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TESTING OF GREENLEAF CERAMIC CUTTING TOOLS WITH AN INTERRUPTED CUTTING

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Original scientific paper

This paper will be dealing with a solution of ceramic cutting tools availability in interrupted machining. Tests will be provided on fixture - interrupted cut simulator. This fixture was constructed at Department of Machining and Assembly, VŠB – Technical University of Ostrava. Criteria of tool wear are destruction of cutting tool or 6000 shocks. Testing cutting tool material will be Greenleaf GEM-7™ and WG-300® products. Cutting speed (408 m/min and 580 m/min) and cutting feed (0,15 mm, 0,2 mm, 0,25 mm and 0,3 mm) will be variable parameters and cutting depth will be a constant parameter (a_p = 1 mm). The main outputs of the tests will contribute to the wider usage of these cutting materials in interrupted machining. At the present time these materials are advised as cutting inserts for interrupted machining by some producers.

Keywords: *machining, interrupted cutting, ceramic cutting tools*

Ispitivanje Greenleaf keramičkih reznih alata s prekinutim rezanjem

Izvorni znanstveni članak

Ovaj će se rad baviti rješenjem dostupnosti keramičkih reznih alata u prekinutoj obradi. Ispitivanja će se obaviti na simulatoru učvršćenje - prekinut rez. Ovo učvršćenje je izgrađeno na Zavodu za strojnu obradu i montažu, VŠB - Tehničkom sveučilištu u Ostravi. Kriteriji za trošenje alata su uništenje alata ili 6000 udara. Testni materijal reznog alata bit će Greenleaf GEM-7™ i WG-300® proizvodi. Brzina rezanja (408 m/min i 580 m/min) i posmak rezanja (0,15 mm, 0,2 mm, 0,25 mm i 0,3 mm) bit će promjenjive veličine a dubina rezanja bit će stalan parametar (a_p = 1 mm). Glavni rezultati testova doprinijeti će široj uporabi tih reznih materijala u prekinutoj strojnoj obradi. U današnje vrijeme ove materijale preporučuju neki proizvođači kao rezne umetke za prekinutu strojnu obradu.

Ključne riječi: *obrada, prekinuto rezanje, keramički rezni alati*

1 Introduction
Uvod

All cutting tool edges are liable to wear during machining. To this extent tool wear is figured from start to end of tool life. Tool life is the time the cutting tool works from clamping to final wear and is calculated in minutes. It is applicable, when edge machining metal within parameter limits, as is quality, required design. etc. [1, 7].

The choice of the right cutting tool is critical for the highest machining achievement. Material and cutting geometry are selected according to experience. Vibration generated in machining induces the early termination of tool life. This may be due to poor tool-holder stiffness or incorrect holding of the chuck, [2, 8].

Experiments were conducted on a special preparation at longitudinal turning which was constructed at Department of Machining and Assembly. Special preparation for these tests is clamped to the lathe chuck and it is supported by the modified point which is established in tail stock sleeve. The basic construction consists of special cylinders which are milled four mortises as in Fig. 1.

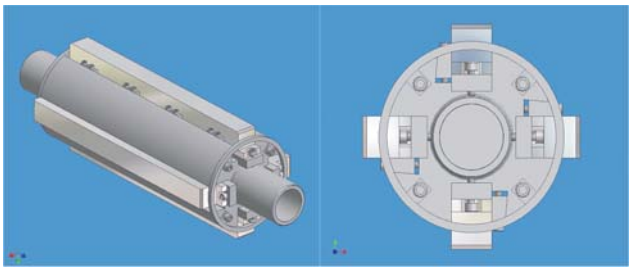

Figure 1 *Preparation for slide turning*
Slika 1. *Priprema za uzdužno tokarenje*

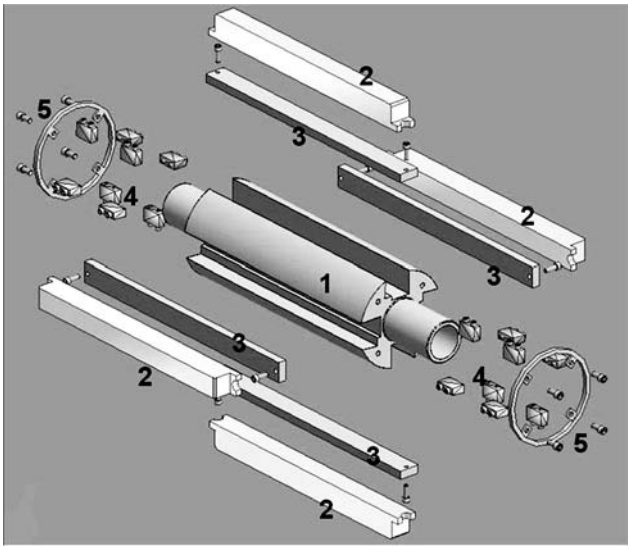

Figure 2 *Photo and scheme of Interrupted Cut Simulator* [3]
Legend: 1) preparation – body, 2) machined slats, 3) interchangeable pads, 4) chucking wedges, 5) safety rings
Slika 2. *Fotografija i shema simulatora prekinutog rezanja* [3]
Legenda: 1) priprema – tijelo, 2) rezna letvica, 3) izmjenjive pločice, 4) pričvrsni klinovi, 5) sigurnosni prsteni

This preparation was made under the grant project GACR 101/93/0129 in the laboratories of Department of Machining and Assembly [3]. The edge of indexable cutting insert is exposed to 4 shocks during one revolution. For testing it is essential to clamp the whole preparation to the turning-lathe, to put slats into preparation and especially to prepare and secure rigid clamping of individual slats. The complete construction and description of individual parts is in Fig. 2.

1.1
Machine tool
Strojni alat

Tests were conducted in the laboratories of the Department of Machining and Assembly (VŠB - Technical University of Ostrava) on the Bulgarian turning lathe ZMM SLIVEN (Fig. 3). This turning lathe has a rigid structure, cast-iron bed, which allows rigid clamping and absorbs shocks well. It is equipped with components for a smooth change of speed. It reaches a maximum of 2000 rev/min and the engine power is 6 kW.

Figure 3 *Machine tool ZMM Sliven*
Slika 3. *Alatni stroj ZMM Sliven*

1.2
Cutting parameters
Parametri rezanja

With regard to the manufacturer's recommendation of cutting ceramics and experience of the resolver the following cutting conditions were chosen for testing these types of cutting materials and for our preparation with respect to the machined diameter 260 mm:

- Cutting speed $v_c = 408$ and 580 m/min
- Feed $f = 0{,}15; 0{,}2; 0{,}25$ and $0{,}30$ mm
- Cutting depth a_p = 1 mm (was constant for all type inserts).

Table 1 *Mechanical properties - 15 128 (13MoCrV6)*
Tablica 1. *Mehanička svojstva - 15 128 (13MoCrV6)*

Mechanical properties	$Rp_{0,2}$ / MPa	Rm / MPa	A5 / %	Hardness / HB	E / GPa
15 128 (13MoCrV6)	294	470 - 640	17	135 - 183	214

Table 2 *Mechanical properties - 12 050 (C45)*
Tablica 2. *Mehanička svojstva - 12 050 (C45)*

Mechanical properties	$Rp_{0,2}$ / MPa	Rm / MPa	A5 / %	Hardness / HB	E / GPa
12 050 (C45)	331	637	22,2	max. 225	211

1.3
Slats – material and assembly
Letvice – materijal i montaža

Steel 15 128 (13MoCrV6) (Tab. 1) and 12 050 (C45) (Tab. 2) was chosen as workpiece materials.

If we want to guarantee a constant depth of chips while measuring and we want to avoid vibration it is necessary to cut off the first depth of chips before we start taking the measurements [1, 7, 8].

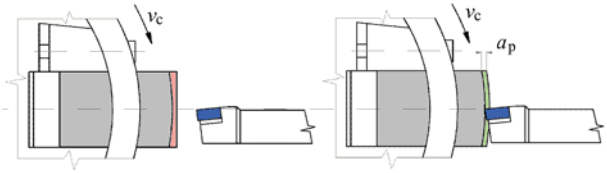

Figure 4 *Cut off the first depth of chips before measurements* [4]
Slika 4. *Odrez prve dubine pločica prije mjerenja* [4]

1.4
Indexable cutting inserts
Rezne pločice koje se mogu indeksirati

Two types of Greenleaf ceramic cutting inserts were tested:

a) GEM-7™- Al_2O_3 + TiC composite ceramic with a high degree of predictability in roll turning and hard alloy (up to 65 HRC) machining. [6]
b) WG-300®- patented whisker-reinforced ceramic with excellent wear and shock resistance at high surface speeds. WG-300 is very effective at machining nickel and cobalt based super-alloys and other hard materials at metal removal rates up to 10 times higher than carbide. [6]

Ceramic cutting tools such as Greenleaf's GEM-7™ composite material and WG-300® whiskered material are representing an important place in heavy turning when combined with rigid, well-designed holding systems. [6]

1.5
Cutting geometry
Geometrija rezanja

These indexable cutting inserts will be attached to the tool holder CSRNR 25×25 M12-K. All types of indexable cutting inserts have a normalize shape SNGN 120716 T02020.

According to ISO 3685 norm (Tool Life Testing of Single Point Turning Tools), the following cutting geometry was selected [5]:

- cutting edge angle: $\kappa_r = 45°$
- cutting edge inclination: $\lambda_s = -6°$
- rake angle: $\gamma_o = -6°$
- clearance angle: $\alpha_o = 6°$
- included angle: $\varepsilon_r = 90°$.

1.6
Monitoring number of shocks
Prećenje broja udaraca

The limit value of 6000 shocks was determined on the basis of previous experience in terms of time and material demandingness. If the tested cutting insert the last limit value it is considered as satisfactory and the testing process can be finished. The critical value (number of shocks) corresponds to a different machined length for each feed.

Formula for calculation of the number of shocks:

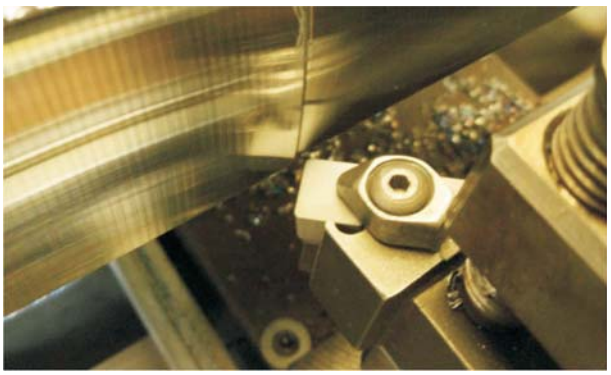

Figure 5 *Ceramic cutting insert and tool holder*
Slika 5. *Keramička rezna pločica i držač alata*

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

R – number of shocks to the chip, -
l – machining length, mm
f – feed per revolution, mm.

2
Tests – results and evaluations
Testovi – rezultati i ocjene

All introduced values in the tables are arithmetic diameters of three independent measurements.

2.1
Measurement - GEM-7 ceramic cutting inserts for 15 128 (13MoCrV6) material
Mjerenje – keramička rezne pločice GEM-7 za materijala 15 128 (13MoCrV6)

Table 3 *Table of measured and calculated values*
Tablica 3. *Tablica izmjerenih i izračunatih vrijednosti*

GEM-7 15 128 (13MoCrV6)					
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	110	1760
0,30	195	2600	0,30	50	667

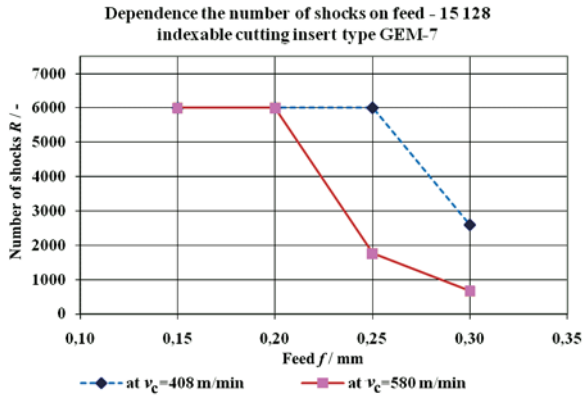

Figure 6 *Dependence of the number of shocks on feed – cutting inserts type GEM-7*
Slika 6. *Ovisnost broja udaraca i posmaka – rezne pločice tipa GEM-7*

In Fig. 6 we can see that the number of shocks for GEM-7 inserts decreases with increasing the value of the feed. These ceramic cutting inserts withstood a smaller number of shocks at higher cutting speed (v_c = 580 m/min) than at lower cutting speed. The number of shocks began to decline at 0,3 mm feed – for lower cutting speed v_c = 408 m/min. The number of shocks began to decline at 0,25 mm feed – higher cutting speed.

2.2
Measurement - GEM-7 ceramic cutting inserts for 12 050 (C45) material
Mjerenje – keramička rezne pločice GEM-7 za materijala 12 050 (C45)

Table 4 *Table of measured and calculated values*
Tablica 4. *Tablica izmjerenih i izračunatih vrijednosti*

GEM-7 12 050 (C45)					
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	210	5600
0,20	300	6000	0,20	160	3200
0,25	375	6000	0,25	195	3120
0,30	310	4133	0,30	75	1000

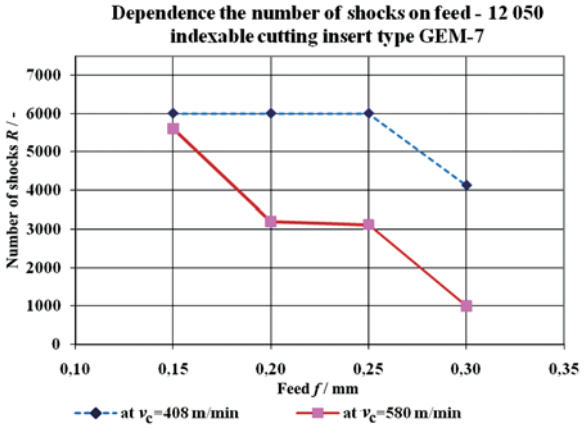

Figure 7 *Dependence of the number of shocks on feed – cutting inserts type GEM-7*
Slika 7. *Ovisnost broja udaraca i posmaka – rezne pločice tipa GEM-7*

In Fig. 7 we can see that the number of shocks for GEM-7 inserts also decreases with increasing the value of feed as in the previous case. Tested cutting inserts did not withstand the limit value of 6000 shocks at higher cutting speed v_c = 580m/min. It means that GEM-7 inserts do not have high resistance and ability to perform an interrupted cut in 12 050 (C45) material at higher cutting speeds.

2.3
Measurement - WG-300 ceramic cutting inserts for 15 128 (13MoCrV6) material
Mjerenje – keramička rezne pločice WG-300 za materijala 15 128 (13MoCrV6)

We can see in Fig. 8 that indexable cutting inserts (WG-300 type) reached the limit number of shocks at both cutting

speeds and feeds of all. That means they have a high resistance and ability to perform an interrupted cut.

Table 5 *Table of measured and calculated values*
Tablica 5. *Tablica izmjerenih i izračunatih vrijednosti*

WG-300 15 128 (13MoCrV6)					
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

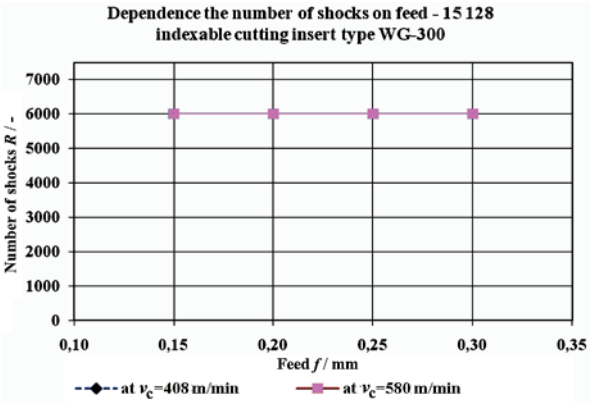

Figure 8 *Dependence of the number of shocks on feed – cutting inserts type WG-300*
Slika 8. *Ovisnost broja udaraca i posmaka – rezne pločice tipa WG-300*

2.4
Measurement - WG-300 ceramic cutting inserts for 12 050 (C45) material
Mjerenje – keramička rezne pločice WG-300 za materijala 12 050 (C45)

Table 6 *Table of measured and calculated values*
Tablica 6. *Tablica izmjerenih i izračunatih vrijednosti*

WG-300 12 050 (C45)					
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	50	1333
0,20	300	6000	0,20	65	1300
0,25	375	6000	0,25	80	1280
0,30	450	6000	0,30	105	1400

We can see in Fig. 9 that indexable cutting inserts (WG-300 type) reached the limit number of shocks at lower cutting speed for all feeds. That means that WG-300 inserts have a high resistance and ability to perform an interrupted cut at v_c = 408 m/min. If we increased the cutting speed to v_c = 580 m/min, the ability to withstand the limit number of shocks will be lower.

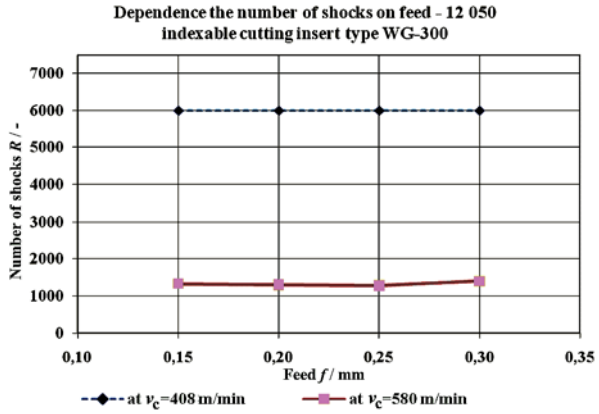

Figure 9 *Dependence of the number of shocks on feed – cutting inserts type WG-300*
Slika 9. *Ovisnost broja udaraca i posmaka – rezne pločice tipa WG-300*

2.5
The number of shocks in dependence on cutting speed for individual feeds
Broj udara u ovisnosti o brzini rezanja za pojedinačne posmake

Measurements were carried out at two selected cutting speeds v_c = 408 m/min and v_c = 580 m/min. Feed per revolution changed at intervals f = (0,15; 0,20; 0,25; 0,30) mm. The results for all types of ceramic cutting inserts are represented in the following figures.

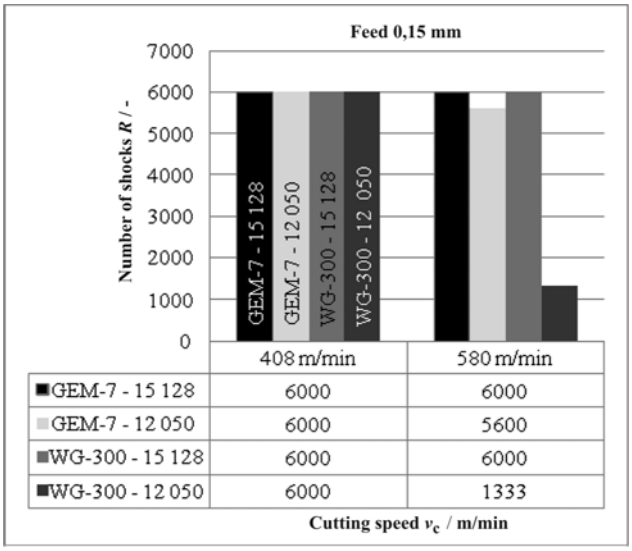

Figure 10 *Dependence of number of shocks on cutting speed for feed 0,15 mm - 15 128 (13MoCrV6) and 12 050 (C45) material*
Slika 10. *Ovisnost broja udaraca i brzine rezanja za posmak 0,15 mm – materijali 15 128 (13MoCrV6) i 12 050 (C45)*

From the dependency graph of number of shocks R on cutting speed at 0,15 mm feed (Fig. 10) it can be concluded that the number of shocks is the same for all cutting inserts and materials at v_c = 408 m/min. Maximal number of shocks (at higher cutting speed) withstood inserts only on 15 128 materials. The WG-300 inserts achieved the lowest number of shocks on 12 050 materials at higher cutting speed.

From the dependency graph of number of shocks R on cutting speed at 0,2 mm feed (Fig. 11) it can be concluded that the number of shocks is the same for all cutting inserts and materials at v_c = 408 m/min as in previous case. Maximal

number of shocks (at higher cutting speed) withstood inserts only on 15 128 materials.

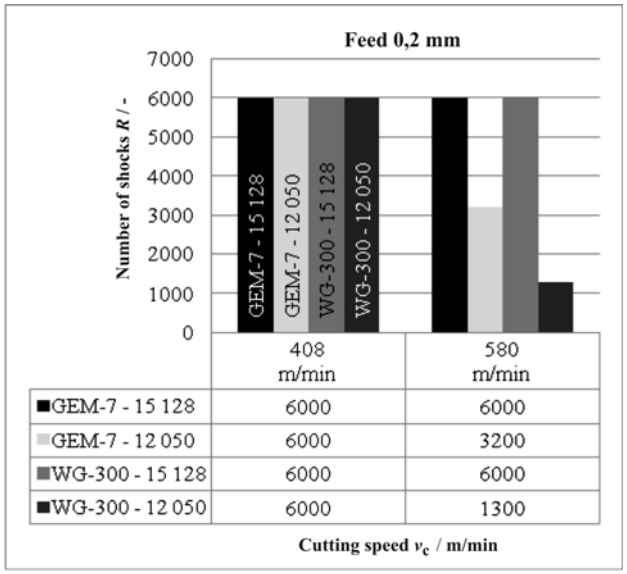

Figure 11 *Dependence of number of shocks on cutting speed for feed 0,2 mm - 15 128 (13MoCrV6) and 12 050 (C45) material*
Slika 11. *Ovisnost broja udaraca i brzine rezanja za posmak 0,2 mm – materijali 15 128 (13MoCrV6) i 12 050 (C45)*

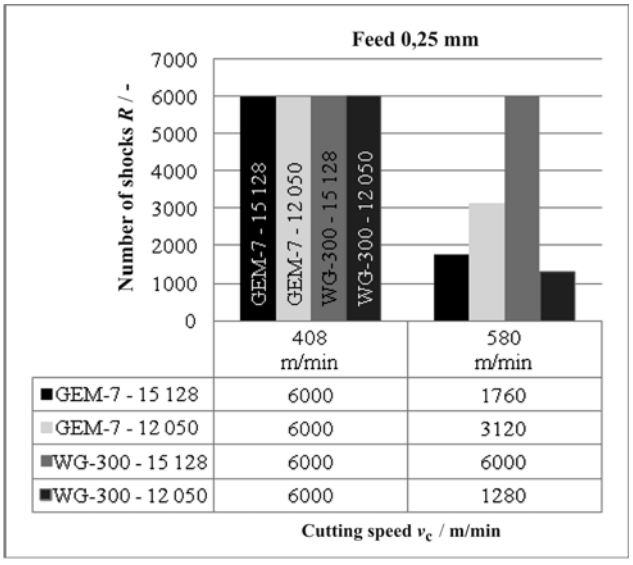

Figure 12 *Dependence of number of shocks on cutting speed for feed 0,25 mm - 15 128 (13MoCrV6) and 12 050 (C45) material*
Slika 12. *Ovisnost broja udaraca i brzine rezanja za posmak 0,25 mm – materijali 15 128 (13MoCrV6) i 12 050 (C45)*

Dependency graph of number of shocks R on cutting speed (at 0,25 mm feed) (Fig. 12) shows that the number of shocks is maximal for all cutting inserts and materials at v_c = 408 m/min as in previous cases. Only WG-300 inserts (on 15 128 material) withstood maximal number of shocks at 0,25 mm feed. Other plates reached low number of shocks at this feed.

The dependency graph number of shocks on lower cutting speed (Fig. 13) shows that two inserts achieved without problems the limit number of shocks at 0,3 mm. From dependency graph number of shocks for higher cutting speed v_c = 580 m/min (at 0,3 mm feed) it can be concluded that only one cutting insert achieved maximum number of shocks. Ceramic cutting inserts WG-300 is the best solution for 15 128 material. These cutting inserts

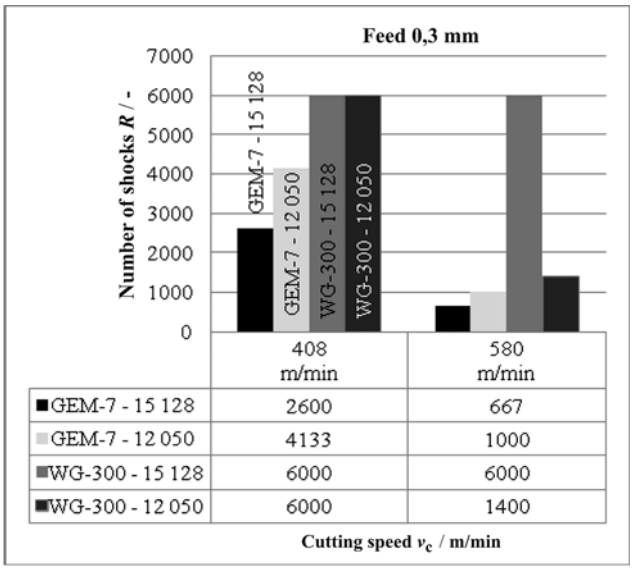

Figure 13 *Dependence of number of shocks on cutting speed for feed 0,3 mm - 15 128 (13MoCrV6) and 12 050 (C45) material*
Slika 13. *Ovisnost broja udaraca i brzine rezanja za posmak 0,3 mm – materijali 15 128 (13MoCrV6) i 12 050 (C45)*

withstood the maximal number of shocks for all feeds and at both cutting speeds.

3 Conclusion
Zaključak

The submitted paper deals with the problems of tool life tests of ceramic cutting inserts at interrupted cutting. Two types of ceramic cutting inserts for testing were supplied by Greenleaf Corporation. The individual types of cutting inserts were tested at two different cutting speeds 408 and 580 m/min and four feeds 0,15 mm, 0,20 mm, 0,25 mm and 0,30 mm. When the indexable cutting insert reached a limit value of 6000 shocks the test process was finished and the cutting insert was characterized as satisfactory. The tests show that ceramics cutting tools are acceptable for interrupted cutting procedures.

The number of shocks for GEM-7 inserts (15 128 material) decreases with increasing value of the feed. These ceramic cutting inserts withstood a smaller number of shocks at higher cutting speed (v_c = 580 m/min) than at lower cutting speed. The number of shocks began to decline at 0,3 mm feed – for lower cutting speed v_c = 408 m/min.

The number of shocks for GEM-7 inserts (12 050 material) also decreases with increasing value of feed as in the previous inserts. The tested cutting inserts did not withstand the limit value of 6000 shocks at higher cutting speed v_c = 580 m/min. It means that GEM-7 inserts do not have a high resistance and ability to perform an interrupted cut in 12 050 (C45) material at higher cutting speeds.

WG-300 indexable cutting inserts (15 128 material) reached the limit number of shocks at both cutting speeds. Ceramic cutting inserts WG-300 is the best solution for 15 128 material. This cutting inserts withstood maximal number of shocks for all feeds and at both cutting speeds.

WG-300 indexable cutting inserts (12 050 material) reached the limit number of shocks at lower cutting speed. WG-300 inserts have a high resistance and ability to perform an interrupted cut at v_c = 408 m/min.

The tests showed that WG-300 ceramic cutting inserts can be used for interrupted cut at machining 15 128

(13MoCrV6) material. These inserts withstood maximal number of shocks for all feeds and at both cutting speeds.

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4
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