Hotter, Faster, Harder Cutting

Whisker-reinforced ceramic inserts perform even under hostile conditions.

Keith H. Smith

Fig. 1 — A selection of popular ceramic inserts including composite and whisker-reinforced materials.

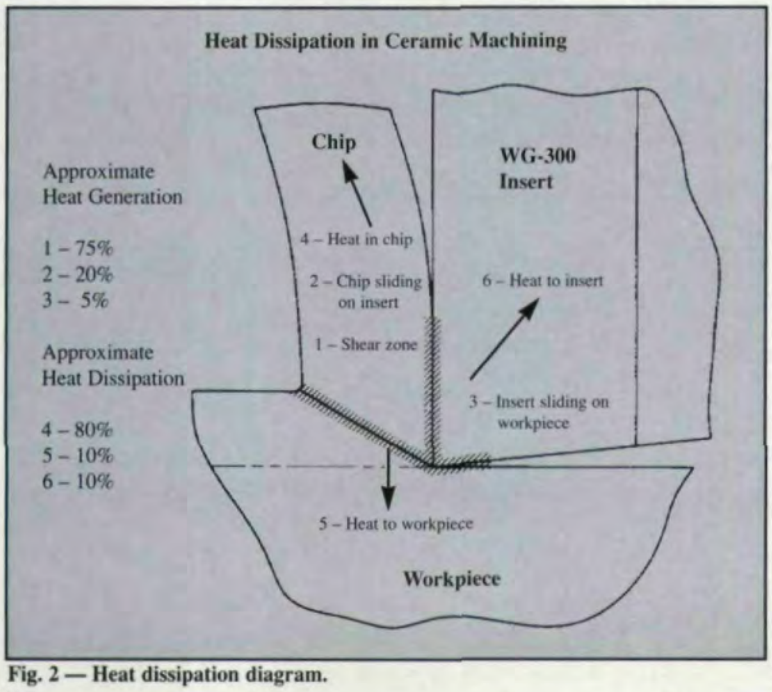

Fig. 2 — Heat dissipation diagram.

What Is Whisker-Reinforced Ceramic?

Whisker-reinforced ceramic as applied to cutting tool inserts comprises a matrix of aluminum oxide into which approximately 50% by volume of high-purity silicon carbide "whiskers" are randomly dispersed. The "whiskers" are, in fact, single crystals having dimensions of approximately 0.6 microns in diameter x 10–80 microns in length. These "whiskers" have a tensile strength on the order of 1,000,000 psi (690 MPa). The composite material that is the best known and most widely applied using this technology is designated WG-300 and manufactured by the Greenleaf Corporation of Saegertown, PA.

When reinforced with silicon carbide whiskers, the aluminum-oxide-based composite exhibits a number of highly desirable properties not found in any other material; namely, very high hot hardness (as high as 1400°C has been measured), exceptional resistance to thermal shock, high abrasion wear resistance, excellent resistance to mechanical shock, chemical inertness and high hardness (94.5 Ra). These properties enable cutting tools to perform reliably and repeatedly in what are regarded as very hostile situations.

For example, nickel-base alloys such as Inconel can be readily machined at speeds as high as 2,000 S.F.M., which is 8 to 10 times the highest speed achieved with tungsten carbide tools. Hardened materials up to 62 Rc can be machined, often as a substitute for grinding. It has been shown that in bearing surface applications, a machined surface will often outwear a ground surface. This is probably due to the elimination of abrasive particles on the surface of the parts.

In the gear industry, there are applications in the facing of hardened gears where the cutting tool is required to pass across the intermittent surface of the gear teeth. Provided that speed is maintained and the feed rate kept within reasonable boundaries, this type of operation can be achieved with a very high rate of reliability, often at speeds as high as 300 to 500 S.F.M.

Whisker-reinforced ceramics owe their performance very largely to their ability to withstand very high cutting temperatures without sacrificing strength and hardness. Cutting tools are, therefore, programmed to achieve a temperature of approximately 1200°C ahead of the tool in the shear zone. In this way, the velocity of the tool generates sufficient heat to plasticize the material immediately ahead of it, facilitating its removal. Therefore, whisker-reinforced ceramics cannot be used to form gear teeth because the short interrupted cuts required for that process will not generate the required heat.

In the hardness range of 43–62 Rc, in continuous engagement operating in turning, boring and grooving, whiskered ceramics offer an alternative technique that can dramatically reduce floor-to-floor times and increase quality and profitability.

A nomogram has been developed that will indicate the approximate surface speed needed to generate the desirable 1000–1200°C temperature ahead of the tool at a given hardness. If speeds *lower* than the recommended speed are mandated, then a corresponding decrease in feed rate from the recommended will be necessary to maintain the required heat.

To use the nomogram, go to the centered horizontal bar and locate the material hardness. Go directly vertically to the upper curve to find the starting speed and then vertically to the lower curve to find a starting feed rate.

In addition to whisker-reinforced ceramics, there are other materials available in the ceramic family that will perform very well on hard ferrous materials. One of these is a material designated GEM-6, which is a composite of titanium carbide and aluminum oxide with special additives. While lower in strength than WG-300 whiskered materials, GEM-6 is extremely wear-resistant and lower in cost and can be expected to perform well in interrupted operations.

It should be mentioned that coolants are recommended for use with whiskered materials because of extreme resistance to thermal shock, whereas the opposite can be said about composite inserts, which are mostly run dry.

The same starting speeds and feeds chart can be used for composite materials.

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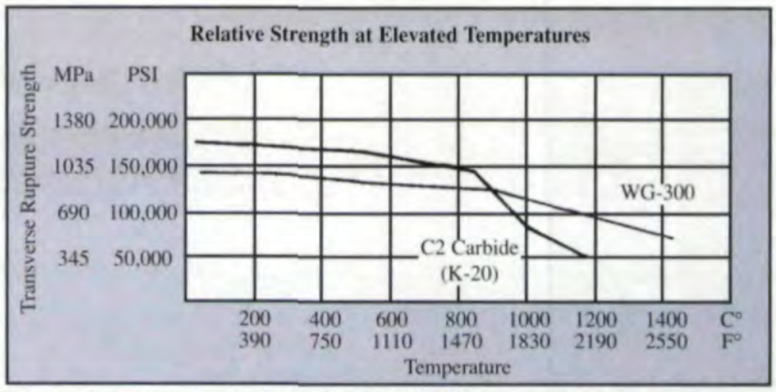

Fig. 3 — Relative strength of carbides and WG-300 at elevated temperatures.

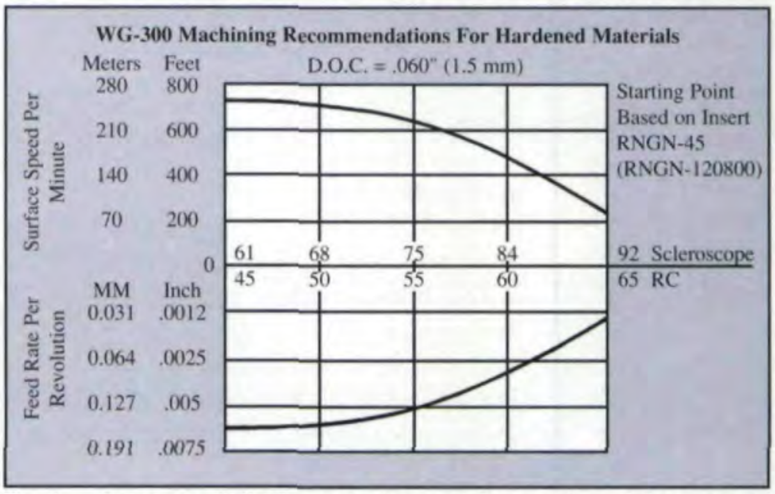

Fig. 4 — Nomogram indicating approximate surface speed needed to generate 1000°–1200°C at a given hardness.

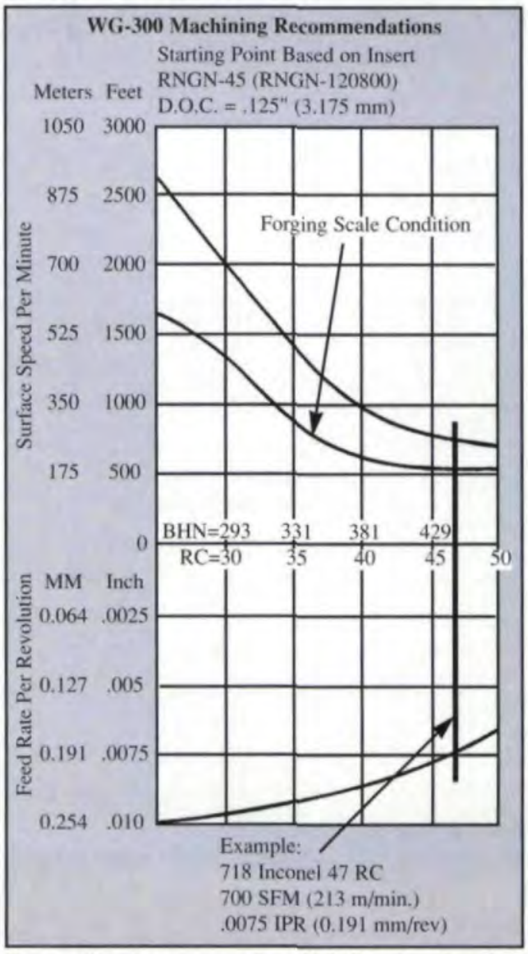

Fig. 5 — Sample nomogram for nickel alloy aircraft engines.

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