Dr. Neil Canter / Contributing Editor

Lightweight self-lubricating metal matrix composites

These materials can be designed to meet a specific performance requirement.

DEVELOPMENT OF NEWER MATERIALS THAT ARE LIGHTER IN WEIGHT is continuing due to the demands being placed for greater efficiencies in applications such as automobiles. The U.S. automotive industry is faced with having to achieve a Corporate Average Fuel Economy (CAFE) rating of 54.5 miles per gallon (mpg) by 2025, which is substantially higher than the current 2016 requirement of 35.5 miles per gallon.

KEY CONCEPTS

- Self-lubricating metal matrix composites have been prepared by combining a metal alloy such as aluminum with a solid lubricant such as graphite.
- A casting technique prepares metal matrix composites that contain between 0.5% and 10% graphite particles by volume in an aluminum matrix.
- Preparation of a metal matrix containing graphite and silicon carbide in the aluminum cast alloy A356 resulted in a major reduction in heat transmission through the lubricant in a rotary engine and an improvement in fuel economy.

In addressing this issue, use of metals such as aluminum and magnesium have increased, but there is need for lightweight materials that provide even superior mechanical and physical properties. Dr. Pradeep Rohatgi, chief technical officer for Intelligent Composites LLC in Milwaukee, Wis., and distinguished professor and director of the UWM Composite Center at the University of Wisconsin-Milwaukee, says, “Aluminum alloys are prone to scuffing, welding, high coefficients of friction and high wear rates.”

One option that is under examination is to develop composites that combine a metal alloy with a second material that can assist with improving performance. One example is found in a recent TLT article that discusses a lightweight metal matrix syntactic foam.[1] This material is prepared by the introduction of silicon carbide particles as a filler in the magnesium alloy AZ91D. Two key characteristics of this material is that it exhibits superior vibration dampening properties as compared to the base magnesium alloy and has such a low density that it will float on water.

Another class of materials that have been under development for 40 years are metal matrix composites. Rohatgi says, “Metal matrix composites combine a metal alloy such as aluminum with a second material that can be in the form of particles, whiskers, fillers or hollow microballons and enhances the properties of the metal. This enables us to develop a new composite that is tailored for a specific application need. In the case of lubrication, we can prepare self-lubricating metal matrix composites that contain a solid lubricant such as graphite, boron nitride, mica or talc in combination with a metal alloy.”

Use of metal matrix composites as components in a rotary engine led to improved fuel economy.

An example of a metal matrix composite is the incorporation of graphite into an aluminum alloy. Rohatgi says, “We have been able to add graphite particles which have diameters between 20 and 200 microns at a treat rate between 0.5% and 10% by volume into an aluminum matrix. The resulting composite is very effective in reducing friction and wear in applications such as a shaft running against a bearing. In contrast to solid lubricants that are spray coated onto parts, the metal matrix is a semi-continuous layer that remains effective even when a little bit of the material wears away because the graphite particles are uniformly dispersed through the aluminum matrix meaning another set of graphite particles are available in the new layer to reduce friction and wear."

Metal matrix composites can be prepared in one of two manners. Rohatgi says, "The traditional procedure has been to press and sinter powder metals with the second material. This process is not suitable for scale-up because it only is effective on a small scale and is costly."

A second approach is to use a casting technique where the metal is liquefied and the second material is added followed by stir mixing. Then the suspension is poured into a mold and solidified. David Weiss, CEO for Intelligent Composites LLC, says, "We have found this to be a very cost effective way to produce various types of metal matrix composites including those that form complex shapes. Large batches made in this manner can produce up to nine metric tons of material at a time."

Figure 1 | **Lightweight self-lubricating metal matrix composites represent a new approach for potentially improving automobile fuel efficiency.** *(Figure courtesy of Intelligent Composites, LLC.)*

APPLICATION IN A ROTARY ENGINE

One of the initial applications where metal matrix composites were used was in cylinder lines present in air brake compressors. Weiss says, "A large amount of compressor oil was bypassing the collector and ending up in the air tanks, which hindered performance. Use of a metal matrix composite in the cylinder lines led to a 60% reduction in compressor oil that bypasses the collector."

Rotary engines displayed potential to replace current internal combustion engines but have not been used due to inferior fuel economy results and the discharge of a higher level of emissions. Testing is underway to evaluate metal matrix composites as components used in rotary engines.

For this study, the metal matrix composite is prepared with two materials, graphite and silicon carbide, that are incorporated into the aluminum cast alloy, A356. Weiss says, "Rotary engine testing was conducted using dynamometer equipment and including engine oil in the evaluation. The results showed that transmission of heat through the oil, a major problem with rotary engines, is significantly reduced and an improvement in fuel economy is achieved."

This is an example demonstrating that metal matrix composites can be prepared with not only a wide variety of materials but with combinations of materials. Rohatgi adds, "We believe that use of metal matrix composites in engine components also will enable the lubricant to last for a longer period time leading to a lengthening of drain intervals."

Rohatgi also points out that metal matrix composites were used successfully in the engines of Formula 1 racecars with good success.

For the future, Rohatgi and his colleagues are looking to produce cylinder sleeves composed of metal matrix composites and evaluate them in internal combustion engines. This material has the potential to assist OEMs with achieving greater fuel efficiency.

Additional information can be found in an article published in 2012[2] and by contacting Chris Jordan, Chief Marketing Officer of Intelligent Composites at **chris@intelligentcomposites.com**.

REFERENCES

1. Canter, N. (2015), "Lightweight metal matrix syntactic foam," *Tribology and Lubrication Technology*, **71** (8), pp 12 – 13.
2. Macke, A., Schultz, B. and Rohatgi, P. (2012), "Metal Matrix Composites," *Advanced Materials & Processes*, **170** (3), pp 19 – 23.