Journal of Advances and Scholarly Researches in Allied Education
Vol. 17, Issue No. 1, April-2020, ISSN 2230-7540

Manufacturing and Applications of Ceramic Matrix Composites in the Automotive Industry

Dr. Vishal Kumar*

Associate Professor, Department of Physics, Government Women (PG) College, Kandhla, District-Shamli, State-Uttar Pradesh

Abstract - A reduction in exhaust emissions, fuel consumption, and vehicle weight is necessary for the advancement of the modern automobile industry at the same time as an increase in safety and vehicle performance. The introduction of new modern materials with increased qualities in place of traditional materials can fulfill these difficult and mutually contradictory conditions. This is a trend that has been going on for a long time and is expected to continue into the next decade. For automobile parts requiring great mechanical endurance and strong resistance to extreme temperatures with a decreased bulk, ceramic-based composite materials (CMCs) are becoming increasingly popular. Many different forms of ceramic base composites are routinely utilized as matrices, including oxide, silicon carbide (SiC), carbon, and others. CMCs are now employed in the production of individual vehicle engine components, valves, turbine parts, exhaust and intake systems, brake disks, and other brake system components, amongst other things.

Keywords - Ceramic Matrix Composites, Automotive Industry, ceramic-based composite materials.

--x--

INTRODUCTION

There are many different types of composites, yet they all share the same basic characteristics. Typically, it is composed of two phases: a continuous one known as the matrix, and a dispersed one known as reinforcement. Construction, oil and gas, electrical & electronics and consumer goods are some of the industries where ceramic matrix composites (CMC) are used. Ceramic matrix composites are used extensively in the automotive sector. Brittle failure, low fracture toughness and restricted thermal shock resistance are important drawbacks of conventional technical ceramics, which are all solved by CMC materials. Because of this, CMC materials are employed in industries that demand high-temperature reliability and resistance to corrosion and wear. In the automotive industry, ceramic matrix composite braking systems are a popular choice. Automotive clutches also use ceramic matrix composites. They may run with little or no cooling, which greatly improves the cycle's efficiency.

Over standard steel and injection molded automobile parts, there are numerous advantages to using composites. In addition to weight and cost savings, recyclability is also a factor here. One-third of the weight of previously employed nickel (Ni) super-alloys is now made up of ceramic matrix composites. Ceramic matrix composites are commonly used in the automobile sector to make brake disks and other components of the brake system that are subjected to high temperatures. Carbon-reinforced ceramic matrix composites provide a number of advantages over metal disks, such as less wear, improved corrosion resistance, and lower weight, making them ideal for vehicles with a regular driving load of 300,000 kilometers.

The surge in disposable income of customers is expected to fuel the global automotive industry in the passenger automobile sector. The demand for luxury cards is expected to rise as a result of an increase in disposable income worldwide. However, environmental concerns are expected to have a negative impact on the market during the next few years. Automobile makers are working hard to make their vehicles lighter so that they can run more efficiently and use less fuel. As a result, OEMs are switching from old materials to more modern designed composites like ceramic matrix composites. Shock absorber responsiveness, road-holding comfort, agility, fuel efficiency, and consequently driving comfort are all improved by reducing the weight of a vehicle. As a result, demand for automotive ceramic matrix composites is expected to rise throughout the forecast period. A major impediment to broader adoption in price-sensitive markets, however, is the high cost of the technology. Despite this, ceramic matrix composites makers have been working on ways to cut the price of their products.

Advanced metal-matrix composites

The Center for Composite Materials and the Center for Advanced Materials Manufacture (CAMM) are leading forces behind several innovations in the field of advanced cast metallic materials. Metal-matrix composites are metals or alloys that incorporate particles, whiskers, fibers, or hollow micro balloons madeof a different material, and offer unique opportunities to tailor materials to specific design needs. These materials can be tailored to be lightweight and with various other properties including:

- High specific strength and specific stiffness
- High hardness and wear resistance
- Low coefficients of friction and thermal expansion
- High thermal conductivity
- High energy absorption and a damping capacity

In addition to these properties, new MMCs are being developed at UWM with self-healing, self-cleaning, and self-lubricating properties, which can be used to enhance energy efficiency and reliability of automotive systems and components.

Table-01: Metal-Matrix Composite (Mmc) Materials Being Developed In Automotive Applications

Property	Materials	Application
Wear resistance	SiC-, Al_2O_3-, and/or graphite-reinforced micro and nano MMCs	Bearing surfaces, cylinder liners, pistons, cam shafts, tappets, lifters, rockers, brake components
Light weight, energy absorption	Fly ash cenosphere- and low-density ceramic microballoon-reinforced syntactic foam MMCs	Crumple zones, frame members and reinforcements, pedestrian impact zones, batteries
Self-cleaning	MMCs with hydrophobic reinforcements, biomimetic coatings, and surface finishes	Water pumps, water jackets, exposed metallic components
Self-lubricating	Micro and nano MMCs incorporating graphite, MoS_2, TiB_2, hexagonal BN, or other solid lubricants	Bearing journals, cylinder liners, pistons, cv joints, gear surfaces
Self-healing	MMCs incorporating shape memory alloys or hollow reinforcements filled with low-melting healing agents	Difficult-to-access, fatigue prone, and critical components, such as driveshafts, wheels, steering knuckles and columns, and connecting rods
High thermal conductivity	Micro and nano MMCs reinforced with high conductivity carbon, diamond, or cubic boron nitride (cBN) powder	Cylinder liners, water passages, brake components, turbo/supercharger components, catalytic converters, electronics packaging
High strength	Micro and nano MMCs reinforced with SiC or Al_2O_3 particles, carbon nanotubes (CNT), carbon or Nextel fibers, and in-situ ceramics	Connecting rods, brake calipers, brake rotors, brake calipers
Low cost	MMCs containing fly ash or waste sand as fillers	Intake manifolds, accessory brackets, low-load brackets, oil pans, valve covers, alternator covers, water pumps

Pistons and cylinder liners

Cast iron cylinder liners are usually required for aluminum engine blocks because metal has poor wear characteristics. A porous silicon preform is used by Porsche in the cast aluminum block to create MMC cylinder liners, and Honda employs alumina and carbon fibers in the die cast aluminum bores in a similar way. Improved wear and cooling efficiency over cast iron liners can be achieved through these approaches. Aluminum alloy pistons and cylinder liners with scattered graphite particles have been created by the University of Wisconsin-Madison (UWM). In the absence of boundary lubrication, graphite-containing aluminum has a lower friction coefficient and wear rate and does not seize. Concentrated graphite particles are concentrated in an inner periphery where they are needed to provide solid lubrication by using centrifugal casting. In gas and diesel engines and race cars, aluminum graphite pistons and liners have lower friction coefficients and wear rates. The liner's wear rate is reduced because a graphite film forms on the aluminum when the graphite shears under wear circumstances. Al-graphite composites have a friction coefficient as low as 0.2, according to testing. In lightweight aluminum engine blocks, this material can be used for cylinder liners to enable engines to reach operating temperatures more quickly while also providing higher wear resistance, improved cold start emissions, and decreased weight. Conventional casting methods, such as sand, permanent mold, die casting, and centrifugal casting, can be used to cast aluminum-based composite liners in place.

Main bearings

Lead-free aluminum or copper matrix composites containing graphite particles discovered at UWM can replace copper-lead bearings currently used in crankshaft main bearing caps. Nontoxic graphite and aluminum and copper-graphite composite bearings save weight in place of lead-filled copper. Deformation of graphite particles in bearings results in a continuous graphite film, which offers self-lubrication of the component, allowing for better component longevity. A wide range of journal bearings in the powertrain could benefit from these materials. In a single stage, centrifugal casting of metal-graphite suspensions can produce functionally gradient bearings of aluminum and copper alloys (Figs. 1 and 2).

Fig. 1: Aluminum-graphite particle composite piston and cylinder liner developed at UWM Center for Composite Materials. The inset microstructure shows that graphite particles concentrate in the inner periphery of the liner

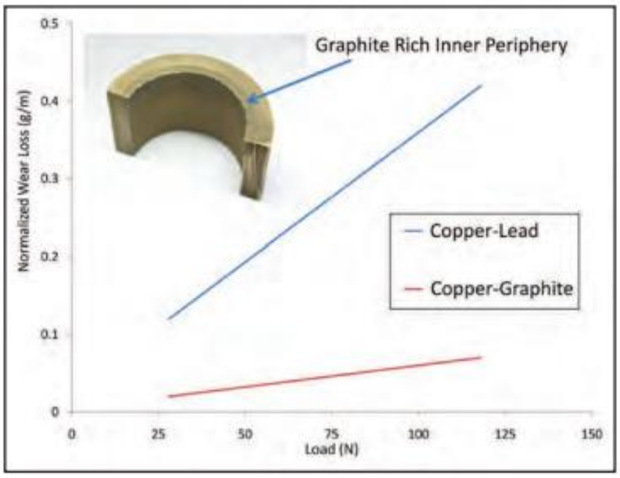

Fig. 2: Copper-graphite composites outperform leaded copper in normalized wear loss in sliding wear. Inset shows a cross section of an unfinished centrifugally cast copper-graphite bearing.

Reliability, survivability, and reduced maintenance

Engineered materials with self-repairing capabilities are being developed by UMW in a manner comparable to how biological systems mend. Known as self-healing materials, they are a novel type of material that can repair damage, such as cracks or voids, on its own. Shape memory alloy wires, which can "remember" their shape, are used to give metals a self-healing feature. When heated and stretched over a crack, these wires pull the crack edges together as they return to their original shape (Fig. 3a). It's possible to incorporate micro tubes or micro balloons that hold a low-melting alloy into high-melting casts, which burst upon cracking to allow the lower melting alloy to fill and close any intruding cracks. The ability of polymeric and ceramic materials to self-heal has been established, and UWM is currently striving to produce self-healing in metallic materials by combining long and short fibers of shape-memory alloys and micro-balloons and micro-tubes filled with low-melting healing alloys (Fig.3)

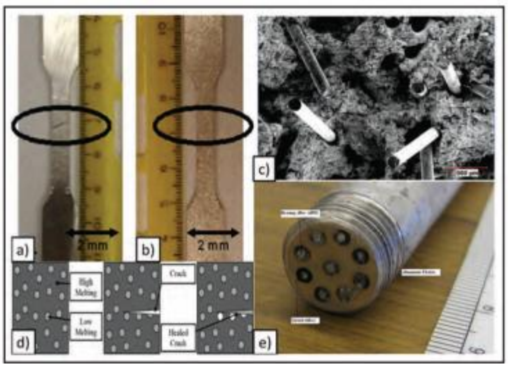

Fig. 3: (a) Shape-memory alloy (SMA) wire-reinforced tensile bar with crack[18]; (b) SMA wire-reinforced tensile bar with healed crack[18]; (c) SEM image of fractured surface showing NiTi SMA wires extending from the crack surface in a Sn-20% Bi matrix; (d) schematic of self-healing metal using an encapsulated low-melting point phase; and (e) aluminum composite containing quartz tubes filled with an aluminum brazing alloy

These self-healing materials can help enhance the survivability of automobiles and lead to reduced maintenance and increased reliability. UWM is also developing super hydrophobic metal-matrix composites and surface treatments on conventional alloys including nanostructured coatings, to have self-cleaning components that can lead to increased safety and reduced maintenance in automobiles.

CONCLUSION

The automotive ceramic matrix composites market in Asia Pacific is anticipated to expand rapidly during the forecast period due to the expansion in the automotive industry in countries such as China, India, Malaysia, and Japan. Thus, Asia Pacific is anticipated to dominate the global market during the forecast period. North America and Europe follow Asia Pacific in the automotive ceramic matrix composites market in terms of share. Latin America is anticipated to offer high growth opportunities for the reinforced automotive ceramic matrix composites market, due to the expansion in the automotive industry in the region. The automotive ceramic matrix composites market in Middle East & Africa is also likely to expand in the near future. owever, several manufacturers operate around the world. Key players in the automotive ceramic matrix composites market include SGL Group, Ceramtec, Composites Horizons, ATK/COI Ceramics, United Technologies Aerospace Systems, and COI Ceramics Inc.

REFERENCES

1. S.B. Singh, Metal Matrix Composites: A Potential Material for Futuristic Automotive, SAE Technical Paper 2003-26- 0038, 2003.

2. M. Kim, et al., Development of Cast-Forged Knuckle using High Strength Aluminum Alloy, SAE Technical Paper 2011- 01-0537, 2011.

3. A. Sherman and P. Sklad, Collaborative Development ofLightweight Metal and Alloys for Automotive Applications, SAE Technical Paper, 2002-01-1938, 2002.

4. P.K. Rohatgi, Use of Lightweight Metal-Matrix Composites for Transportation

Applications in India, SAE Technical Paper 2004-28-0070, 2004.

5. W.H. Hunt and D.B. Miracle, Automotive applications of metal matrix composites, D.B. Miracle, S.L. Donaldson (Eds.), ASM Handbook: Composites, Vol 21, ASM International, Materials Park, Ohio, p 1029-1032, 2001.

6. P.K. Rohatgi, S. Ray, and Y. Liu, Tribological Properties of Metal Matrix Graphite Particle Composites, International Materials Reviews, (USA-UK), Vol 37, No. 3, p 129, 1992.

7. P.K. Rohatgi, et al., Solidification during Casting of MetalMatrix Composites, Invited paper, ASM Handbook, Vol. 15, ASM International, p 390-397, 2008.

8. M. Gumus, Reducing cold-start emission from internal combustion engines by means of thermal energy storage system, Appl. Therm. Eng., Vol 29, p 652-660, 2009.

9. M. Kestursatya, J.K. Kim, and P.K. Rohatgi, Friction and Wear Behavior of Centrifugally Cast Lead Free Copper Alloy Containing Graphite Particles, Metallurgical and Materials Trans., Vol 32A, No. 8, p 2115-2125, 2001.

10. Q. Jun, A. Linan, and P.J. Blau, Sliding Friction and Wear Characteristics of Al2O3-Al Nanocomposites, Proc. of STLE/ASME IJTC, p 59-60, 2006.

11. B.F. Schultz, J.B. Ferguson, and P.K. Rohatgi, Microstructure and Hardness of Al2O3 Nanoparticle Reinforced Al-Mg Composites Fabricated by Reactive Wetting and Stir Mixing, Mat. Sci. and Eng. A, doi:10.1016/j.msea.2011.09.042, 2011.

Corresponding Author

Dr. Vishal Kumar*

Associate Professor, Department of Physics, Government Women (PG) College, Kandhla, District-Shamli, State- Uttar Pradesh

Email - vkphylec@yahoo.in