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Metal and Polymer Matrix Composites II

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The Metal and Polymer Matrix Composites II (MPMC II) symposium was organized as a part of the TMS 2016 Annual Meeting & Exhibition (TMS2016) in Nashville, Tennessee. It followed the success of the first edition of this symposium that was organized as a part of Materials Science and Technology 2013 conference in Montreal, Canada. The MPMC II symposium contained 37 oral and six poster presentations. Selected presenters were invited to publish in this special topic collection of *JOM*, which contains nine papers. These papers present topics related to lightweight aluminum and magnesium matrix composites, lightweight polymer syntactic foams, and additive manufacturing. Weight reduction is a priority in transportation structures to reduce fuel consumption. Progress in the science and technology of lightweight composite materials helps in moving closer to the weight reduction goals for automobile manufacturers and enables new applications of these composites.

COMPOSITE MATERIALS FOR WEIGHT REDUCTION

Weight reduction and performance improvement are desired in all modes of transportation.[1] Reduction in the weight of aircraft directly adds to the payload capacity and flying range. Similar advantages are also envisioned for vehicle weight reduction. Corporate Average Fuel Economy (CAFE) standards are pushing for weight reduction in vehicles to improve fuel economy and reduce emissions. Composite materials are playing an important role in meeting the weight reduction requirement because of their light weight. Higher performance of composite materials compared to traditional materials also helps in weight reduction due to achieving the same performance level with less material. Large scale usage of carbon fiber composites in the Boeing Dreamliner is an example where composites successfully replaced a traditional material for weight saving.

Ground transportation vehicles are also witnessing increased use of composites, although most of the current examples are primarily limited to high-end expensive cars. One such example of a limited production run car, the McLaren 570S, is shown in Fig. 1. Several large-scale parts of carbon-fiber-based composites are used in this car that was displayed in the 2015 New York International Auto Show. A broad survey of various small-production and mass-produced cars revealed that carbon fiber composites are being rapidly adopted in several models. Rear air diffusers or front air splitters of carbon fiber composites are now found on the Cadillac CTS, Audi R8, and Porsche 918 Spyder, among many other models. Rear view mirror casing and driver and passenger seat molds are also made of carbon fiber composites in several production models. While interest in carbon fiber based composites has been high in such applications due to the possibility of molding them in complex shapes and contours, lightweight metal matrix composites (MMCs) are also candidate materials because of their utility in reducing the weight of the engine, transmission and exhaust systems. Due to high temperature conditions, these components cannot be made of polymer matrix composites (PMCs). Aluminum and magnesium matrix composites have emerged as candidates for such applications. The all-aluminum 2015 Ford F150 pickup truck pushes the use of aluminum, which may pave the way for future higher performance aluminum matrix composites being applied in such applications. It is expected that advancement in technology related to magnesium matrix composites and reduction in the price of magnesium as applications grow will result in rapid growth in the area of magnesium matrix composites.

Advancements in composite materials have led to development of a wide variety of material systems and processing methods. Research efforts continue

Nikhil Gupta is the guest editor of the topic Metal and Polymer-Matrix Composites II in this issue, which highlights presentations from the TMS 2016 Annual Meeting & Exhibition, Nashville, TN, February 14–18, 2016.

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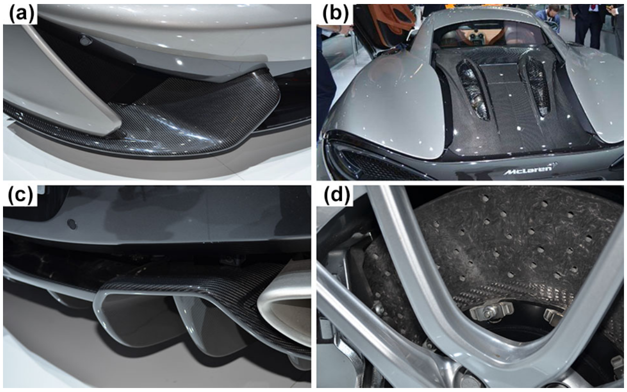

Fig. 1. Carbon composite parts in McLaren 570S displayed at 2015 New York International Auto Show (a) front air splitter, (b) engine cover, (c) rear diffuser and (d) brake disk.

on all fronts to develop the science and technology related to MMCs and PMCs. The Metal and PMCs Symposium II at TMS2016 was planned to provide a platform to researchers working on various aspects of MMCs and PMCs and capture the state of the art in these areas, which is also reflected by the articles included in this special issue topic. The symposium is sponsored by the Composite Materials Committee of TMS.

SUMMARY OF PAPERS

Although carbon and glass fiber reinforced PMCs are widely used and extensively studied, one of the papers showcased even lighter composites. “Quasi-Static and High Strain Rates Compressive Response of Injection Molded Cenosphere/HDPE Syntactic Foam” by Bharath Kumar et al. discusses hollow particle filled composites called syntactic foams. These composites are used in weight sensitive systems where low density (0.5–1 g/cm^3) of these materials can provide weight saving compared to traditional fiber reinforced composites. The study shows that the compressive properties of HDPE matrix syntactic foams are strain rate dependent. The compressive strength is found to increase with the test strain rate. Such properties are relevant to their applications in automobiles and consumer products.

Advances in 3D printing are now enabling printing components of composite materials for many critical applications in the aerospace sector. The article by Zeltmann et al. entitled “Manufacturing and Security Challenges in 3D Printing” discusses several challenges that exist in the present 3D printing technology. This article demonstrates how changes in orientation of a part on the build plate of a 3D printer can cause changes in mechanical properties. It also shows defects below a critical size may go undetected in the specimens by routine tensile testing. However, such small defects may still be significant for fatigue conditions.

Sabau et al. present a discussion on joining of carbon fiber laminate with aluminum in the article “Surface Characterization of Carbon Fiber Polymer Composites and Aluminum Alloys after Laser Interference Structuring.” Joining of metal with PMCs is a major consideration in automotive and aerospace structures as corrosion can be enhanced in such joints. This article discusses the procedure of preparing the surface of the laminate with laser treatment and modification of carbon fiber surface for improved bonding with aluminum.

“Emerging Environment Friendly Magnesium Based Composite Technology for Present and Future Generations” by Meenashisundaram and Gupta highlights the role of nanoparticle incorporation on the mechanical properties of magnesium alloy matrix nanocomposites. As the lightest weight structural metal presently available, magnesium has been a focus of a large number of studies in recent years.[2] The literature review presented in this paper shows that nanoparticle reinforcement can simultaneously improve the yield strength and ductility in magnesium alloys. Although a number of commercial alloys are now available for use in automobiles and parts such as wheels of magnesium alloys are widely used, misconceptions still exist about flammability and corrosion of magnesium alloys. Discussion on magnesium alloys and the present state of the art can help in accelerating the applications of this light metal.

Mandal and Mitra discuss the complex microstructural evolution and mechanical properties during mushy state rolling in “Effect of Mushy State Rolling on the Microstructure, Microhardness, and Microtexture in Al-4.5wt.%Cu-5wt.%TiB_2 In-Situ Composite.” It is documented that mushy state rolling of the as-cast composite generates a bimodal microstructure, which consists of very fine equiaxed grains adjacent to the rolled surface and comparatively larger elongated grains away from the rolled surface of the sample. Properties of the composite also change accordingly.

Muller and Nair present the study “Dislocation Nucleation in Metal-Graphene Nanocomposites Under Mode I Loading” based on molecular dynamic simulations of nickel-graphene nanocomposite laminates. Graphene is currently considered one of the most promising reinforcements for composites. This study finds that graphene prevents the transmission of dislocations between different regions of the Ni-matrix. It is also observed that multilayer graphene nanocomposites are prone to delamination at the interface.

Vo et al. present the study “Development of a Precipitation-Strengthened Matrix for Non-Quenchable Aluminum Metal Matrix Composites.” This study develops non-quenched Al-0.06 Sc-0.03 Zr and Al-0.09 Sc-0.045 Zr (at.%) alloys for composite matrix application. It is shown that the dilute Al-0.09 Sc-0.045 Zr at.% alloy and the same alloy containing 0–4 vol.% alumina short fibers do not result in precipitation upon slow cooling from a high temperature, and can be aged to increase their strength. Enhanced properties of these alloys make them promising in armor applications.

Das et al. discuss processing of AA1100 aluminum alloy reinforced with magnetostrictive galfenol ($Fe_{82}Ga_{18}$) particles in "Magnetic Properties of Friction Stir Processed Composite." Results show that the processing was successful in fabricating the composite and a higher volume fraction of galfenol results in a higher magnetic interaction between the galfenol particles and a higher magnetostriction response.

In another study focused on processing of composites, "In Situ Nanocrystallization-Induced Hardening of Amorphous Alloy Matrix Composites Consolidated by Spark Plasma Sintering," Singh et al. discuss results on $(Fe,Cr)_{23}(C,B)_6$. They show that densification and nanocrystallization of particles during spark plasma sintering resulted in enhancement of hardness from about 1150–1375 VHN.

SUMMARY

The second edition of the Metal and PMCs, organized as a part of TMS2016, presented the state of the art in processing methods of a wide range of composite materials and their mechanical properties. This focused topic contains nine articles; additional articles can be found in the proceedings of the conference. The articles presented in this focused topic are related to processing methods such as casting, friction stir processing, spark plasma sintering, mushy state rolling and 3D printing. Advancement in the processing methods are enabling next generation higher performance composite materials that are useful in industrial applications for products with reduced weight and enhanced properties.

The following papers being published under the topic of Metal and Polymer-Matrix Composites II provide excellent details and research on the subject. To download any of the papers, follow the url http://link.springer.com/journal/11837/68/7/page/1 to the table of contents page for the July 2016 issue (vol. 68, no. 7).

- "Quasi-Static and High Strain Rates Compressive Response of Injection Molded Cenosphere/HDPE Syntactic Foam" by B.R. Bharath Kumar, Ashish Kumar Singh, Mrityunjay Doddamani, Dung D. Luong, and Nikhil Gupta
- "Manufacturing and Security Challenges in 3D Printing" by Steven Eric Zeltmann, Nikhil Gupta, Nektarios Georgios Tsoutsos, Michail Maniatakos, Jeyavijayan Rajendran, and Ramesh Karri
- "Surface Characterization of Carbon Fiber Polymer Composites and Aluminum Alloys after Laser Interference Structuring" by Adrian S. Sabau, Clayton M. Greer, Jian Chen, Charles D. Warren, and Claus Daniel
- "Emerging Environment Friendly Magnesium Based Composite Technology for Present and Future Generations" by Ganesh Kumar Meenashisundaram and Manoj Gupta
- "Effect of Mushy State Rolling on the Microstructure, Microhardness, and Microtexture in Al-4.5wt.%Cu-5wt.%TiB_2 In-Situ Composite" by Monalisa Mandal and Rahul Mitra
- "Dislocation Nucleation in Metal-Graphene Nanocomposites Under Mode I Loading" by Scott E. Muller and Arun K. Nair
- "Development of a Precipitation-Strengthened Matrix for Non-Quenchable Aluminum Metal Matrix Composites" by Nhon Q. Vo, Jim Sorensen, Eric M. Klier, David N. Seidman, and David C. Dunand
- "Magnetic Properties of Friction Stir Processed Composite" by Shamiparna Das, Nelson Y. Martinez, Santanu Das, Rajiv S. Mishra, Glenn J. Grant, Saumyadeep Jana, and Evgueni Polikarpov
- •"In situ Nanocrystallization-induced Hardening of Amorphous Alloy Matrix Composites Consolidated by Spark Plasma Sintering" by Ashish Singh, Tanaji Paul, Shravana Katakam, Narendra B. Dahotre, and Sandip P. Harimkar

REFERENCES

1. A. Macke, A. Schultz, P.K. Rohatgi, and N. Gupta, *Metal Matrix Composites for Automotive Applications. Advanced Composite Materials for Automotive Applications: Structural Integrity and Crashworthiness*, ed. A. Elmarakbi (Warrendale, PA: The Minerals, Metals & Materials Society; Hoboken, NJ: John Wiley & Sons, 2014), pp. 313–344.
2. M. Gupta and M.L.S. Nai, eds., *Magnesium, Magnesium Alloys, and Magnesium Composites* (Warrendale, PA: The Minerals, Metals & Materials Society; Hoboken, NJ: John Wiley & Sons, 2011).