

AN OVERVIEW OF HYBRID METAL MATRIX COMPOSITES – CHARACTERIZATION, DIRECTED APPLICATIONS, AND FUTURE SCOPE

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ABSTRACT:

Agencies are related with material growth and the enhancement of each material to its superclasses is been the prime requirement of research. Combinations of material form the present era of exploring metallurgy field. Composites are one such that evolved during its process from 1500 BC. The advancement in the composites has uplifted itself from primitive to its next stage. The hybrid composites navigated for purpose of lightweight, wear resistance and for combining advantages of the reinforcements based upon the necessity and need of applications. Hybrid composites are developing as an improvement over previously existing conventional composites. The present work focuses on the various hybrid metal matrix composites and its area of applications. The paper enlightens the hybrid reinforcements and matrix materials used in the growing fields. Hybrid composites are high tech and potential materials most sought in the fields of automotive application due to its high strength, stiffness, low cost and weight.

Keywords: Hybrid composites, Automotive applications.

INTRODUCTION

The sustainable industry growth and people's life improvement greatly depend on the use of alternative product in various fields. Hybridization is a process of incorporating two or more reinforcements in order to yield better stiffness, strength, high strength to weight ratio and other mechanical properties. Hybrid composites primarily consist of one matrix and two or more reinforcement. Hybrid Composite materials are formed by reinforcing two or more materials of varying properties with matrix phase.

Composite materials are heterogeneous mixtures of two or more

homogeneous phases at macro scale, which have been bonded together. In composites, a set of desirable properties can be obtained. Many in nature occurring materials can be regarded as composite e.g. bones, woods and others. Man-made composites are used since thousands of years, e.g. straw and natural fibers in bricks, laminated woods, etc. Hybrid Composites have potential to substitute single reinforced composites due to improved properties. Composites are broadly classified based upon generations. The four generations of composites are:

- 1st generation (1940s): Glass Fiber Reinforced Composites
- 2nd generation (1960s): High Performance Composites in the post-Sputnik era
- 3rd generation (1970s & 1980s): The Search for New Markets and the Synergy of Properties
- 4th generation (1990s): Hybrid Materials, Nanocomposites and Biomimetic Strategies

The fourth generation has gained a significant focus in this work until today. In addition, Types of Metal Matrix Composites are:

TYPES OF METAL MATRIX COMPOSITES

Aluminum matrix

- Continuous fibers: boron, silicon carbide, alumina, graphite
- Discontinuous fibers: alumina, alumina-silica, flyash, BLA, Rice husk
- Whiskers: silicon carbide
- Particulates: silicon carbide, boron carbide, fly ash, BLA, Rice husk

Magnesium matrix

- Continuous fibers: graphite, alumina
- Whiskers: silicon carbide
- Particulates: silicon carbide, boron carbide

Titanium matrix

- Continuous fibers: silicon carbide, coated boron
- Particulates: titanium carbide

Copper matrix

- Continuous fibers: graphite, silicon carbide
- Wires: niobium-titanium, niobium-tin
- Particulates: silicon carbide, boron carbide, titanium carbide.

CHARACTERIZATION OF HYBRID METAL MATRIX COMPOSITES [2]

Aluminium / silicon carbide/ fly ash hybrid composites

The alloy series used was 2024. The Density for 10% weight fraction composite was 2.0 g/cm^3 and there was a weight reduction in comparison with pure alloy of 54%. Hardness, tensile strength, and yield strength increased by 17%, 57%, and 67% in comparison with unreinforced composites. The fracture toughness increases with increase in reinforcement. The above composite manufactured using stir casting and its advantages are lightweight, low cost and enhanced mechanical properties.

Aluminium / magnesium / ceramics / BLA (Banana Leaf Ash) hybrid composites

The aluminium alloy series used was 356. Density decreases with increase in BLA content. Hardness, ultimate tensile strength and yield strength also decreases with increase in BLA content and specific strength, decreases with an increase in BLA content. The main advantage is low weight.

Aluminium / magnesium / ceramics particulates/ Rice Husk hybrid composites

The aluminium alloy series used was 356. Rice husk density is 1.6 g/cm^3 . Tensile strength reduced on addition of RHA. Specific strength and fracture toughness of RHA higher than Al_2O_3 . The advantages are light in weight and its easy availability.

Aluminium / silicon carbide / mica hybrid composites

The aluminium alloy series used was 356. Tensile strength, density, hardness was higher as compared to unreinforced composites. The main advantage is high hardness, attractive for hardness demanding applications in automotive sector.

Aluminium / silicon carbide / boron carbide

The aluminium alloy series used is 7075. The hardness increases linearly with increasing contents of hard ceramic reinforcements. Indentation was high by reinforcing 18% of reinforcement. Toughness was high compared to unreinforced composites. Good wear resistance is one of the advantages of hybrid composites.

SiC fibre-reinforced titanium / titanium aluminide hybrid composites [5]

Ductile titanium alloy and brittle titanium aluminide hybrid matrix reinforcement with silicon carbide fibres were fabricated. The mechanical characteristics studied were tensile strength, fracture toughness, low-cycle fatigue life and fatigue crack growth rate.

Copper / TiC / graphite hybrid metal matrix composites [6]

Development of hybrid composite of copper metal matrix reinforced with TiC and graphite particles were studied. The significant requirements such as wear resistance and better tribological properties in addition to good electrical conductivity necessitate the development of copper-based advanced metal matrix composites for electrical sliding contact applications. Though the addition of graphite to copper matrix induces self-lubricating property, the strength of the composite reduces. The improvement in the strength of the composite can be achieved by reinforcing harder ceramic particles such as SiC, TiC, and Al_2O_3

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

Synthesis of Selected Cast Aluminium Matrix Composites of interest to automotive industries over the last 25 years is shown Table 1.1

Table 1.1 Fabrication Techniques used in Composites for last 25 years [1]

Composite	Techniques used	Locations
Al/Gr	Gas injection and Stir casting	Inco
Al/SiC/ Al_2O_3	Stir Casting	IITK,

		India
Al/Mica/SiC	Stir Casting	IISc, India
Al/TiO ₂ /ZrO ₂	Stir Casting	RRL, India
Al/Gr/ Al ₂ O ₃	Pressure Casting	Hitachi, Japan
Al/Microball oons	Stir Casting	RRL, India
Al/Sic/Al ₂ O ₃	Pressure less Infiltration	Lanxide

The table 1.2 shows the selected automotive demonstrator components in Metal matrix composites.

Table 1.2 Composite Component Manufacturers [1]

Sl.No	Component	Manufacturer
1	Piston	Dural, Martin Marietta, Lanxide
2	Piston Ring Groove	Toyota
3	Piston Crown(Combustion Bowl)	T&N, JPL, Mahle and OTHERS
4	Brake Rotor, Caliper, Liner	Dural, Lanxide
5	Piston	Zollner
6	Drive Shaft	GKN, Dural
7	Connecting Rod	Nissan
8	Connecting Rod	DuPont, Chrysler
9	Cylinder Liner, Pistons, Bearings	Assoc. Eng., CSIR, IISc.
10	Piston, Connecting Rod	Martin Marietta
11	Valve Spring, Retainer Cam, Lifter Body	Lanxide

FABRICATION OF HMMCs (HYBRID METAL MATRIX COMPOSITES) - STIR CASTING TECHNIQUES [1]

A basic requirement of the foundry processing of composites is the initial intimate contact and bonding between the ceramic phases and the molten alloy. This is achieved either by mixing the ceramic dispersoids into molten alloy or by pressure infiltration of molten alloys into preform of the ceramic phases, followed by stirring of the composite in melts. The metal-particle/fibre slurry can be cast either by conventional foundry techniques such as gravity, pressure-die or centrifugal casting or by newer techniques such as squeeze casting, spray codeposition or melt spinning.

The incorporation of particulates or fibers into liquid matrix melts, stirring the mixture for bonding and allowing it to solidify is called stir casting.

SOLIDIFICATION TECHNIQUES

Sand casting:

The slow solidification rates obtained in insulating sand moulds permit considerable buoyancy- driven segregation of particles. They are mainly preferred for tribological applications.

Die casting:

The relatively rapid solidification rates in metallic moulds generally give rise to a more homogeneous distribution of particles in cast matrix.

Centrifugal casting:

Centrifugal casting for composite melts containing particle dispersions results in the formation of two distinct zones in the solidified material; a particle-rich zone and a particle-impoverished zone. Centrifugal casting is preferred mainly for cylinder liners and bearings.

Compo casting:

Particles and continuous fibers of SiC, Al₂O₃, graphite, and boron carbide have been incorporated into vigorously agitated, partially solidified aluminium alloy slurries by the compo casting techniques.

Pressures die casting:

It allows larger and more intricate components shapes to be produced rapidly at relatively low pressures (<15Mpa). Good

particle-matrix bonding and elimination of porosity is possible.

Pressure infiltration of preforms:

The process involves unidirectional pressure infiltration of fiber preforms or powder beds to produce void-free, near-net-shape castings of composites. Toyota has been in use in heavy diesel engines.

Thixomat injection moulding

This relatively new process, similar to plastic injection moulding, has been developed by Dow for injection moulding mixtures of metal and ceramic powders to form composite parts.

Pressureless spontaneous infiltration:

Lanxide has developed a process of spontaneous infiltration of Al₂O₃ or SiC powder beds by magnesium-containing molten aluminium alloys placed over the powder beds.

Table 1.3 Directed Applications of Hybrid Metal Matrix Composites

Sl.No	Hybrid Reinforcements	Component	Property	Benefits
1	SiC (p) – Al ₂ O ₃	Piston	Wear resistance, high strength	Reduced weight
2	Al ₂ O ₃ (f) - Graphite	Piston Ring Groove	Wear resistance	Higher running temperature
3	Al ₂ O ₃ (f) –MoS ₂	Piston Crown(Combustion Bowl)	Fatigue resistance, creep	Opportunity to use Al, reduced reciprocating mass
4	SiC(p) – TiB ₂	Brake Rotor, Caliper, Liner	Wear resistance	Reduced weight
5	Fiberfrax	Piston	Wear resistance, high strength	Reduced weight

6	SiC(p) – hexagonal BN	Drive Shaft	Specific stiffness	Reduction of parts and weight
7	SiC(w) – Carbon nanotubes	Connecting Rod	Specific stiffness and strength; thermal expansion	Reduced reciprocating mass
8	Al ₂ O ₃ (f) – Nextal fibers	Connecting Rod	Specific stiffness and strength; thermal expansion	Reduced reciprocating mass
9	Gr(p) – nano conductive carbon- diamond	Cylinder Liner, Pistons, Bearings	Gall resistance, reduced wear and friction	Increased power output
10	TiC(p) – insitu ceramics	Piston, Connecting Rod	Wear, Fatigue	Reduced weight and wear
11	Al ₂ O ₃ – waste sand as fillers	Valve Spring, Retainer Cam, Lifter Body	Wear, Strength	Reduced weight and increased life
12	Fly ash cenosphere- low density cernamic microballon	Crumple zones, frame members, batteries	Low density	Light weight and energy absorption

The table 1.3 shows the directed applications of the composites. The potential automovite application of metal-matrix composites is justified with the need of following properties such as high temperature, fatigue, creep, and wear resistance for piston and its related parts. The damping, stiffness, and reduced friction in connecting rods and in piston ring groove. Seizure resistance, low friction in Cylinder Block (liner).

FUTURE SCOPE

The optimum materials of the present era are composites and its practical applications are introduced as the year's progress. One such company is Honda.

Honda has demonstrated the advantages of using a hybrid preform containing short carbon and alumina fibers

in cylinder block made by a new single-step, die-casting method. It is necessary to expose hybridization mixing reinforcemetns of different chemical compositions, shapes and surface treatments-since hybrids have a greater potential of resulting in composites that combine diverse properties. Hybridization of preforms can also facilities processing in certain situations.[4]

It is also necessary to develop the field knowledge base to optimally redesign of the total system when the use of hybrid metal matrix composites for particular components. As automotive industry strives to meet imposed asthetics, fuel economy,

emissions controls but on the other hand, consumers expect, the firm to concentrate on advancements and sophistication made in the field of hybrid metal-matrix composites. This could pull down the kerb weight of vehicle from one thousands kilograms to grams, enhancing economy of drive.

The promising benefits include weight reduction, less vibrations in vehicle, emission controls, maintaining fuel economy and reducing overall cost in automotives

CONCLUSION

Locomotion is part of human life. The component that aid in locomotion are automotives, hence the major contribution of them to support human life easing the barriers of cost, weight, and safety relies on material. The next generation of hybrid metal matrix composites exists as less implemented in field works. Major projects should be directed towards practical implementation to reduce further researching and processing costs and achieve the reliability required by the automotive industry. The paper has highlighted, hybrid materials are better than existing conventional composites, which can be considered as replacement for the existing materials.

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