УДК 621.002.3

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Cutting Tools Materials

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Many types of tool materials, ranging from high carbon steel to ceramics and diamonds, are used as cutting tools in today's metalworking industry. It is important to be aware that differences do exist among tool materials, what these differences are, and the correct application for each type of material. The various tool manufacturers assign many names and numbers to their products. While many of these names and numbers may appear to be similar, the application of these tool materials may be entirely different. In most cases the tool manufacturers will provide tools made of the proper material for each given application. In some particular applications, a premium or higher priced material will be justified. This does not mean that the most expensive tool is always the best tool. Cutting tool users cannot afford to ignore the constant changes and advancement that are being made in the field of tool materials technology.

To produce quality product, a cutting tool must have three characteristics:

- Hardness: hardness and strength at high temperature.
- Toughness: so that tools do not chip or fracture.
- Wear resistance: having acceptable tool life before needing to be replaced.

Hardness is generally considered as the strength of intermolecular bonds in maintaining their shape without any permanent deformation. It can be also interpreted as the ability of a material in localizing deformation. In the context of cutting tools, hardness is defined as the ability to penetrate into the softer materials (workpiece). Hardness is also a performance measure which describes the capability of tool material in resisting against the permanent changes in shape and geometry during machining. This characteristic becomes more important when the cutting tool is exposed to the extreme heat generated during cutting operation. In this case, a successful cutting is the one with hot hardness which is capable of maintaining its hardness at high temperature.

However, it must be pointed out that extreme hardness is not necessarily a desired feature as it is directly associated with tool fragility or brittleness. High hardness increases the sustainability of the tool against permanent change in shape and geometry during machining while it consequently lowers the fracture strength or toughness during impacts.

Throughout its service life, a cutting tool is subjected to different types of loading, unloading, vibration and other interfering factors. A successful candidate surviving these situations is the one who absorbs the energy imposed by cyclic forces and vibrations without showing any signs of fracture. This capability is generally referred to as toughness which is the ability of a cutting tool to absorb energy before fracture.

Another desired characteristic that a successful cutting tool must possess is wear resistance. Wear is normally defined as the erosion of tool particles by means of another moving surface. Based on the definition of wear, wear resistance can be defined as the ability of cutting tool material to retain its integrity against erosion and eventually demonstration of acceptable tool life.

A desired cutting tool for particular application is the one that demonstrates a balanced combination of all aforementioned features. The question to be addressed here is what types of cutting tools are appropriate for machining titanium and its alloys.

Cutting tools materials can de devided into two main categoreis: stable and unstable. Unstale materials are substances that start at a relatively low hardness point and are then heat treated to promote the growth of hard particles inside the original matrix, which increases the overall hardness of the material at the expense of some its origanal toughness. Since heat it the mechenism to alder the sructure of the substance and at the same time the cutting action produces a lot of heat, such substances are inherently unstable under machining conditions.

Stable materials are substances that remain relatively stable under the heat produced by most machining conditions, as they don't attain their hardness though heat. They wear down due to abrasion, but generally don't chang their properties much use.

Most stable materials are hard enough to break before flexing, which makes tnem very fragile. To avoid chipping at the cutting edge, some tools made of such materials are finished with a sightly blunt edge, which results in higher cutting force due to an increaced shear area, however, tungsten carbide has the ability to attain a significantly sharper cutting adge than tooling steel for uses such as ultrasonic machining of composities. Fragility combined with high cutting forces results in most stable materials being unsuitble for use in anything but large, heavy and rigid machinery and fixtures.

Unstable materials, being generally softer and thus tougher, generally can stand a bit of flexing without breaking, which makes them much more suitable for unfavorable machining conditions, such as those encountered in hand tools and light machinery.

New materials with superior characteristics had been continually introduced to the market during the twentieth century, among them being cemented carbedes, ceramics and sintered axides, diamond, boron nitride, etc.

Cemented carbides

Produced by powder metallurgy technique with sintering at 1000°C, speed can be used 6 to 8 times that of H.S.S, can withstand up to 1000°C, high compressive strength is more than tensile strength. They are very stiff and their young's modulus is about 3 times that of the steel, high wear resistance, high modulus of elasticity, low coefficient of thermal expansion, high thermal conductivity, low specific heat, low thermal expansion.

Ceramics and sintered oxides

Ceramics and sintered oxides are basically made of Al_2O_3. These are made by powder metallurgy technique, used for very high speed (500m/min), used for continuous cutting only, can withstand up to 1200°C. Have very abrasion resistance, used for machining CI and plastics, have less tendency to weld metals during machining. Generally used ceramic is sintered carbides. Another ceramic tool material is silicon nitride which is mainly used for CI.

Diamond

Cutting tool material made of diamond can withstand speeds ranging from 1500 to 2000m/min. On ferrous metals diamond are not suitable because of the diffusion of carbon atoms from diamond to work-piece, can withstand above 1500°C. A synthetic (man made) diamond with polycrystalline structure is recently introduced and made by powder metallurgy process.

Cubic Boron Nitride

The trade name is Borozone. Consists of atoms of Nitrogen and Boron and produced by power metallurgy process. Used as a substitute for diamond during machining of steel, used as a grinding wheel on H.S.S tools, excellent surface finish is obtained.