# CUTTING CERAMIC DURABILITY IN MACHINING PROCESS OF BEARINGS STEEL 100CR6

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The theory and practice in engineering industry is not the same. Durability of cutting tools is defined in standard ISO 3685. In standard ISO 3685 is defined T-$v_c$ dependence for different cutting materials and standard included process evaluation of tool durability for cutting materials made of high speed steel, sintered carbide and cutting ceramic. Standard ISO 3685 contains instructions how to create T-$v_c$ dependence for cutting tools made of cutting ceramic. In this standard are only instructions how to create T-$v_c$ dependence according to Taylor. The article compares T-$v_c$ dependencies for various cutting ceramics ($Al_2O_3$, $Al_2O_3$+$ZrO_2$, $Al_2O_3$+TiCN) with T-$v_c$ dependence defined in standard ISO 3685, because this standard describes T-$v_c$ dependence for all entered cutting materials together.

**KEYWORDS**

cutting speed, T-$v_c$ dependence, standard ISO 3685, tool durability, bearing steel 100Cr6

## 1 INTRODUCTION

Issue cutting tools durability is very topical for small and medium-sized enterprises, because cutting tools durability significantly influences economics of these enterprises.

A lot of manufacturer of cutting tools determined durability of cutting tool only on the assumption or presumption. Problematic of tool durability and its lifetime is defined in standard ISO 3685. This standard describes how to define *T*-$v_c$ dependence for different cutting materials by means of machining long-term test method. The base of this test is turning workpieces on the equal diameter. [Orlovsky 2010, Cep 2010]

Standard ISO 3685 defines cutting tools durability for workpieces made of steel by means of *T*-$v_c$ dependence described in this standard according to Taylor. According this standard are dependencies valid for all entered steels together. [10] Turning is the most basic process in machining, because it forms 30% from all technologies of machining [Isakov 2009, Duplak 2010, Macala 2007]. Turning are used a lot of types cutting tools made from different materials [Helmi 2008, Nagendra 2006]. One of these materials is cutting ceramic. Ceramic cutting tools have been in use for approximately 90 years [Whitney 1994]. As new materials were developed during a specific era, the properties of the cutting tool improved.

However, as new cutting tools were developed, new materials that demanded even more rigorous machining requirements were also developed [Black 2007, Krolczyk 2015, Petru 2014]. Interest in ceramics as a high speed cutting tool material is based primarily on favourable material properties [Neslušan 2007, Vasilko 2009]. As a class of materials, ceramics possess high melting points, excellent hardness and good wear resistance. Unlike most metals, hardness levels in ceramics generally remain high at elevated temperatures which means, that cutting tip integrity is relatively unaffected at high cutting speeds. Ceramics are also chemically inert against most workmetals [Holesovsky 2014, Krolczyk 2015, Michalik 2010].

**Figure 1.** Illustration figure of ceramic cutting tools

## 2 SPECIFICATION OF STANDARD ISO 3685

The standard ISO 3685 describes for all cutting materials common *T*-$v_c$ dependence. Current valid relation of T-$v_c$ dependence is described by Taylor formed basics of standard ISO 3685. *T*-$v_c$ dependence was designed according to Taylor in logarithmic scale [Hloch 2012, Lattner 2014, STN ISO 3685 1999]. Very significant problem in standard ISO 3685 is evaluation of results. Characteristics and dependences for all cutting materials are same [Zelenak 2012, Szarkova 2013].

## 3 USED EXPERIMENTAL METHODS

For determine durability dependence are used two basic methods. First method is short-term durability test and second method is machining long-term test method. For short-term durability test are implementing intermittent cutting test, whose basis is the stub test or strip test. For experiments was used machining long-term test method, because can the whole process describe more precisely. Significant problem with short-term durability test is the generation of suppressors [Cep 2010, Holesovsky 2012].

## 4 SPECIFICATION OF MACHINING LONG-TERM TEST METHOD

Machining long-term test method is essentially only one. Criterion is value of cutting speed and it makes by turning or milling with describes constant cutting parameters, type of cutting tool with defined geometry and graduated cutting speeds to the optimal tip blunting. This test is considered as basic and by this test takes measure objectivity of machinability for others tests. Disadvantage of this test is consumption of workpieces and time consumption [Cuma 2009, STN ISO 3685 1999].

Description of machining long-term test method:

1) Time measurement process of depreciation on back of tool VBB, for few value of cutting speeds at

constant cutting parameters and construction curve of blunting.

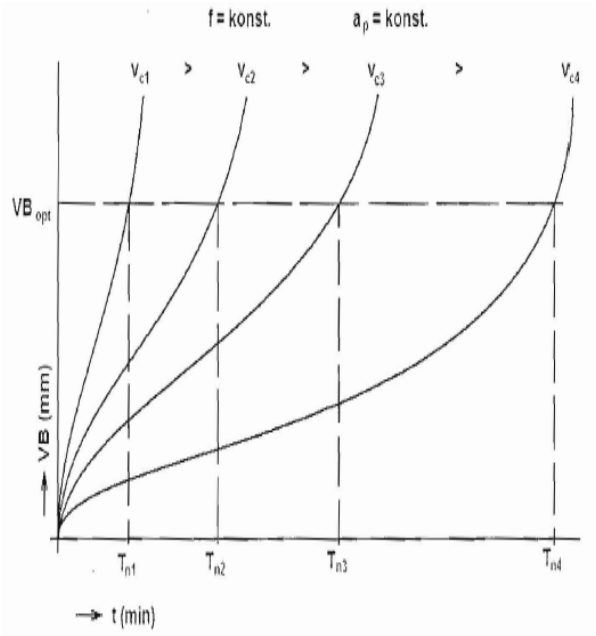


**Figure 2.** Curve of blunting for variable cutting speeds [Cuma 2009]

2) Specification criterion of depreciation $VB_{opt}$ and determination tip durability for each cutting speed.

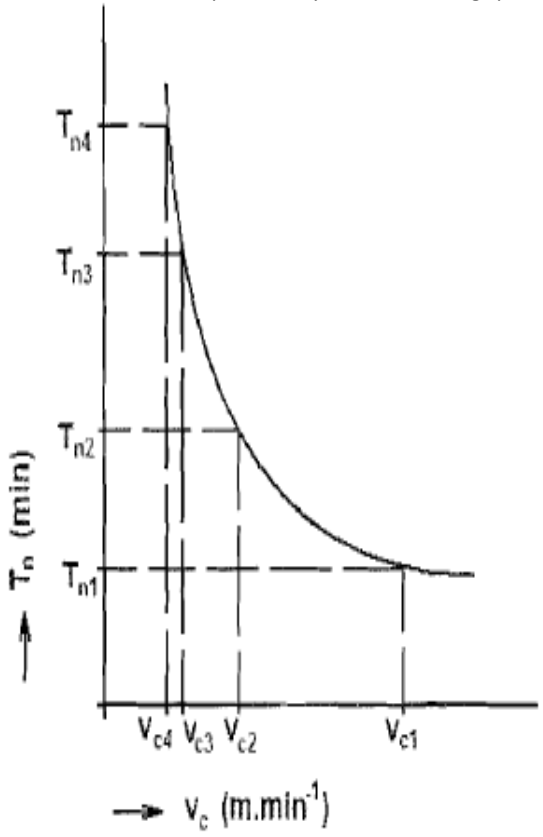


**Figure 3.** Determination of particular durability by the criterion of depreciation [Cuma 2009]

3) Construction $T_n$=f($v_c$) dependence in logarithmic scale and determination index of machinability for selected durability under comparison cutting speed tested material and etalon material.

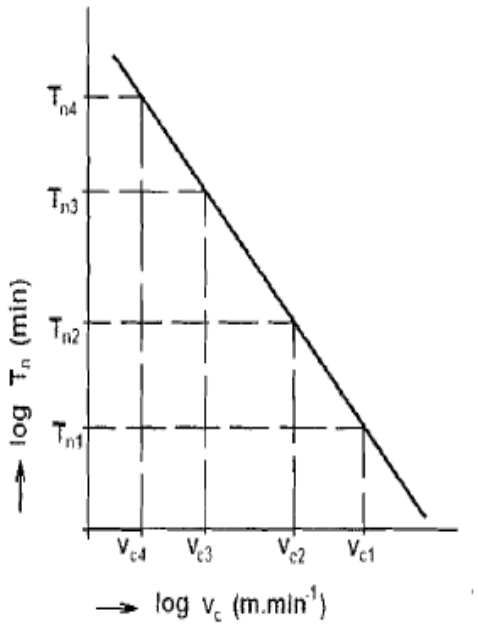


**Figure 4.** T-$v_c$ dependence in logarithmic scale [Cuma 2009]

## 5 EXPERIMENT SPECIFICATION

Very important step, before the actual experiments is specification of technological system. In technological system for these experiments were contained machine - tools - workpiece.

### *5.1 Used machine*

The first step was to select appropriate machine. For tests was selected universal center lathe SU 50, due to stiffness this device and its uses for experiments in standard ISO 3685.

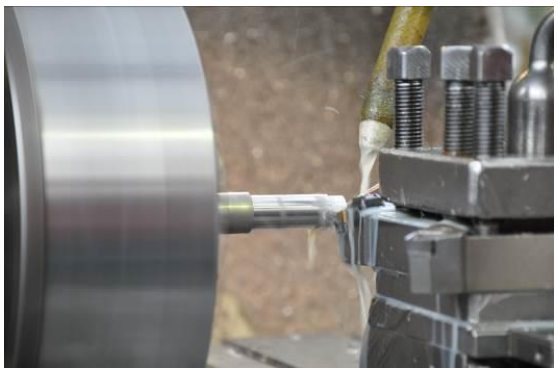

**Figure 5.** Machining process on lathe SU 50

### *5.2 Used cutting tools*

In second step were specified tools for experiments. Cutting tools for experiments were selected according to problem assignment that was defined in introduction. For experiments were selected three types of cutting ceramics tools. Cutting plates selected for experiments are: $Al_2O_3$, $Al_2O_3$+$ZrO_2$, $Al_2O_3$+TiCN. $Al_2O_3$ are defined as basic cutting ceramics type and it is pure oxide ceramics, more precisely alumina without coatings and additives. $Al_2O_3$+$ZrO_2$ are defined as white ceramics with high tenacity and wear resistance. Using of this ceramic type is for turning by high cutting speeds. $Al_2O_3$+TiCN are defined as black ceramics and there are recommended for roughing and finishing operations.

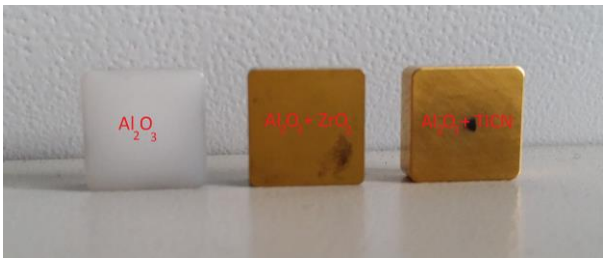


**Figure 6.** Machining process on lathe SU 50

### 5.3 *Specification of workpiece material*

In the third step were specified the workpieces for experiments. Workpieces for experiments are made of steel 100Cr6. Material for workpieces is from specific material list with guaranteed chemical structure and mechanical properties.

**Table 1.** Chemical structure of material 100Cr6

| Chemical structure of 100Cr6 [%] | | | | |
|---|---|---|---|---|
| **C** | **Mn** | **Si** | **Cr** | **Fe** |
| 0.9 | 0.37 | 0.27 | 1.45 | 96.7 |
| **Ni** | **Cu** | **P** | **S** | |
| 0.1 | 0.19 | 0.001 | 0.003 | |

**Table 2.** Mechanical properties of material 100Cr6

| Mechanical properties of 100Cr6 | | | |
|---|---|---|---|
| **Rm [MPa]** | **A5 [%]** | **HB** | **$Rp_{0,2}$ [Mpa]** |
| 700 | 27 | 195 | 410 |

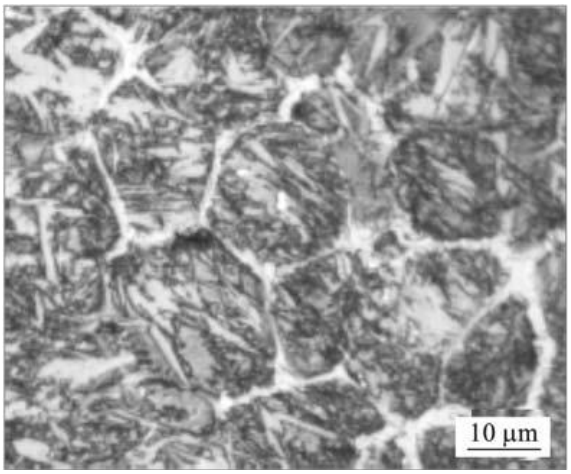


**Figure 7.** Microstructure of 100Cr6

These experiments were made under defined technological conditions. Tool durability was proven with kinetic machining long-term test method. Experiment inputs were workpieces with equal diameters; those were used at turning process. For each cutting speed the diameter should have the same value, because examined material has different consistency in different depth. Experiment was finished once wear criterion was reached.

## 6 TECHNOLOGICAL CONDITIONS USED FOR EXPERIMENTS

$v_c$ = 20 - 700 m.min$^{-1}$; $a_p$ = 0.2 mm;
$f$ = 0.1 mm ; $r_\varepsilon$= 0.8mm; $\kappa_r$=80°; $\kappa'_r$=10°; $VB$ = 0.3 mm;

**Table 3.** Results of $T$-$v_c$ dependence for $Al_2O_3$

| $v_c$ [m.min$^{-1}$] | $T$ [min] | $v_c$ [m.min$^{-1}$] | $T$ [min] |
|---|---|---|---|
| 20 | 17 | 180 | 15 |
| 30 | 15.5 | 220 | 10 |
| 47 | 27 | 234 | 9 |
| 51 | 27.1 | 250 | 9 |
| 56 | 27.2 | 270 | 9 |
| 78 | 28.5 | 369 | 7.5 |
| 100 | 30 | 430 | 6.4 |
| 123 | 29 | 504 | 6 |
| 128 | 28.7 | 550 | 5.3 |
| 136 | 28 | 580 | 5.1 |
| 140 | 25 | 640 | 4.7 |
| 150 | 20.5 | 690 | 4.3 |
| 155 | 20 | 700 | 4.1 |

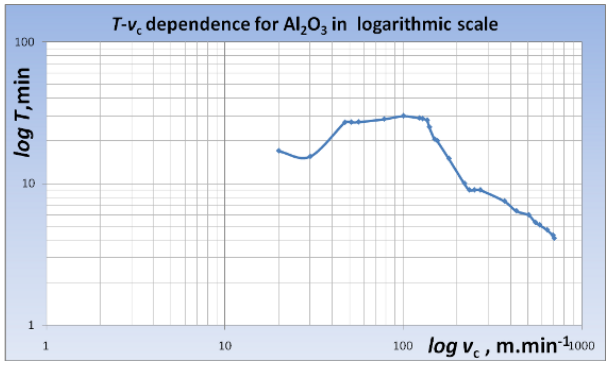


**Figure 8.** T-$v_c$ dependence for $Al_2O_3$ in logarithmic scale

**Table 4.** Results of $T$-$v_c$ dependence for $Al_2O_3$+$ZrO_2$

| $v_c$ [m.min$^{-1}$] | $T$ [min] | $v_c$ [m.min$^{-1}$] | $T$ [min] |
|---|---|---|---|
| 20 | 19 | 180 | 38.7 |
| 30 | 18 | 220 | 34.6 |
| 47 | 32 | 234 | 34.2 |
| 51 | 33 | 250 | 33.7 |
| 56 | 35 | 270 | 31.2 |
| 78 | 40.1 | 369 | 24.4 |
| 100 | 46.3 | 430 | 22.6 |
| 123 | 44.7 | 504 | 19 |
| 128 | 44.6 | 550 | 17.1 |
| 136 | 44.4 | 580 | 16.3 |
| 140 | 44.3 | 640 | 11.7 |
| 150 | 44.1 | 690 | 9.6 |
| 155 | 43.9 | 700 | 9.1 |

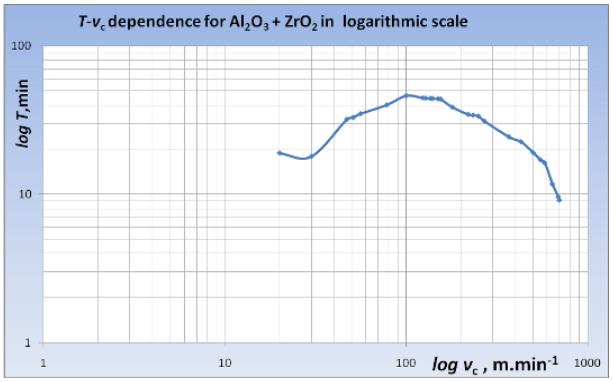


**Figure 9.** T-$v_c$ dependence for $Al_2O_3$ + $ZrO_2$ in logarithmic

**Table 5.** Results of T-$v_c$ dependence for $Al_2O_3$

| $v_c$ [m.min$^{-1}$] | $T$ [min] | $v_c$ [m.min$^{-1}$] | $T$ [min] |
|---|---|---|---|
| 20 | 19.7 | 180 | 41.1 |
| 30 | 19 | 220 | 39.2 |
| 47 | 34 | 234 | 37.9 |
| 51 | 35 | 250 | 36.2 |
| 56 | 35.9 | 270 | 34.8 |
| 78 | 41.7 | 369 | 26.9 |
| 100 | 49.9 | 430 | 23.1 |
| 123 | 48.1 | 504 | 20.7 |
| 128 | 47.8 | 550 | 18.3 |
| 136 | 47.2 | 580 | 16.9 |
| 140 | 46.9 | 640 | 13.8 |
| 150 | 45.2 | 690 | 11.4 |
| 155 | 45 | 700 | 10.2 |

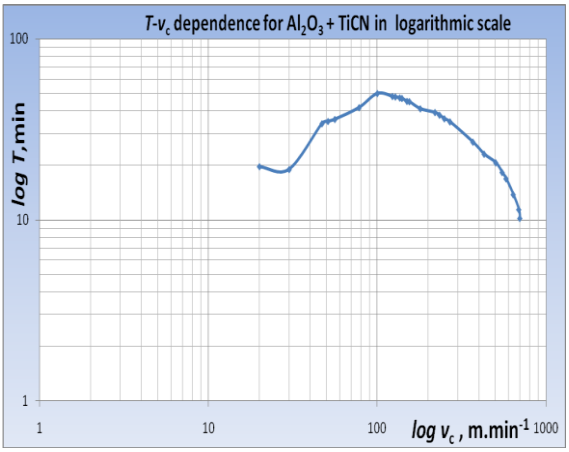


**Figure 10.** T-$v_c$ dependence for $Al_2O_3$ + TiCN in logarithmic scale

## 7 CONCLUSION

Every one process in engineering industry is defined by some standard ISO. Procedures for technical sciences are defined in standards these standards described technological conditions, dependencies, settings, diverse cutting parameters etc. Precision and completeness of standard ISO represents primary factor in technical sciences. Defects and imprecision described in standard ISO need to be fixed. Experiments are necessary to prevent false information. This paper was oriented on durability selected ceramic cutting plates in machining process of steel 100$Cr_6$.

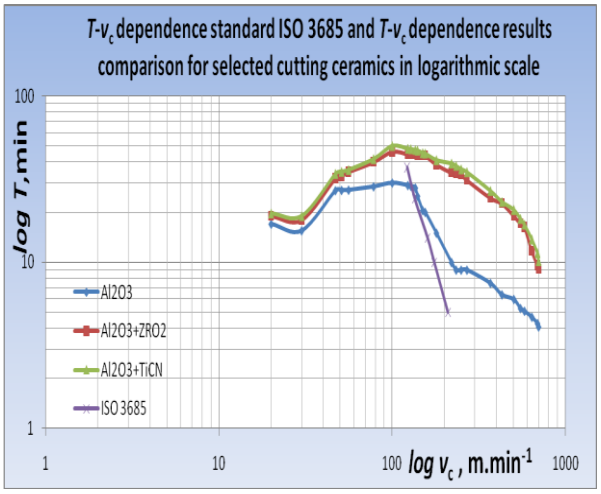


**Figure 11.** Comparison standard ISO 3685 and experiment results

The durability issue of cutting tools is defined in standard ISO 3685. This standard defines all process how to create and to define cutting tools durability by means of $T$-$v_c$ dependence according to Taylor. Executed experiments showed, that between the standard ISO 3685 and experiment results are expressive differences. The following figure (11) shows differences between standard ISO 3685 and selected ceramic plates. Experiment was executed for three types ceramic cutting plates and for all three types are in graph visible differences. Standard ISO 3685 is invalid for machining of steel 100$Cr_6$ by ceramic cutting plates.

For small and medium-sized enterprises is durability of cutting tool very important factor how to save some money. For these enterprises means prolong the life of cutting tool the obtaining of important gains, that enabling them to develop. Execution experiments defined the optimized cutting tools durability under defined technological conditions in machining process of steel 100$Cr_6$. Under defined technological conditions were the highest durability ceramic cutting plates at the cutting speed of about 100m.min$^{-1}$. The highest durability was under defined technological conditions for cutting plates made of $Al_2O_3$+TiCN.

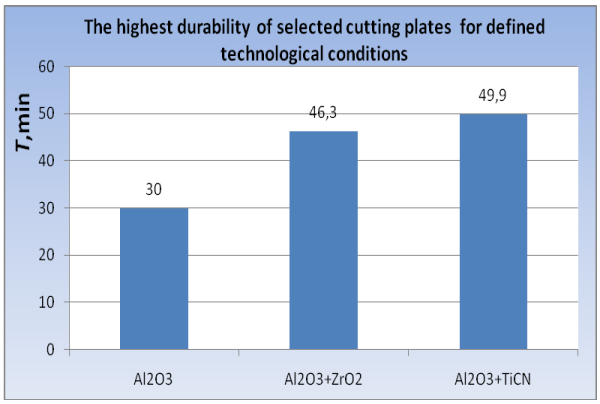


**Figure 12.** The highest durability of selected cutting plates

Deeper exploration of durability cutting materials defined in standard ISO 3685 is very important, because only valid information and correct dependencies may be included in technical standards.


## ACKNOWLEDGMENTS

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