

## COMPARISON OF CUTTING CERAMICS WITH HARD METAL CUTTING TOOLS

**N. Sönmez, M. Özgürler and C. Yaman**

Yıldız Technical University, 80750 Beşiktaş, Istanbul, Turkey

*Abstract: Cutting ceramic tools are used especially at high cutting speeds in the machining process. The highly brittle type of structure and the tendency for cleavage (crack formation) are the unfavorable properties of these materials, which keep their hardness at high temperatures. The hard metals are produced by sintering of the carbides such as whisker WC, TiC and TaC with the presence of Co as a binder. The high wearing resistance and high thermal strength characteristics of these materials are due to their high hardness values and due to the use of Co respectively. The main purpose of studies done in this field is generally to produce cutting tools bearing high hardness, strength and toughness properties at high temperatures of 1000 °C - 1100 °C. The cutting ceramics and hard metals are used in this study. The strength characteristics and behaviors and the related life times are studied depending on the cutting speeds. The comparison of the results and the feasibility for the economical purposes are investigated.*

*Keywords: ceramic tools, tool life, hard metal*

### 1. INTRODUCTION

The development of handling techniques and the advancement of cutting speeds are proceedingly limited by cutting tool's life. Tool life is generally closely related to its hot strength properties. The temperatures of high cutting speeds cause rapid wear and decrease the life of the cutting tool. Therefore, the main aim of the research and developments is no operation hardness at high temperatures (1000-1100 °C) and in addition to this to get cutting materials, which have sufficient strength and toughness properties at such temperatures [1].

The change of cutting speed in lathing of low carbon content steels, which have 850 N/mm<sup>2</sup> in tensile strength respective of the years is shown in figure 1. As the hardness, crushing and hot wear strength degree rises; concessions are made in return for toughness and breaking strength. This behavior leads to some limitations on the form of the cutting tool as well as the selection of the cutting conditions and geometry of the handling piece (Discontinued cutting, strokes on the cutting edge... etc). In addition to this, high stability is essential for the tool machine. Relations of toughness and breaking strength of different cutting materials are shown on figure 2. [2,3].

### 2. PHYSICAL, MECHANICAL AND TECHNOLOGICAL COMPARISONS

Hard metals are materials, which are generally produced from WC or TiC type carbides sintered by Co as a binder. These materials are wear resistant because of the high hardness of carbides and hot strength because of cobalt [4]. Vickers hardness of hard metals is twice as much as high-speed steels (HSS) in room temperature and they keep their hardness up to 600 °C temperature level. Over that temperature, both materials hardness decrease approximately 10 % from original hardness. When the temperature passes over the 600 °C limit, hot strength of HSS rapidly decreases but hard metal keeps 60 % of its original hardness up to approximately 900 °C. After 1000 °C however hard metal shows a plastic deformation and cutting wedge geometry becomes deformed (Figure 3), [5,6]. Correspondingly, it's known that essential composition of cutting ceramics is Al<sub>2</sub>O<sub>3</sub> and its hardness approximately three times higher than HSS in room temperature. Even though cutting ceramics heats up to 1200 °C their hardness equals hard metals hardness in room temperature. It's clear that cutting ceramics can show a far higher resistance against high cutting temperatures than hard metals [7].

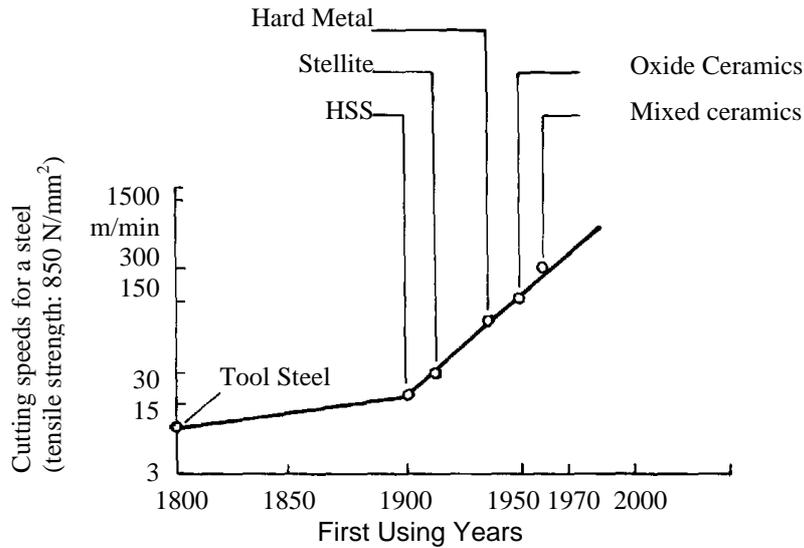


Figure 1. Developments in cutting materials.

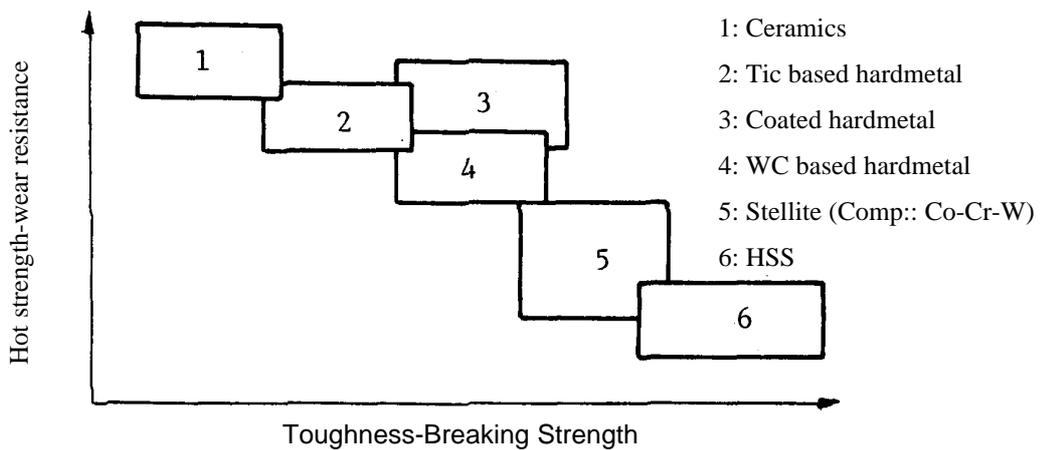


Figure 2. Relations between wear resistance-hot strength and Toughness- breaking strength in different cutting materials.

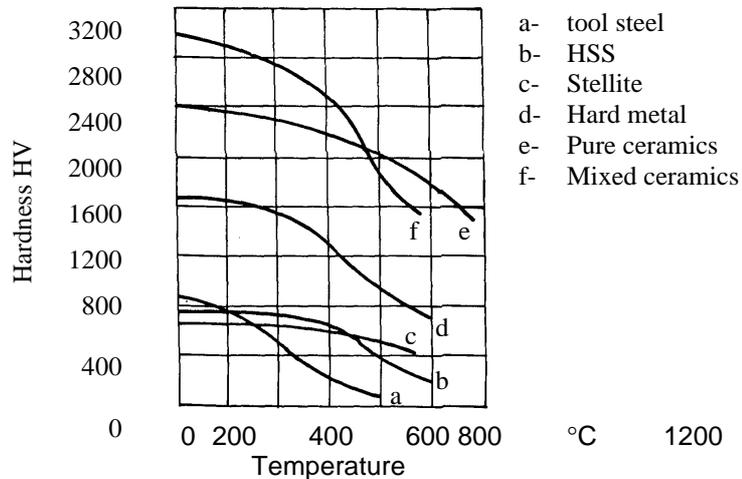


Figure 3. Variation of hardness in relation to temperature in various cutting tool materials.

Chemical endurance of cutting ceramics is similar to the situation with heat. As an oxidized material, ceramics is resistant to oxygen of air at high temperatures. Besides, ceramics don't contain cobalt, which chemically looks like iron. This feature differs ceramics from ferrous materials.

Despite these positive properties, cutting ceramics have a lower bending strength than hard metals. However flexibility of hard metals is half as much as HSS. Crushing strength of oxide ceramics is the same as of hard metals in room temperature. But at 1100 °C, it can show the same crushing strength which steel shows at room temperature (Figure 4). Thermal conductivity of cutting ceramics is not more than the fractions of HSS. Thermal conductivity of HSS is twice as much as that of hard metals [7,8].

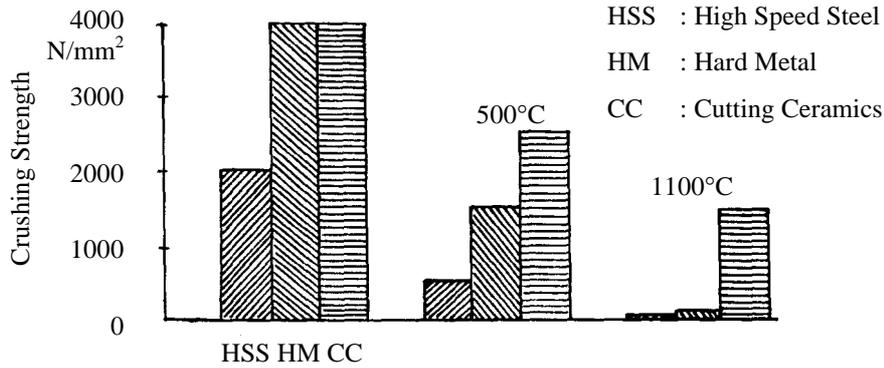


Figure 4. Crushing strength of HSS, hard metal and cutting ceramics at high temperatures

Those approximate values, which refer to above-mentioned features, are valid for cutting ceramics, which are made from pure aluminum oxide. Another type that is known as mixed ceramics contains especially titanium carbide. This TiC element brings up the flexibility and crushing strength of cutting ceramics the same level as hard metals. It raises its thermal conductivity; increases the hardness in room temperature at a rate of 25 %. However it decreases hot strength considerably. That is hardness reached over 800 °C, falls below the hardness of pure Al<sub>2</sub>O<sub>3</sub> at the same temperature. This situation creates different areas of use for ceramics made from Al<sub>2</sub>O<sub>3</sub> and form mixed ceramics. The tool life's of four prominent cutting materials in relation to their cutting speeds are given in figure 5-a. In addition to T-v curves, the tool life curve L is given in figure 5.b [8].

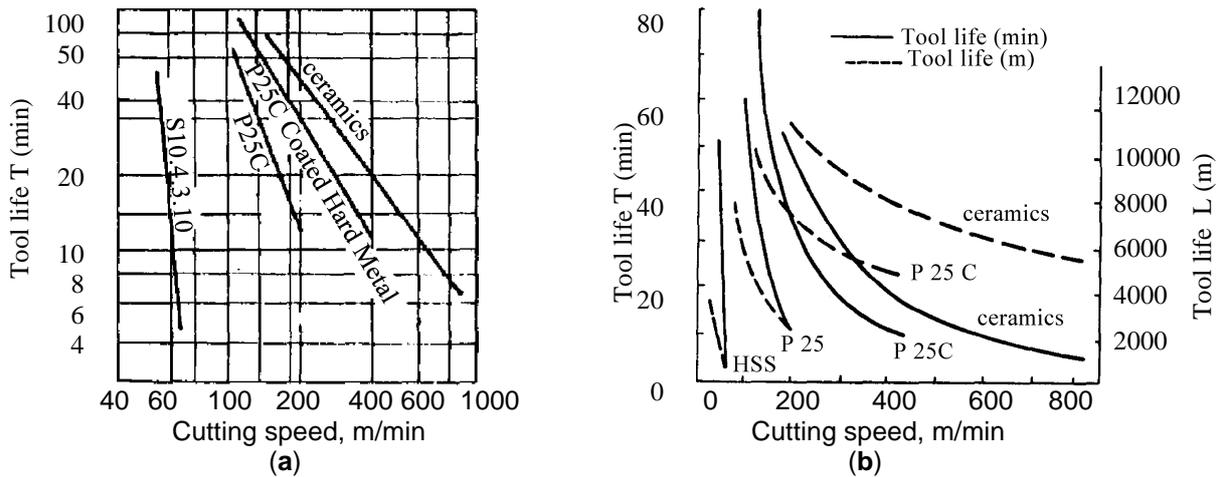


Figure 5. Effect of cutting speed (v) on tool life (T)  
a: Appearance in double logarithm scale (system)  
b: Appearance in linear scale (system)

Tool life  $L$  is obtained by cutting speed  $V$  multiplied tool life  $T$

For ceramics; tool life is  $800 \text{ m/min} \times 7 \text{ min} = 5600 \text{ m}$  or  $200 \text{ m/min} \times 50 \text{ min} = 10\,000 \text{ m}$ .

For hard metal P 25; tool life is  $200 \text{ m/min} \times 12 \text{ min} = 2400 \text{ m}$  or  $115 \text{ m/min} \times 50 \text{ min} = 5750 \text{ m}$ .

According to figure 6.b, ceramics materials give almost the same tool life. A cutting speed difference of seven times is observed here. Consequently, the number of pieces of work processed and the amount of production is a few times more than expected within the same period of time.

High cutting speed requires high temperature resisting cutter materials. Because the greater part of energy, which exists in the process of machining, changes into heat by friction, change of form and shearing stress. This amount of heat is realized out together with shearing.

There is a need to explain the differences between this material's structures from other hard metals, to express possibility of reaching very high cutting speed with ceramic materials. The particules, which make hardness in hard metals, are bonded in a metallic way. In ceramics, there is sintering without a metallic bonding. In hard meta, heat resistance of connector metal mentions temperature behavior of tool. In other words, heat resistance of tool is known as heat resistance of metal. By increasing temperature, hardness of connector in the cutting edge decreases the friction increases and by passing an edge temperature, in the cutting edge of hard metal plastic form changing begins. Therefore cutting geometry of hard metal and working conditions are chosen as this: The temperature at the cutting edge remains lower. So, cutting speed is the most important setting parameter while lathing or milling [10].

The ceramic cutting tools are produced by pressing and sintering, like hard metal cutting tools. Carbides in hard metal change place with  $\text{Al}_2\text{O}_3$ . A large part of cutting ceramic plates; because of lower flexibility resistance, is not produced in the geometric form of reversible plates made in hard metal. The throw away ceramic cutting bid according to throw away hard metal cutting tool bid mostly must be thick and there is need to specific holding nippers [9].

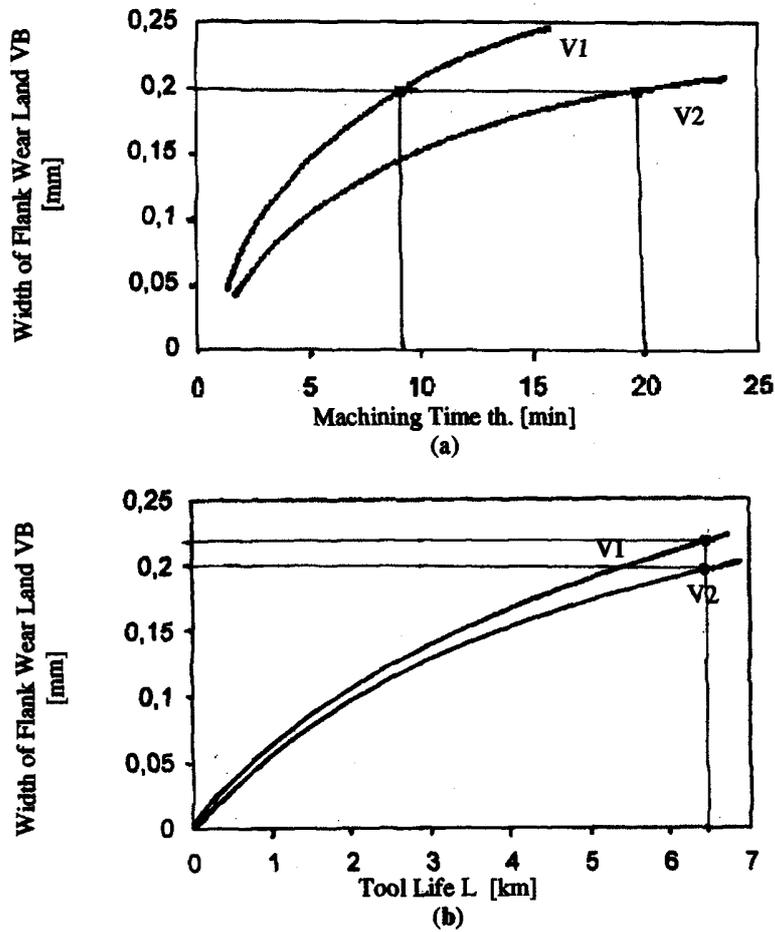
Because of their inherent brittleness, ceramic tools are subject to chipping, cracking, fracturing, and gradual wear by abrasion. Also, since they have high hardness at elevated temperatures, ceramic tools usually perform better at high-speed ranges when compared to carbide tools. A recent study of ceramic tools reports that they can also exhibit a tendency to weld between tool and work and a certain degree of plastic deformation of the tool at elevated temperature. Correlation between the microstructure and properties of ceramic tools relative to the cutting performance have been investigated by several reseachers. When carbide tools fail mainly by plastic deformation and gradually wear caused by several types of wear mechanism such as abrasion, adhesion, diffusion, oxidation, etc. ceramic tools usually fail by chipping, cracking, fracturing, as well as gradual wear caused primarily by abrasion and possible by some chemical reactions at the chip-tool interface[12].

### 3. EXPERIMENTAL STUDIES

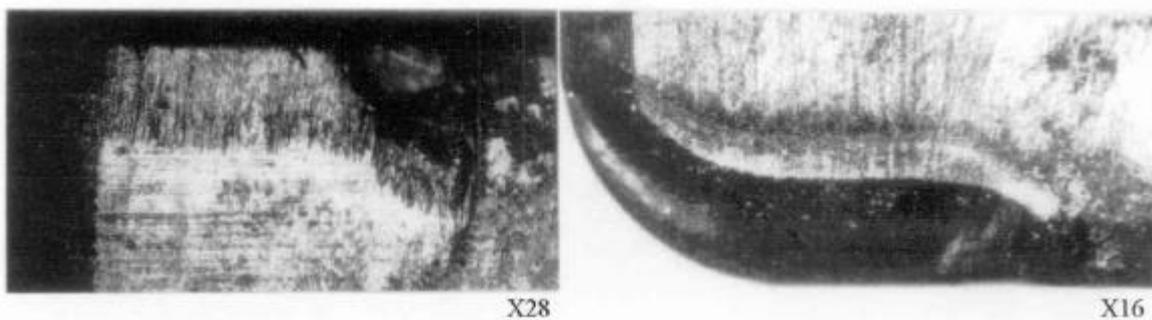
It is possible to see in figure 6, physical property of cutting ceramics, which is different from other cutting materials, has positive effect to wearing behavior. In these experiments, SNGN 12 08 08 T 02020 WIDOLOX R cutting ceramics has been used and Ck 60 steel is processed. Different cutting speeds have been applied and wearing track of wideness by depending on process time (Figure 6.a). In figure 6.b, by depending on cutting line carried to vertical axis (Figure 6.b). As it is seen on diagram 6.b. , the cutting ceramic for the same cutting lines contains the same wearing track of wideness. It is reached to  $VB = 0,2 \text{ mm}$  wearing track of wideness, at a speed of  $325 \text{ m/min}$  cutting speed and  $L_1 = 5.85 \text{ km}$  tool life or at a speed of  $650 \text{ m/min}$  cutting speed and  $L_2 = 6.5 \text{ km}$  tool life. As it is seen cutting speed 2 times high but decreasing in the cutting line is 10 % approximately. For both cutting speed  $L = 6.5 \text{ km}$  tool life is considered  $VB_1 - VB_2 = 0.22 - 0.20 = 0,02 \text{ mm}$  difference is seen. This difference corresponds to the highest increase in the cutting speed. It's important to mention, for each cutting edge the same number of work piece is processed. To use  $325 \text{ m/min}$  or  $650 \text{ m/min}$  cutting speed is not changing processed piece number.

### 4. CONCLUSION

Ceramic cutting tools are considered as contributors for hard metals. They are not substitutes for hard metals. Because of cost increase; usage of ceramics tools must be done carefully. These are used where hard metals are quickly worn but they are not used where it is broken. Cutting ceramics are mostly used instead of hard metals.



**Figure 6.** VB, Width of flank wear land in processing of Ck 60 steel with SNGN 12 08 08 T 02020 WIDOLOX R cutting ceramics. ( $a=1.25$  mm,  $s=0.16$  mm/r, Cutting speeds  $V_1=650$  m/min,  $V_2=325$  m/min.  
 a: VB according to machining time (th)  
 b: VB according to tool life (L)



**Figure 7:** Typical wear patterns of ceramic tool in machining Ck60 steel at cutting speed of 325 m/min, and feed of 0.16 mm/r.

In spite of this we cannot say all properties of them are known. Besides we cannot say that we use all their facilities. Because in many of the manufacturing plants where conventional lathes are used, there are not many constructors who think the effect of machining cost to the total cost. Today still the longer tool life is aimed to be achieved that makes the usage of cutting tools economic but also it increases time rate of management. In N.C.Lathes, machining cost for per piece is decreased, but the tool life is only a few minutes. This statement makes manufacturer closer to the cutting ceramics. Quick development of cutting ceramics and unravel machining attitude need to make detailed investigation about the matter.

## REFERENCES

- [1] R. Vladimir and M. Boleslav , Anwendung von Schneidkeramik, *Werkstatt und Betrieb*, 2 München, (1979), p. 819-822.
- [2] K. Kammer, Schneidkeramik, Diamant und Bornitrid zur Gusswerkstoffbearbeitung, *Yndustrie Anzeiger*, 46, Essen, (1979) , p. 836-840.
- [3] H. Brandt and K. Peitz, Fraesen mit Keramik, *Werkstatt und Betrieb* 6 München, (1980) , p. 353-364.
- [4] N. Sönmez. and M. Özgürler, Sert Metaller, *Mühendis ve Makina Dergisi* 30 (355), Ankara, (1989), p.19-23.
- [5] H.J. Obering M.G. Burmester, Drehen mit Schneidkeramik, Drehen Technologie, SPK-Werkzeuge, Berlin, (1983).
- [6] W. König, Fertigungsverfahren Band 1, Drehen, Fraesen, Bohren, WDI-Verlag GmbH, Düsseldorf, 1981.
- [7] H.K. Tönhoff and S. Bartsch, Wear Mechanisms of Ceramic Cutting Tools, *Amer. Cer. Soc. Bulletin* 67 (6), (1988), p. 1020-1026.
- [8] V. Gamoll, Keramische Scheidstoffe-stand der technik und Ausblicke, *Wt-Z. ind. Fertig* 70 (1980), p. 405-409.
- [9] M. Özgürler and N. Sönmez, Seramik Kesici Takımlar ve Kullanma Alanları, II. Üniversite-Sanayi Yıbbirliđi, Sempozyumu, Kayseri, 25-27 January,1988.
- [10] M.T. Nigata, Fraesen von Zylinderblocken mit Schneidkeramik, *Werkstatt und Betrieb Yssue* 3, München, (1980), p. 66-168.
- [11] M. Özgürler, Kesme Seramik Torna Kalemelerinde Abynmanın ve Ömür Dađyımın Ystatistik Etüdü, Doktora Tezi, Yıldız University, (1986).
- [12] P.M. Noaker, When Ceramics Make Sense, *Manufacturing Engineering* 111 (september) (1993), p. 49-51.

**AUTHORS:** Univ. Prof. Dr. Ni°an SÖNMEZ, Univ. Assoc. Prof. Dr. Cemalettin YAMAN, Department of Metallurgical and Material Science Engineering and Univ. Assoc. Prof. Dr. Mesut ÖZGÜRLER, Department of Industrial Engineering, Yıldız Technical University, 80750 Besiktas, Istanbul, Turkey, Phone Int. ++90 212 259 70 70 (2801) or ++90 212 2 61 86 74, E-Mail: nisan @yildiz.edu.tr