TUNGALOY CERAMIC CUTTING TOOLS AT INTERRUPTED MACHINING

Robert ČEP – Adam JANÁSEK – Marek SADÍLEK – Lenka ČEPOVÁ

Abstract: *The paper deals with testing of ceramic cutting tools with an interrupted machining. Tests have been performed on fixture – interrupted cut simulator constructed at Department of Machining and Assembly, FME, VŠB-TU Ostrava within the scope of the Czech Science Foundation project. The criterion of tool wear is either destruction of cutting tool or 6000 shocks. Testing cutting tool material used in this research is ceramic cutting tool produced by Tungaloy Company. Tested machined materials are 13MoCrV6 and C45 steels. The cutting speeds (408 and 580 m/min) and cutting feeds (0.15; 0.2; 0.25 and 0.3 mm) are investigated with variable parameters whereas the cutting depth is a constant parameter. The pictures of index-able inserts and graphs of dependence at variable cutting speed and cutting feed are shown as a result of a conducted investigation.*

Keywords:
– Machining
– Interrupted Cut
– Ceramic Cutting Tool
– Tests
– Index-able Cutting Insert

1. INTRODUCTION – THE METHODOLOGY OF TOOLS TESTING

Through the centuries, producers of ceramic cutting tools have taken big steps forward. Namely, increasing durability in maintaining high levels of strength and hardness lend a big advantage [2, 6]. Some producers of these materials advise cutting inserts for interrupted machining as a path to be followed at the present time.

Turning tests are focused on machining by smoothly cutting at constant or variable depth of the cut [7]. In this work one of the developed tests has been used. It is longitudinal turning, so-called „slat test". Experiments which are to be conducted require special preparation (Fig. 1), constructed at Department of Machining and Assembly, VŠB – Technical University of Ostrava [5].

The factors related to increasing the tool edge temperature and accelerating the wear are the cutting volume in one cutting cycle, the cooling conditions, and the tool edge shape parameters such as the rake angle and the clearance angle [8].

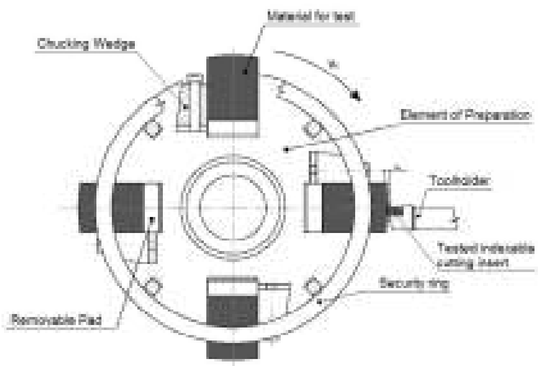

Figure 1. Scheme of preparation [1]

Figure 2. Photo of Interrupted Cut Simulator

The preparation is executed in the shape of a cylinder that contains four exchangeable slats that are clamped in the grooves by the chucking wedge. The basic construction consists of special cylinders which are four milled mortises. Slats can be put under it using washers that provide the stable cutting diameter. The edge of index-able cutting insert is exposed to four shocks during one revolution. The product is also equipped with circ-lips. In order to guarantee a constant depth of chips and to avoid vibration, it is necessary to cut off the first layer of chips before measurements.

2. PARAMETERS – LONGITUDINAL TURNING TEST

2.1. Index-able Cutting Inserts

Ceramic testing cutting tools were supplied by Tungaloy Company. We have tested two types of ceramic index-able cutting inserts:

- FX105,
- CX710.

Our ceramics consist of high-purity fine powder oxides, nitrides, and carbides sintered through normal pressure, gas pressure and HIP sintering. The fine and dense structure ensures superiority in wear resistance, adhesion resistance, oxidation resistance and heat resistance. These grades enable high-speed cutting over a wide range from finishing to light cutting, offering high accuracy and high quality finished surfaces. Ceramics grades are classified into alumina-base and silicon-nitride-base groups, each selectable according to its application. [3]

Table 1. Properties of ceramic cutting inserts [3]

Grade	Features
FX105	A silicon nitride based ceramics used for high speed cutting of cast irons has superior strength, toughness and thermal characteristics in comparison with alumina-base ceramics.
CX710	Si_3N_4 - based ceramics for high speed cutting of cast irons is of higher toughness and heat conductivity than FX105.

2.2. Slats Materials

We chose steels 15 128 (13MoCrV6) and 12 050 (C45) as work piece materials.

Table 2. Chemical composition – 15 128(13MoCrV6) material

C	Mo	Mn	Si	P	S	V	Si	Cr	Al
0.1-0.18	0.4-0.6	0.45-0.7	0.15-0.4	max 0.04	max 0.04	0.22-0.35	0.15-0.4	0.05	0.025

Table 3. Chemical composition – 12 050 (C45) material

C	Mn	Si	P	S	Cu	Ni	Cr	Mo	V	Ti
0.478	0.64	0.24	0.013	0.003	0.02	0.02	0.05	0.005	0.004	0.003

Firstly, the preparation should be clamped to the turning lathe. It is fastened to the turning lathe chuck and buttresses with the tip established in tailstock sleeve. Slats are gradually put in the preparation, which are clamped with wedge-shaped jaws. In order to achieve a constant depth and to avoid vibration, it is necessary to cut off the first layer of chips before measurements can be initiated.

2.3. Cutting Parameters and Cutting Geometry

We have chosen these parameters with regard to manufacturer's recommendation of cutting ceramics and experience of the resolver. The following cutting conditions were chosen for testing these types of cutting materials:

Table 4. Cutting parameters

Cutting parameters			
Cutting speed	v_c [m/min]	408	580
Feed	f [mm]	0.15; 0.20; 0.25; 0.30	
Cutting depth	a_p [mm]	1	

Cutting geometry for ceramics testing cutting tool was chosen with regard to ISO 3685 norm - Tool Life Testing of Single Point Turning Tools [4]. All types of index-able cutting inserts, which are investigated, have a normalized shape SNGN 120716 T02020.

2.4. Machine Turning Tool

Tests were conducted in the laboratories of the Department of Machining and Assembly on the turning-lathe ZMM SLIVEN - see in Figure 3. This turning lathe has a rigid structure which allows for rigid clamping and absorbs shocks very well. The performance of electric machines is 6 kW and reaches the maximum of 2000 RPM.

Figure 3. Turning Machine Tool - ZMM Sliven

2.5. Monitoring the Number of Shocks

The main criterion for measuring the tool life may be tool wear and toolfracture. This moment was noticed while changing the cutting sound, sparking or worsening of surface roughness. The limit value of 6000 shocks was determined on the basis of previous experience in terms of time and material demands. If index-able cutting inserts withstand this value, the experiment can be successfully conducted, and cutting insert will be described as satisfactory. Measurement has been repeated 3 times.

The formula for calculation the number of shocks:

$$R = \frac{4 \cdot l}{f} \quad (1)$$

3. EVALUATION OF MEASUREMENT – NUMBER OF SHOCKS ON FEED

3.1. Tungaloy FX105 - 15 128 (13MoCrV6) material

We can see that FX105 ceramic cutting inserts reached the limited number of shocks at both cutting speeds and all feeds. That means that they have high resistance and ability to perform an interrupted cut in this material. Silicon nitride based ceramics could be used for this material.

Table 5. Measured values for FX105 – 15 128 material

FX105 15 128 (13MoCrV6) material					
v_c = 408 m/min, a_p = 1 mm			v_c = 580 m/min, a_p = 1 mm		
f [mm]	l [mm]	R [-]	f [mm]	l [mm]	R [-]
0.15	225	6000	0.15	225	6000
0.20	300	6000	0.20	300	6000
0.25	375	6000	0.25	375	6000
0.30	450	6000	0.30	450	6000

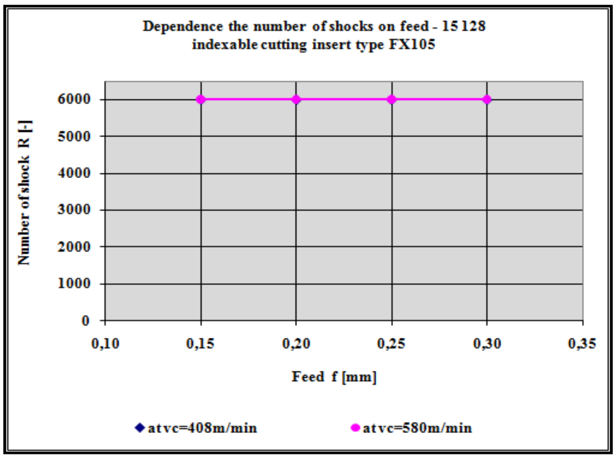

Figure 4. Number of shocks on feed – FX105 inserts

3.2. Tungaloy FX105 – 12 050 (C45) material

From table 6 is evident that FX105 ceramic cutting inserts reached the limit value at lower cutting speed for all feeds. The cutting inserts withstand fewer number of shocks when cutting speed is v_c = 580 m/min. The number of shocks decreases with the increase of the feed value. FX105 ceramic cutting inserts were able to withstand the limit value of 6000 shocks at 0.15 mm and 0.2 mm.

Table 6. Measured values for FX105 –12 050 material

FX105 12 050 (C45) material					
v_c = 408 m/min, a_p = 1 mm			v_c = 580 m/min, a_p = 1 mm		
f [mm]	l [mm]	R [-]	f [mm]	l [mm]	R [-]
0.15	225	6000	0.15	225	6000
0.20	300	6000	0.20	300	6000
0.25	375	6000	0.25	225	3600
0.30	450	6000	0.30	130	1733

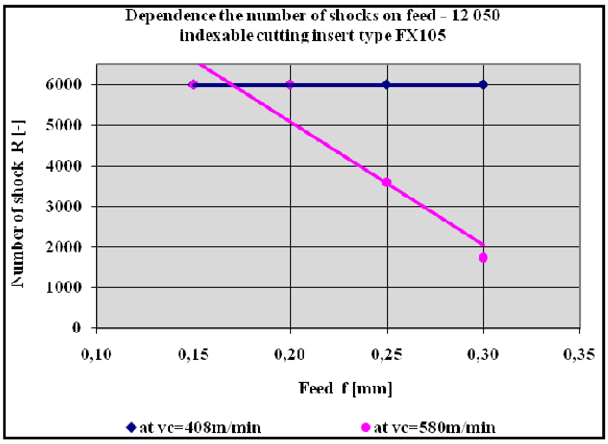

Figure 5. Number of shocks on feed – FX105 inserts

3.3. Tungaloy CX710 - 15 128 (13MoCrV6) material

CX710 ceramic cutting inserts reached the limit number of shocks at both cutting speeds and all tested feeds. That means they have high resistance and ability to perform interrupted cut in this material.

Table 7. Measured values for CX710 – 15 128 material

CX710 15 128 (13MoCrV6) material					
v_c = 408 m/min a_p = 1 mm			v_c = 580 m/min a_p = 1 mm		
f [mm]	l [mm]	R [-]	f [mm]	l [mm]	R [-]
0.15	225	6000	0.15	225	6000
0.20	300	6000	0.20	300	6000
0.25	375	6000	0.25	375	6000
0.30	450	6000	0.30	450	6000

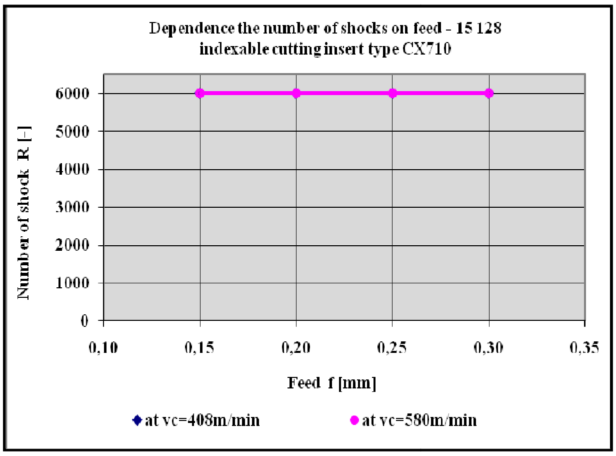

Figure 6. Number of shocks on feed – CX710 inserts

3.4. Tungaloy CX710 – 12 050 (C45) material

CX710 ceramic cutting inserts reached the limit value at lower cutting speed for all feeds. The cutting inserts withstand fewer number of shocks when cutting speed is v_c = 580 m/min than with increasing feed of cutting insert - like in the previous case for the 12 050 (C45) material. The number of shocks decreases with the increase of the feed value. CX710 ceramic cutting inserts were able to withstand the limit value of 6000 shocks at 0.15 mm and 0.2 mm.

Table 8. Measured values for CX710 – 12 050 material

CX710 12 050 (C45) material					
v_c = 408 m/min a_p = 1 mm			v_c = 580 m/min a_p = 1 mm		
f [mm]	l [mm]	R [-]	f [mm]	l [mm]	R [-]
0.15	225	6000	0.15	225	6000
0.20	300	6000	0.20	300	6000
0.25	375	6000	0.25	280	4480
0.30	450	6000	0.30	160	2133

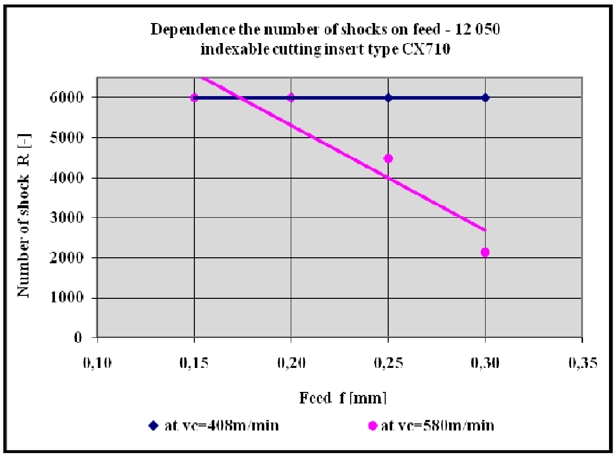

Figure 7. Number of shocks on feed – CX710 inserts

4. EVALUATION OF MEASUREMENT – INDIVIDUAL FEEDS

We have processed all measured values for all tested types of ceramic cutting inserts provided by Tungaloy Company. The results for all feeds are displayed in the following diagrams.

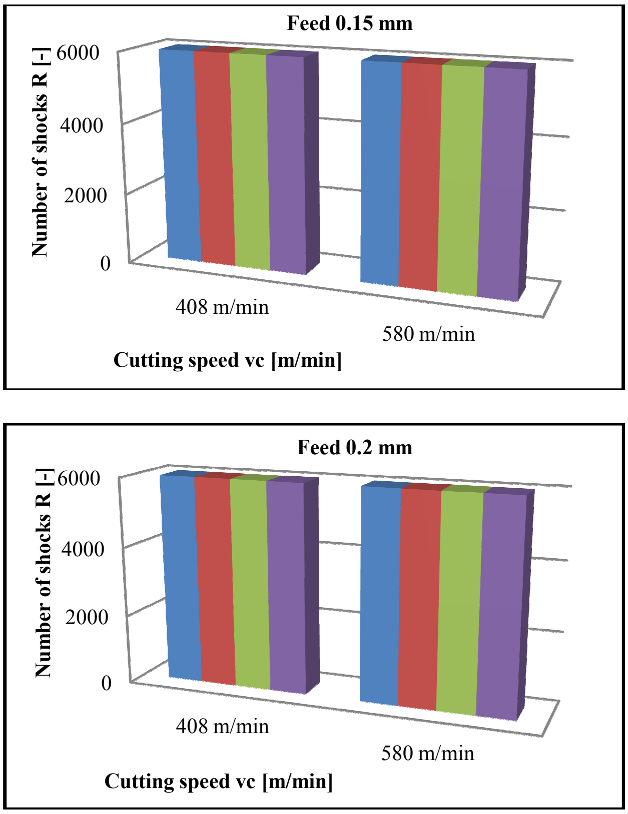

Figure 8. Dependence of number of shock on cutting speed for feed 0.15 and 0.2 mm

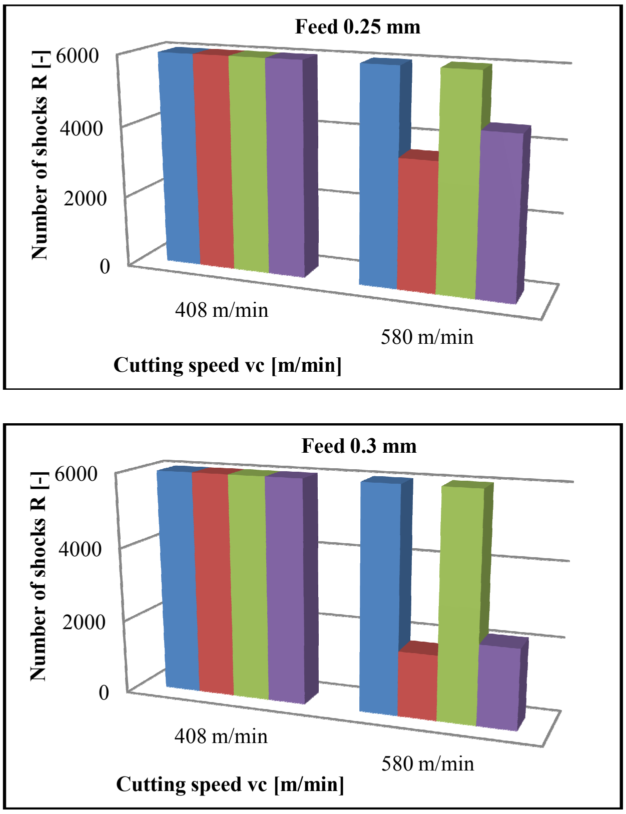

Figure 9. Dependence of number of shock on the cutting speed for 0.25 and 0.3 mm feed

The dependency graph of a number of shocks at the cutting speed of 0.15 mm feed represents that the number of shocks is the maximal for all cutting inserts at v_c = 408 m/min and v_c = 580 m/min. These ceramic cutting inserts are suitable for an interrupted cut at 0.15 mm feed.

From the dependency graph of a number of shocks at the cutting speed of 0.2 mm feed, is evident that the number of shocks is the maximum for all cutting inserts at v_c = 408 m/min and v_c = 580 m/min too. Also, it can be concluded that these ceramic cutting inserts are suitable for interrupted cut at 0.2 mm feed. Both ceramic cutting inserts have achieved the maximum number of shocks at these feeds.

The dependency graph of a number of shocks at the cutting speed of 0.25 mm feed, shows that the number of shocks is the same for all cutting inserts and materials at lower cutting speed v_c = 408 m/min. Cutting inserts did not withstand the maximum number of shocks at both cutting speeds. Inserts withstand the maximum number of shocks only on 15 128 material at higher cutting speed. FX105 ceramic cutting inserts have achieved the lowest number of shocks on 12 050 material at higher cutting speed.

Also, the dependency graph and the number of shocks occurring with the cutting speed of 0.3 mm feed, points out that the number of shocks is the same for all ceramic cutting inserts and materials at v_c = 408 m/min as in the previous case. Cutting inserts withstand the maximal number of shocks at higher cutting speed only on 15 128 materials. FX105 ceramic cutting inserts have achieved the lowest number of shocks on 12 050 material. The ability to withstand shocks decreases with increasing feed.

5. CONCLUSION

Through the centuries, producers of ceramic cutting tools have taken big steps forward. Properties have improved resistance to mechanical stress and tool wear, high temperature resistance, high accuracy, high quality finished surfaces and a wide range from finishing to light cutting. Some producers of these materials advise ceramic inserts for interrupted machining at present.

FX105 ceramic cutting inserts (15 128 material) have reached the limited number of shocks at both cutting speeds and all feeds. That means they have high resistance and ability to perform interrupted cut in this material. FX105 ceramic cutting inserts (12 050 material) have reached the limited value at a lower cutting speed for all feeds. The cutting inserts withstand fewer number of shocks when cutting speed is v_c = 580 m/min than with increasing feed of cutting insert. The number of shocks decreases with the increase of the feed value. FX105 ceramic cutting inserts are able to withstand the limit value of 6000 shocks at 0.15 and 0.2 mm.

CX710 ceramic cutting inserts (15 128 material) reached the limit number of shocks at both cutting speeds and all feeds. That means they have high resistance and ability to perform interrupted cut in this material. CX710 ceramic cutting inserts (12 050 material) have reached the limited value at lower cutting speed for all feeds. The cutting inserts withstand fewer number of shocks when cutting speed is v_c = 580 m/min than with increasing feed of cutting insert - like in the previous case for the 12 050 (C45) material. The number of shocks decreases with an increasing value of the feed. CX710 ceramic cutting inserts are able to withstand the limited value of 6000 shocks at 0.15 and 0.2 mm.

These tests have showed that FX105 and CX710 ceramic cutting inserts can be used for an interrupted cut. Both cutting inserts withstand the maximum number of shocks at 15 128 (13MoCrV6) material (at lower or higher cutting speed) which means that FX105 and CX710 inserts have high resistance and ability to perform an interrupted cut in 15 128 (13MoCrV6) material.

6. ACKNOWLEDGMENT

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7. LIST OF SYMBOLS

number of shocks	R,	-
machining length	l,	mm
feed per revolution	f,	mm
cutting depth	a_p,	mm
cutting speed	v_c,	m/min

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