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Application of hard cutting materials for machining by chip removal – Designations of the main groups of chip removal and groups of application

The main concern in the use of this standard is how to assign the group of application for a given hard cutting material provided that the chemical composition, mechanical and physical properties of this material are known. The standard states (clause 4.3) that “working conditions expressed in table 5 in very general terms and manufactures of hard cutting materials may possibly describe them, for their own purposes, in terms more directly related to the fields of use for the hard cutting material they manufacture.” In reality, this is not the case. Manufacturers of hard cutting materials do not know the physics of the contact processes taking place at tool-chip and tool-workpiece interfaces and thus cannot describe properly these working conditions. Although they may provide a user with a detailed list of the mechanical and physical properties of the hard cutting materials they produced (for example, in the USA, these properties are determined using ASTM and ASM standards), they cannot correlate these properties with those involved in the cutting process.

Two characteristics of hard cutting materials are used in the standard, namely, wear resistance and toughness. Moreover, according to the standard, they vary in opposite directions. For example, if toughness increases then wear resistance decreases and vice versa. Problems start when one asks what is the meaning of these wear resistance and toughness.

Wear resistance is not a defined characteristic of the tool material as well as the methodology of its measurement. The nature of tool wear, unfortunately, is not clear enough yet in spite of numerous theoretical and experimental studies. Although various theories have been introduced hitherto to explain the wear mechanism, the complicity of the processes in the cutting zone hampers formulation of a sound theory of cutting tool wear. Cutting tool wear is a result of complicated physical, chemical, and thermomechanical phenomena. Because different “simple” mechanisms of wear (adhesion, abrasion, diffusion, oxidation etc.) act simultaneously with predominant influence of one or more of them in different situations, identification of the dominant mechanism is far from simple, and most interpretations are subject to controversy. As a result, experimental, or post process methods are still dominant in the studies of tool wear and only topological or simply, geometrical parameters of tool wear are selected and thus reported in tool life consideration.

The most common experimental technique used by hard tool material manufacturers to characterize wear resistance is a FALEX-type pin-on-disk tribometer. The main problem is that in this tribometer, the continuous sliding contact occurs by cyclic reintroduction of the same surface element from the counter-material. Repeated contact occurs between many machine elements, such as journal bearings, rotating seals and engine pistons. By contrast in metal cutting, tools generally slide against a fresh, not previously encountered surface (known in physics of materials as juvenile surfaces). Therefore, in laboratory wear testing it is important to reproduce the contact conditions similar to those occurred at the tool-chip interface. The standard laboratory test set-ups for sliding wear are either of pin-on-disk or pin-on-ring type, both characterized by repeated contact between the surfaces. This design has obvious experimental advantages but the resulting contact conditions differ from those at the tool-chip interface. Thus most attempts to use controversial testing for prediction of the contact conditions at the tool-chip interface have been unsuccessful. Moreover, it is impossible to account for a particular tool geometry (rake, flank, inclination angles,

radius of the cutting edge, etc), regime parameters (feed, depth of cut), and the dynamic properties of the machining system.

Even specialists on hard materials (for example, G.S. Upadhyaya, *Cemented Tungsten Carbides: Production, Properties, and Testing*, Noyes Publication, Westwood, New Jersey USA, 1998) point out that the results of the standard (ASTM standard B 611-85) abrasive wear resistance test “should not be understood as wear characteristics of carbide” (p. 279).

Toughness of a hard tool material is even less relevant characteristics bearing in mind the methods used in its determination. In cemented carbides, “Short Rod Fracture Toughness” measurement is common, as described in ASTM standard B771-87. The test procedure involves testing of chevron-slotted specimens and recording the loading versus specimen mouth opening displacement during the test.

To understand why the results on toughness obtained in this way are not relevant in machining, one should recall that fracture toughness is not only a characteristic of the material but also a function of the loading conditions. As shown by Astakhov (V.P. Astakhov, *Metal Cutting Mechanics*, CRC Press, Boca Raton, 1998/1999, page 150, Fig. 4.8), fracture toughness can vary by 300% depending on loading conditions (the state of stress, strain rate, temperature). Therefore, toughness of the tool materials should be determined using loading conditions similar to that occurred in machining.

To attract customers, carbide producers make available a lot of different properties of their materials as:

Strength - Tungsten carbide has very high strength for a material so hard and rigid. Compressive strength is higher than virtually all melted and cast or forged metals and alloys.

Rigidity - Tungsten carbide compositions range from two to three times as rigid as steel and four to six times as rigid as cast iron and brass. Young's Modulus is up to 94,800,000 psi.

High resistance to deformation and deflection is very valuable in those many applications where a combination of minimum deflection and good ultimate strength merits first consideration.

Impact Resistant - For such a hard material with very high rigidity, the impact resistance is high. It is in the range of hardened tool steels of lower hardness and compressive strength.

Heat and oxidation resistance - Tungsten-base carbides perform well up to about 1000°F in oxidizing atmospheres and to 1500°F in non-oxidizing atmospheres

Low temperature resistance (cryogenic properties) - Tungsten carbide retains toughness and impact strength in the cryogenic temperature ranges. (-453°F.)

Thermal Conductivity - Tungsten carbide is in the range of twice that of tool steel and carbon steel.

Electrical Conductivity - Tungsten carbide is in the same range as tool steel and carbon steel.

Specified Heat - Tungsten carbide ranges from about 50% to 70% as high as carbon steel.

Weight - The specific gravity of tungsten carbide is from 1-1/2 to 2 times that of carbon steel.

Hot Hardness - With temperature increase to 1400°F, tungsten carbide retains much of its room temperature hardness. At 1400°F, some grades equal the hardness of steels at room temperature.

Tolerances - Many surfaces of even complete parts can be used the way they come from the furnace, "as sintered", such as mining or drilling compacts. In those parts requiring precision ground accuracy, such as stamping dies, close-tolerance preforms are provided for grinding or EDM.

Methods of Fastening - Tungsten carbide can be fastened to other materials by any of three methods; brazing, epoxy cementing, or mechanical means. Tungsten carbide's low thermal expansion rate must be carefully considered when preforms are provided for grinding or EDM.

Coefficient of Friction - Tungsten carbide compositions exhibit low dry coefficient of friction values as compared to steels.

Galling - Tungsten carbide compositions have exceptional resistance to galling and welding at the surface.

Corrosion-Wear Resistance - Specific grades are available with corrosion resistance approaching that of noble metals. Conventional grades have sufficient resistance to corrosion-wear conditions for many applications.

Wear-Resistance - Tungsten carbide wears up to 100 times longer than steel in conditions including abrasion, erosion and galling. Wear resistance of tungsten carbide is better than that of wear-resistance tool steels.

Surface Finishes - Finish of an as-sintered part will be about 50 microinches. Surface, cylindrical, or internal grinding with diamond wheel will produce 18 microinches or better and can produce as low as 4 to 8 microinches. Diamond lapping and honing can produce 2 microinches and with polishing as low as 1/2 microinch.

Dimensional Stability - Tungsten carbide undergoes no phase changes during heating and cooling and retains its stability indefinitely. No heat treating is required.

However, they fail to answer a simple question: 'What all these properties have to do with the cutting process?' or in other words: "How to correlate quantitatively these properties with those relevant to the cutting parameters?" Normally, besides very general qualitative explanation (plenty of words as "better", "higher", "lower" etc. are used), no specific recommendations are given.

The intent of the discussed standard should be to provide assistance to end users in selection of the proper tool material for the application, to help them to select the carbide grade most suitable for a given application. In reality, however, the standard does not serve this purpose.

Conclusion: The Standard is useless for any practical application because it does not equip the user with any relevant information on the selection of proper tool materials.