DESIGNING WEAR PARTS…CARBIDE OR CERAMIC?

The first cemented carbide for a wear-resistant part application was invented in Germany in 1913. It was produced from two carbide, tungsten and molybdenum, and the part was an insert for wire drawing die. From that early start, many different cemented carbide materials evolved having a wide range of properties to resolve wear-part problems. This period also saw the first engineering ceramics materials for wear-resistant applications, and they are now a large and rapidly growing market segment.

Today the array of available materials is very large, and designers are finding it difficult to choose the best wear part materials for gaging, tooling and product component applications. Material characteristic information is published by the manufacturers of both carbide and ceramics materials, but often the information is aimed more at selling the product that in providing engineering guidance. Some published information on ceramics, for example, presents hardness as the determining factor for resistance to wear. It then compares the measured hardness of the ceramic material with that of carbide and draws the conclusion that the higher hardness of ceramic material means superior wear resistance. This is an improper and erroneous conclusion.

Hardness is a primary characteristic of wear-part materials, but it is a slippery property to define when comparing non-related materials (i.e. ceramics to carbides) for a range of different applications. This becomes evident with this question: Why does an EDM wire guide or a drill bushing of cemented tungsten carbide, with a measured Vickers hardness of 1700kg/mm2 (92 Rockwell A), have a useful life substantially greater than one made from a ceramic whose hardness is measured at 2100 (94 Rockwell A)? The reason for this apparent departure from the norm is basic, easily grasped, and the design engineer needs to understand it in order to work knowledgeably with hard materials.

The recognized tests for hardness of materials, Brinell, Rockwell, Vickers, etc., consist of applying known weights and specific indenter shapes to the surface of material samples and measuring the resulting permanent indentations. These test results are useful in evaluating wear resistance when one ceramics material is compared to another and even when a ceramics sample is compared to one of steel, but they are not useful when comparing them to tests on carbide. The reason lies with the difference in the structures of the materials.

Carbide begins as a distributed mixture of tungsten carbide powder (WC) and a small amount of binder powder, generally cobalt (Co), which is processed, shaped, and sintered (heat is applied under various atmospheric conditions). The sintering procedure liquefies the binder which, when cooled, forms a cement in which the hard tungsten carbide powder grains are rigidly imbedded. The grains themselves have a hardness of 2800 kg/mm2-next in hardness to diamond and harder than any ceramic material currently available for wear applications. Thus, a hardness test on carbide basically establishes the depth of penetration of the indenter into the softer binder material containing the distributed, suspended hard grains.

Ceramic materials do not possess this two phase characteristic. They have a monolithic structure-a single, rigid, uniform whole; a hardness test is more definitive and a better measure of wear resistance.

For applications involving rubber action of a smooth steel or ceramic surface in contact with another smooth surface, the measured hardness of the material resists the wear, except in the case of a smooth carbide surface in contact with any other smooth surface. The very hard grains of carbide (2800kg/mm2) on the surface of contact resist the wear: the binder merely holds the grains in place. For these applications the wear life of carbide is 50 to 100 times superior to that of hardened steel and several times better than that of conventional engineering ceramic materials. Examples of this type of application are gage blocks, drill bushings, plug and ring gages, pistons, cylinders, liners, rotary bushings, sleeves, sleeve bearings and shafts, valve seats, wire EDM guides, rollers, etc.

Various tests have been devised to evaluate the wear characteristics of hard materials. One of these, ASTM G65, tests dry abrasion resistance- silica sand is rubbed against the specimen by a rubber wheel. The abrasive action highlights another source of wear for carbides; it tests the strength with which the binder holds the hard tungsten carbide particles in place. When these wear resisting particles are torn loose from the binder, the rate of wear is increased. (Ceramic materials, being monolithic in structure, do not have this characteristic weakness.) Many application require that these forces be resisted, therefore carbide grades have been developed to increase cement strength.

One carbide manufacturer makes a grade which increases cement strength by reducing the binder content to 3% cobalt, the carbide grain size to less than one micron, and incorporates a tantalum carbide additive; it has a measured hardness of 2250 kg/mm2 and resists abrasive wear 5 times better than his standard wear grade (6% cobalt, hardness of 1700 kg/mm2). Another manufacturer, employing a different binder, chromium cobalt, makes a grade with a measured hardness comparable to his standard grade, but dry wheel abrasive wear is improved by a factor of 5. By varying the content of carbides in this way, materials are created with the characteristics to meet an extensive range of wear applications having different requirements.

In addition to hardness and abrasive resistance, other characteristics may be important and can narrow the scope of the search for materials of choice. Density, electrical thermal conductivity, transverse rupture strength (beam strength(, impact resistance, hardness at elevated and reduced temperatures, modulus of elasticity, modulus of rigidity, compressive strength, corrosion resistance (acids, alkalis, and water), coefficient of friction, coefficient of thermal expansion, and magnetism are most of them.

Establishing the best material for an application can be difficult. The range of material properties available in cemented carbide and ceramic materials is extremely wide, and the spectrum is covered by a large number of manufactures. The offering of most manufacturers is limited in scope, and each tends to specialize in selected industry areas. Defined industry-standard products, carbide and ceramics alike are not actually equivalent in properties, manufacturer to manufacturer. Each manufacturer has sought to attract more business in his area of expertise by making his product a little better than that specified by the standard. Finally after you locate a material which has promise, the part must be fabricated and not everyone has that specialized skill. The working surfaces of parts in both carbides and ceramics must be continuous, free from blemishes, finely finished and highly polished. If not, the in-service life, which you have been trying to optimize, will suffer.

For extreme applications, the task to locate the best in performance and cost can be difficult. To meet the challenge, complete specifications detailing your requirements, a list of major manufactures of wear resistant materials, a requirement, and select the best proposal responses. Order a small quantity of preforms, know your fabricator and try the parts in the applications. There is no easier way.