chip's Characteristics

Chip's characteristics relates with shape and size analysis of material cutting from cutting process. It is important, that the generated heat has not been accumulated into machining material but the largest part of the heat should leave by the chip. Appropriate choice of cutting conditions is the most influenced for this process, i.e. cutting speed v_c and feed per tooth f_z.

2.4. Operation of Tool at Machining Process

Properties for cutting tools are characterized by the emergence of the noisiness, a vibration or trembling effect. All three mentioned properties are unfavourable for machining process. We are trying to minimize these unwanted effects by suitable choice of cutting conditions. The basic prerequisite is the existence of sufficient rigidity of whole system; machine tool-workpiece-tool. The edge mostly works at interrupted cut during milling. At the time of tool's entering into workpiece, the cutting edge is exposed to intensive mechanical shocks, which cause the mechanical stress in the immediate nearness of the edge. This shock can cause brittle edge damage, fracture form, etc. [6]

2.5. Axial Depth of Cut $a_{p\ max}$

The milling process leads to large force-stress of the whole system. The method of clamping for workpiece, discharge of spindle and quill has the largest effect for maximal depth of cut. If we want to use the tool at maximal depth of cut $a_{p\ max}$, we have to fulfill conditions as character and type of milling operations (roughing, semi-roughing, finishing), the quality of machined material, condition and quality of the machined material, rigidity, clamping methods, etc. [7,9]

3. EVALUATION OF MACHINING TEST - FUNCTIONAL MACHINING TEST

3.1. Evaluation - Trajectory of Chip Leaving from Cutting Process

Trajectory of chip leaving from the cutting process is the same for all geometries. The chip leaving is not accompanied by the signs of chip sticking on the cutting edge at testing of both depth of cuts a_p and feeds f_z. A surface damage did not emerge during the whole testing.

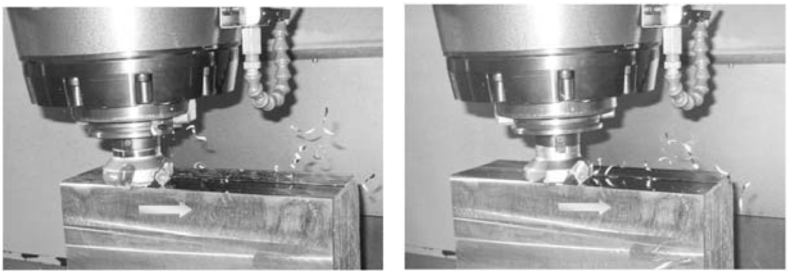

Figure 2. Trajectory of chip leaving from cutting process: (a) Mitsubishi – left; (b) Seco – right.

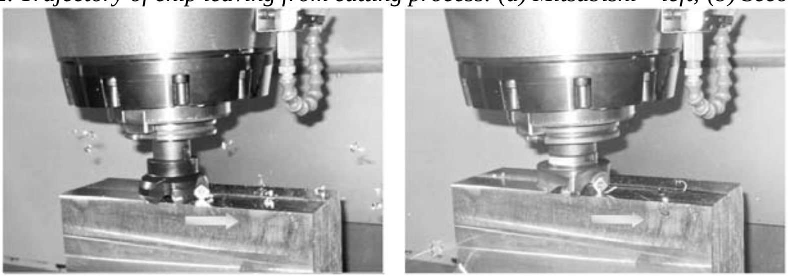

Figure 3. Trajectory of chip leaving from cutting process: (a) Sandvik – left; (b) Pramet – right.

3.2. Evaluation - Chip's Characteristics

The results of cutting tests in terms of chip's characteristics can be summarised that all chips have continuous chips, segmented and coherent. Chip shapes (Mitsubishi, Seco, Pramet) are convenient for smooth chip's leaving from the process and their shape is very good. Sandvik inserts had smooth chip's leaving from the cutting process too, but their shape is not optimal, chips are "*reformed*".

3.3. Operation of Tool at Machining Process

These inserts as (Mitsubishi, Seco and Pramet) formed a very slight trembling effect during machining test. A slight vibration created only at tool's entering into the workpiece, at the axial depth of cut $a_p = 3$ mm. Trembling effect and vibration subsided always at machining of whole milling cutter, with respect to the chosen value of radial depth of cut. Trembling effect and vibration did not arise at lower axial depth of cut $a_p = 1$ mm, which was caused by lower mechanical stress and cutting resistance. Sandvik inserts led to trembling effect and slight vibration, not just at entering of the tool into the workpiece and leaving of cutting process, but during all cutting (applies for both depths $a_p = 1$ mm, $a_p = 3$ mm). This could be attributed by the negative cutter's geometry, which means a higher cutting resistance. Trembling effect and vibration influenced the measured roughness *Ra*, when cutting tool is entering and leaving the cutting process.

Table 2. Ra values at functional machining test: depth of cut (a) a_p = 1mm; (b) a_p = 3 mm.

Manufacturer	Marking Indexable Cutting Insert	Feed per tooth f_z (mm · tooth^{-1})	Roughness R_a (μm) a_p = 1mm	Roughness R_a (μm) a_p = 3 mm
MITSUBISHI	SEET 13T3AGEN-JL; VP30RT	0.10; 0.20	0.74; 1.10	0.86; 1.30
	SEMT 13T3AGSN-JM; VP30RT	0.10; 0.30	0.44; 0.40	0.44; 0.52
	SEMT 13T3AGSN-JH; VP30RT	0.20; 0.40	0.46; 0.70	0.56; 0.80
SECO	SEEX 1204AFTN-M14; F40M	0.15; 0.30	0.24; 0.40	0.42; 0.70
	SEEX 1204AFN-M10; F40M	0.10; 0.20	0.80; 1.90	0.88; 1.50
	SEMX 1204AFTN-M15; F40M	0.10; 0.20	0.52; 0.70	0.52; 0.48

SANDVIK	345R-1305E-PL; 2030	0.08; 0.18	0.40; 0.52	0.30; 0.32
	345R-1305M-PL; 1030	0.08; 0.18	0.70; 1.70	0.60; 0.62
PRAMET	SEET 1204AFSN; 8230	0.20; 0.40	0.80; 1.00	0.80; 1.00
	SEEW 1204AFSN; 8230	0.15; 0.40	0.78; 1.10	0.90; 1.80

3.4. Axial Depth of Cut $a_{p\,max}$

Tests have not been machined at maximal axial depths of cut for verifying the ability to machine stainless steel. We tested only at axial milling depths of cut a_p = 1 mm and a_p = 3 mm. Manufacturers recommend a different maximal axial depth of cut, Mitsubishi $a_{p\,max}$ = 6 mm, Seco $a_{p\,max}$ = 6 mm, Sandvik $a_{p\,max}$ = 6 mm, Pramet $a_{p\,max}$ = 6.5 mm.

Maximal depths of cuts are real for machining group of materials P, according to ISO 513, but unrealistic for group of materials M. Generally, it can be recommended that the maximal depth of cut was about 15 % to 20 % lower. The most important aspect is rigidity of workpiece clamping, rigidity of machining system and also quality of the machined materials. The spindle power is not an important factor for milling by maximal depth of cut $a_{p\,max}$ = 10 mm. Good cutting conditions and sufficient rigidity of workpiece have a high effect on the final quality of the machined surface.

4. CONCLUSION

The main aim was to analyze the current range of Pramet milling tools (manufacturer Pramet Tools, s.r.o. Šumperk Company) and competition on the domestic market. Market analysis of competing solutions for stainless steel milling confirmed, that important position in the market has companies as Mitsubishi Materials, Seco Tools a Sandvik Coromant. The functional tests confirmed the high level of construction for Mitsubishi (type ASX445) and Seco (type R220.53-12). Tested cutters with recommended inserts showed very good machining properties as chip’s formation, visual aspect, shape and size, trajectory of chip leaving from cutting process.

Sandvik Coromant (type 345) with recommended inserts type 345R-1305M-PL and 345R-1305E-PL are not suitable at stainless steel milling, although the manufacturer recommends this tool and he has recommended cutting conditions. The achieved results were really ordinary. The tool’s operation at cutting process was generally worse in comparison with Mitsubishi ASX445 and Seco R220.53-1

The functional tests confirmed the low level of construction for Pramet (type S45SE12F-A). Tested cutter (type 63A05R) with recommended inserts (type SEET 1204AFSN a SEEW 1204AFSN) showed a very good machining properties as chip’s formation, visual aspect, shape and size, trajectory of chip leaving from cutting process.

5. REFERENCES

[1] ČSN - ISO 8688-1 (1993). Cutting Tools. Tool-life testing - milling. Part 1: Planar Milling. Praha: Czech Standardization Institute. (In Slovak)

[2] Mitsubishi Materials Corporation General catalogue – Turning tools, Rotating tools, Tool’s solution: catalogue 2010-2011, (2010), p. 1348

[3] Seco Tools AB Catalogue and technical guide - Milling: catalogue 2009, (2009), p.572

[4] AB Sandvik Coromant (2011). Main Catalogue – Milling: catalogue 2011, p. 336.

[5] Pramet (2009). Milling: cataloque 2009. Pramet Tools, s. r. o., p. 296.

[6] Kocman, K., Prokop, J. Technology of cutting. 1. Publishers: Brno – Academical Publisher CERM, 2001. p 270. ISBN 80-214-1996-2. (In Czech)

[7] ČSN - ISO 513: Classification and use of hard cutting materials for machining – Marking of used groups and subgroups. Praha: Federal Office for Standardization and Measurement, 1995. (In Czech)

[8] Čep, R., Janásek, A., Valíček, J., Čepová, L. (2011). Testing of Greenleaf Ceramic Cutting Tools with and Interrupted Cutting. Tehnički Vjestnik – Technical Gazette. Vol. 18, no. 3, p. 327-332. ISSN 1330-3651.

[9] MM Průmyslové spektrum: Efective Milling for Stainless Steels. Praha: MM publishing, s.r.o., September 2010 [cite 2011-4-25]: available from: http://www.mmspektrum.com/clanek/efektivni-frezovani-nerezovych-oceli>

[10]KOVOSVIT MAS. MCV 1270 Power. [online]. [cite 28. 4. 2008]. Available from: <http://www.kovosvit.cz/cz/mcv-1270/>.