Can Composites Be Designed to Make Better Diesel Engine Components?

Goal: Develop new composite materials for diesel fuel delivery systems and wear components

What are the most important characteristics of a good material for diesel engine components? That depends in part on what role those parts will play in the engine. For fuel delivery systems and wear components, desirable characteristics include wear and corrosion resistance, fracture toughness, high flexure strength, and extensive plasticity.

As if all those requirements weren't enough, these materials must also be compatible with steels and be able to tolerate temperatures as high as 150° C for fuel delivery system components to 815° C for wear components. That's a lot to ask of any existing materials, which is why researchers at Oak Ridge National Laboratory (ORNL) are working to develop new cermets (composite materials made by combining a ceramic and a metallic alloy) for use in manufacturing diesel engine components.

Cermets are made by 1) milling together powders of the desired materials, and 2) forming a shape, and then 3) sintering (heating) those materials together to form dense parts. The sintering process causes the component materials to bond together to form a new material with structural characteristics that are better suited for the intended use than either of the starting materials.

Scope of Work

The ORNL researchers fabricated several compositions but here the focus is on cermets based on Titanium Carbide (TiC) and Nickel Aluminide (Ni_3Al). TiC has long been known as a good material for use in cermets due to its high hardness, but Ni_3Al is a more recent candidate. This occurred with advances in the alloying of Ni_3Al that allowed it to become ductile yet have high yield strength and tolerance to wide temperature ranges. Due to their plasticity, alloys such as Ni_3Al have the potential to greatly enhance the fracture toughness of carbide-based materials such as TiC. Thus, these cermets combine the high hardness of the TiC with the good ductility and strength of the Ni_3Al.

Variables among the different cermets created by the ORNL team included tailor of the TiC grain sizes and varying the Ni_3Al binder phase content. After creating the various cermets, the researchers examined the microstructures of each using scanning electron microscopy, measuring both the TiC grain sizes and the Ni_3Al binder phase thickness.

After characterizing the microstructure of the cermets, test samples of each material prepared using electrical discharge machining, and then surface-finished each sample using diamond abrasive wheels to remove the surface layers. Subsequently, the thermal expansion coefficient, the room temperature fracture toughness and the temperature-dependent flexure strengths in air are characterized.

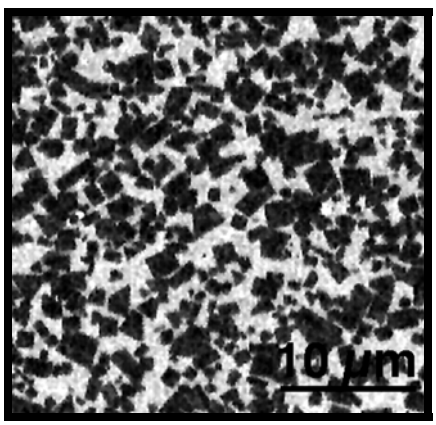
Results and Future Plans

Testing showed that flexure strengths of over 1 GPa could be achieved consistently and that the samples with larger TiC grains and lower Ni_3Al binder content were somewhat weaker than those with smaller TiC grain sizes. With increase in Ni_3Al binder content, all

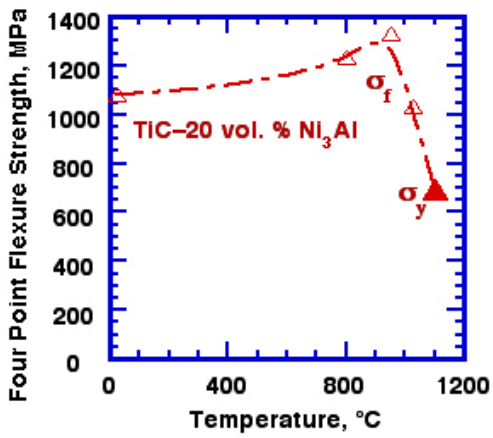
samples had strengths of more than 900 MPa, regardless of TiC grain size. The high flexure strengths are retained to temperatures of ~800°C and then actually increase at 1000°C when tested in air. Above 1000°C, there is a loss of strength as the temperature increases due to the decrease in the yield strength of the Ni_3Al phase. Side by side testing revealed that the room temperature fracture toughness of the TiC-Ni_3Al cermets was comparable to that of commercial WC-Co cermets. It was also shown that by increasing the Ni_3Al content the thermal expansion coefficients of the cermets can adjusted to match those for steels, which is important when combining materials as required in diesel applications.

At present, cermet components are being fabricated for test in diesel fuel systems. Future studies will seek to develop other cermet compositions, which involve other ceramics (oxides and nonoxides), in combination with various metallic alloys (e.g., nichrome).

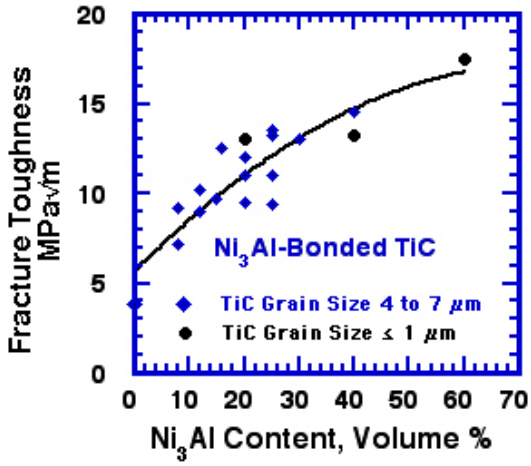
Research Partners
Oak Ridge National Laboratory
CoorsTek
Cummins Engine Company
Southern Illinois University



Cermet is composed of dark TiC grains surrounded by lighter Ni_3Al.



Very high fracture strength achieved in cermet which is retained to ~ 1000°C. Above 1000°C cermet deforms like a metal.



High fracture toughness is obtained by increasing Ni_3Al content.