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Design and Manufacture of Affordable Advanced Composite Materials inAutomotive Industry

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Abstract:

Composite materials have found wide use in many industries, including the automotive industry. Vehicles should be light, have low emissions and energy consumption to provide some environmental protection, while having adequate stiffness and strength to ensure occupant protection. These requirements can be met by using composite materials. Although composites have been present in industry for decades, their use in the automotive sector is relatively new, requiring developments in design and manufacturing processes, testing and recycling – this article suggests details that differentiate the automotive industry from others. Basic recycling methods, related legislation and where recycling products are used are described. Specific uses of composite materials that show a high degree of innovation are presented – hybrid and natural composites, structural batteries and high-performance vehicles.By using lightweight composites in the automotive industry can also carry others advanced emission control system, safety equipment and integrated electronic system without increase total vehicle weight. It can reduce the exhaust emissions and increased fuel economy. This paper focuses on design and manufacture of an affordable advanced composite materials in automotive industry.

Keywords **—Composite materials, automotive industry, emission control, safety, weight.**

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I. INTRODUCTION

Now a days as modernization takes over the world, employing advanced engineering materials has become essential to keep up with the demand. Composite material finds its use to be required for such applications. A composite is a material which has two or more distinct phases or constituents that have different properties, which are built into a complex architecture in micro-, meso- or macro-scale levels. The materials like metals, ceramics and polymers are used in combination to form synthetic composites while natural fibers are also being used as reinforcement. The development of such composite materials has enhanced modern systems, contributing to sustainable development.

Advanced composites are materials whose performance can be improved compared with that of their constituent materials. Structural design and optimization take place at different levels to combine latest developments in each material to constitute a better performing composite. In the composites, materials are combined in a way that enables us to make efficient use of their parent material while minimizing to effect of their deficiencies.

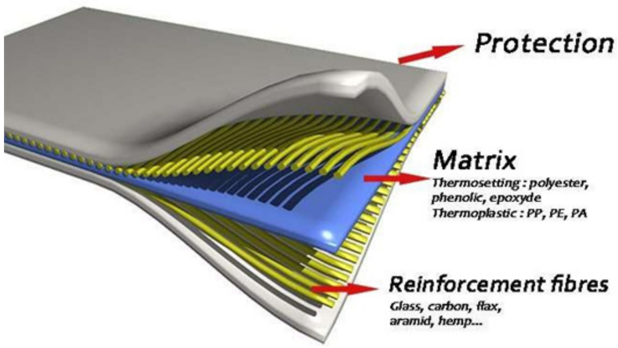

Figure1.CompositeMaterialLayers

The simple term 'composites' gives indication of the combinations of two or more materials in order to improve the properties. The definition of a composite signifies the materials that are composed of two or more dissimilar constituent materials. Composite materials are majorly classified as:

A. Matrix Material

Matrix material binds the composites and acts as binder. It transfers load between its constituents, providing the component shape and determine its surface parameters.

Matrix can be of either polymer, ceramic or metal material. Polymers generally use thermosetting (Resin, Methyl Methacrylate MMA) and thermoplastic materials (Polymethyl Methacrylate PMMA, Polyamide PA), ceramic composites contain glass, alumina or SiC while metal composites use metals like Aluminum, Copper, Titanium, Nickel, etc.

B. Fiber Reinforced Composite Material

In fiber-reinforced polymer composites, fibers are used as reinforcement material. The selection of the reinforcement material depends on the end application. Some common fiber reinforcements are as follows:

1. Glass fiber:

This fiber generates from the silica-based & other formulations of the glass material by heating at 1675°C. Glass fibers have high tensile strength than steel wire of the same diameter, at a lower weight. Dimensional stability, high heat resistance, fire resistance, chemical resistance, good thermal conductivity, dielectric permeability are some of its characteristics.


Figure2.GlassFiber

2. Carbon Fibers

Carbon fibers are made up of carbon atoms bonded forming long chain. Carbon fibers are extremely stiff, strong and light-weight compared to glass fiber. The fibers are strong, stiff, light weight, low coefficient of thermal expansion and good chemical resistance and high temperature resistance.


Figure 3. Carbon Fibre

3. Aramid fibers

Kevlar is made up of aromatic polyamide (aramid) fibers. They possess high strength, abrasion resistance chemical resistance, non- conductivity and less flammability. The aramid fibers are available in yellow colour. Due to its good impact resistance, Kevlar fiber is used in the ballistic applications.

Figure 4. Aramid Fibre

4. *Natural fiber*

Natural fiber-reinforced composites, due to their good characteristics, have become extremely popular in recent years. Due to environmental consciousness and government policies the use of natural fiber in polymer composite is rapidly increasing. Natural fibers have low density, high specific strength and good thermal and acoustical insulation. The natural fiber is extracted from either animals or plants.

Figure5.Natural Fibre

In the 1950s & 1960s, the requirements of the aerospace and defence sectors initiated the design of advanced composite materials. Today, advanced composites are prime structural materials with a rich potential in multiple fields. As knowledge of composite science grows, number of newer materials are being developed integrated with technology, such as functional and multifunctional composites, structure–function integration, intelligent composites and nanocomposites.

Advanced structural and functional composites combined with in processing, computing, characterization and composite applications, 21St century has become a new era of composite materials.

II. LITERATURE REVIEW

Composites simply denote the product material having improved mechanical characteristics owing to its combination of more than two materials when compared with its individual components [1]. Compared with conventional materials, the majority of composites are designed with a view of having high specific strength, less weight, a relatively high resistance to corrosion and so forth. Improved strength, higher fatigue strength, greater physical characteristics, reduced weight, greater surface finish are the major benefits of the composites. Generally, in automotive industry, composite materials are. lighter in weight when compared with most commonly used metals. Composite materials based on the carbon fiber are the highest functional polymer composite employed in automotive, aerospace, military and sporting commodities [2]. In conventional automobiles, the metals comprise the central structure of the vehicles whereas certain interior parts are fabricated with composites. In recent times, carbon fiber composites are regarded as the most suitable material for the reduction of vehicle weight although it might be expensive unlike traditional metals [3,4]. The mechanical properties, microstructure and surface morphology of the composites could be enhanced more than aluminium alloys [5]. In general, composite materials are classified as exceptional materials for their application in the automotive industry [6].

III. OBSERVATIONS

Case 1: Aluminum 6061-Sic Composite for manufacturing of Dovetail Aluminum metal matrix composites (MMCs) reinforced by ceramic particles are famous for low density along with better mechanical properties, such as high strength, fatigue and wear resistance, improved toughness. Aluminum MMCs is an ideal material for construction of light-weight structural and engine parts for the automobile and aerospace sectors.

Aluminum MMCs produced by the stir casting method is much cheaper when compared to steels and cast. On the other hand, they are lighter, tougher and their thermal conductivity and wear resistance are better than those of cast iron. The usage of Aluminum MMCs helps construction of fuel-efficient vehicles and airplanes.

Silicon Carbide is the reinforcement particle in this composite. It is a compound of silicon and carbon i.e., SiC. It is used in refractories, abrasives, ceramics, etc. SiC is composed of tetrahedral of carbon and silicon atom with strong bonds in the crystal lattice. This produces a strong and hard material. It has characteristics like low density, high strength and thermal conductivity, low thermal expansion and high hardness. [13]

Particulate reinforcement metal matrix composites have combination of low density, improved stiffness and strength, high wear resistance and isotropic properties [7-9]. Metal matrix composites is their low ductility which has been overcome recently by introducing special processing technologies, such as squeeze casting, stir casting [10-12].

This paper is concerned with understanding the design procedure behind manufacturing and its fitness for automotive functions. This involves selection of materials to validation of final composite.

1. Material Setup:

For the fabrication, Aluminum Alloy 6061 is used as matrix metal that is reinforced with SiC particles. The reinforcement percentage is varied as 0%, 5% and 10% by weight.

The fabrication process of Al 6061-SiC composites was carried out by stir casting.

2. Finding Critical Function Parameters:

Function parameters are control parameters. Parameters which affect the response of uncontrollable parameters such as Surface roughness, Hardness, Microstructure etc. are called critical function parameters.

In stir casting, there are many factors affecting for properties of developed composite. Particulate preheat temperature, reinforcement of Silicon Carbide wt %, stirring time, stirring speed, pouring temperature are few of them. Here, surface roughness and hardness are used as response variables.

The more effective variables are then selected. Silicon Carbide wt%, Pouring temperature and Stirring time are selected for comparing response of hardness and surface roughness.

3. Defining Levels of Critical Parameters:

Here, three factors are selected. Levels indicate amount of variation in the factors used. Three levels of each parameter is selected for experimentation work. These three levels are as follows.

1 Silicon Carbide wt.%: 0%,5%,10%
2 Pouring Temperature(˚C): 660,710,760
3 Stirring Time (sec): 20,30,40

4. Design of Experiment:

Design of experiment is method used for experimentation. Various forms of DOE viz. Taguchi method, Response surface method and Factorial design method are used for experimentation. Here, Taguchi technique is used.

i)Hardness Measurement: Here, hardness is measured by using Brinell Hardness Testing Machine with 500 Kgf (Load) × 10 mm Ball.

ii)Surface Roughness Measurement: Here, Surface roughness tester is used for measuring arithmetic roughness (Ra) value in µm. after machining of the Dovetail.

Figure6.FinishedproductforMicrohardnessandSurfaceroughness[Aftermachining Dovetail]

5.Analysis of Samples by Simulation Method:

After design is created, DOE is used to plan the experiments and trials then samples are segregated for testing. This includes measurement of Surface roughness (Ra value in µm) using surface roughness tester, Hardness (in BHN) using Brinell Hardness Testing machine.

6.Finding Optimal Solution:

After Experimentation carried, all the results obtained are plotted according to their trial numbers. Then conditions are identified for response variables. Larger the better condition is used for hardness as hardness needs to maximize. And Smaller the better condition is used for surface roughness as it needs to minimize.

7.Validation:

Afterwards results are validated, as results which we get experimentally are correct or not is unknown. It is evidence behind every result. Here, it is done using experimental and analytical comparison.

8.Concluding:

Conclusion is final result obtained by analyzing the observations and validation part. It shows effect and contribution of parameters on response value. The following conclusions were drawn based on the experimental results:

i]Microstructure: Optical micrographs showed approximate uniform distribution of SiC particles. Homogenous dispersion of SiC particles in the Al matrix shows an relation with the stirring method.

ii]Hardness: Hardness is recorded to increases with increase in SiC particles percentage. 5 wt. % of SiC gives hardness of 65 BHN. And maximum hardness of 102 BHN is obtained at 10 wt. % of SiC.

iii]Surface Roughness: No adverse effect of increase in weight % of SiC on the surface roughness values. Variation recorded are in microns.

iv]Developed Aluminum Metal Matrix composite showed improved physical and mechanical properties compared to pure aluminum which also offers opportunities to customize the materials to specific design needs.

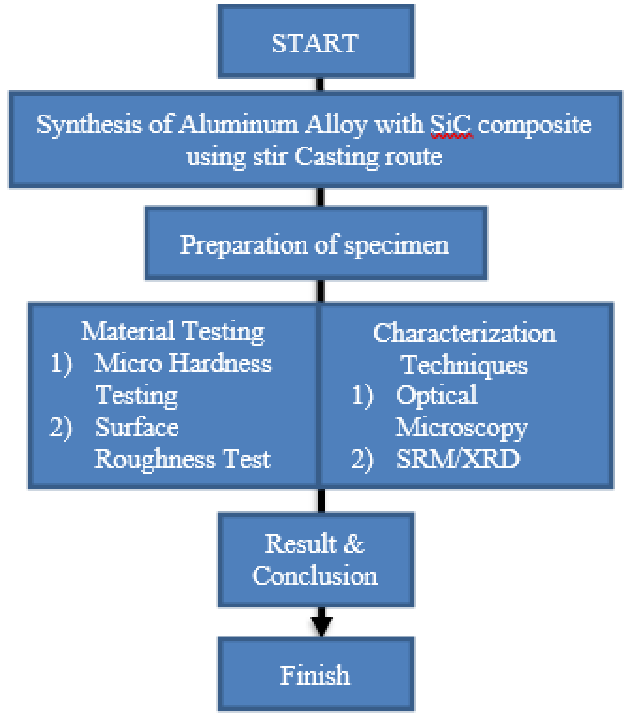

Figure5.FlowChartofEntireDesignProcess

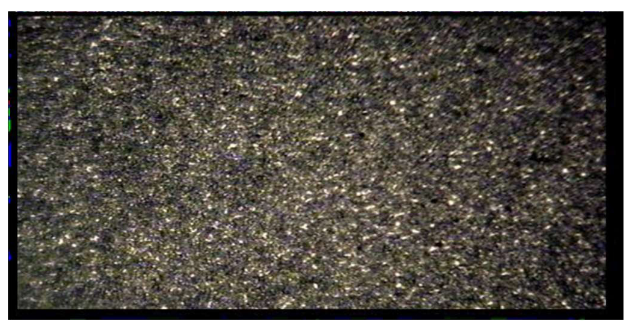

Figure7.MicrostructureofPureAluminum[10X]

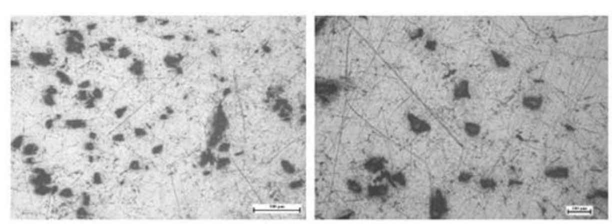

Figure8.OpticalmicrographsofMMC with5wt.%ofSiC[50X,100X]

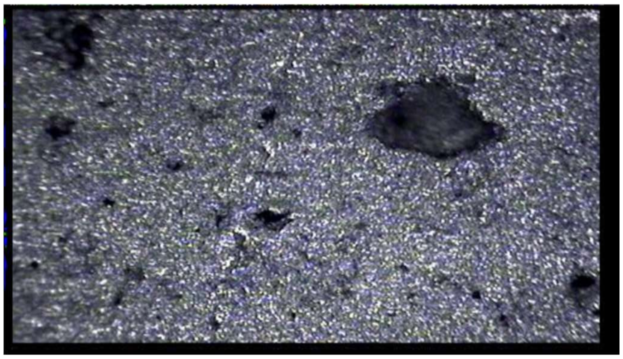

Figure9.Microstructureofwt.10%ofSiC[10X]

Case 2: Natural Fibre Reinforced Polymer Composite

Natural Fibre Reinforced Polymer Composite is a composite which uses natural fibers as reinforcement in the composite. Natural fiber composites include jute, coir, cotton, bagasse, hemp, bamboo, etc. Natural fibers come from plants and these fibers contain lingo- cellulose.

NFRP composites use a polymer matrix and are classified into two types, namely thermoset and thermoplastic [17]. Thermosets are polymers that have stronger stiffness and bonds than thermoplastics. Thermosets cannot be recycled because of their resistance to dimensional stability at high temperatures. Meanwhile, thermoplastics have properties that are easy to recycle, high impact resistance, and are chemically inert. Thermoplastics are easy to reshape because they are easily melted or softened by heating to a certain temperature and hardening by cooling [18]

Many of the researchers have a goal in making use of used cars and recycling plastic that can be utilized [15] because in addition to the physical and metaphysical benefits obtained, the material chosen will make an important contribution to customer satisfaction [16]. Characteristics of NFRP materials such as biodegradation, fiber modification, thermal stability, crystallinity are the main focus for researchers [14]. Furthermore, Al-Oqla and Sapuan [16] mentioned that the presence of pollution is another reason for the optimal use of resources. The use of recycled plastic is claimed to be able to reduce 80% of greenhouse gas emissions. This demand for social-ecological awareness makes plastic an appropriate alternative [16].

This is why for the development of NFRP is proving game changing in the automotive field as these composites are cheap, have optimum mechanical properties and they are sustainable products. Hence many automakers use these NFRPs in their vehicles already.

But brittleness is the biggest disadvantage of the thermosetting polymers. Main requirement for such polymers for them to be used in structural applications is significant improvement in toughness and strength. To improve the toughness and strength of a thermosetting polymer two techniques can be used s viz., addition of micron sized soft materials like elastomeric or thermoplastic or rigid materials i.e. glass or ceramic particles into the thermosetting matrix

Also, many studies have been performed by reinforcing nanometric and micron size metal, metal oxide particle which improves the mechanical properties of the polymeric matrix.

Hence there is still future scope for NFRP to be used as a structural composite in automobiles promising a sustainable lifestyle.

Figure10.NatureFibreReinforcedPolymerComposite

IV. CONCLUSION

Composite materials certainly are a ground-breaking discovery as there is a vast number of applications of these composites. Many manufacturers have already started to modify their designs by switching to composites. But there is still a lot we need to know. As more and more research work is being done, surely composites will be proven to be an best and affordable alternative for automotive industry.

V.REFERENCES

[1] Kumar A, Lal S, Kumar S. Fabrication and characterization of A359/Al2O3 metal matrix composite using electromagnetic stir casting method. J Mater Res Technol 2013;2(3):250–4.

[2] Singh H, Brar GS, Kumar H, Aggarwal V. A review on metal matrix composite for automobile applications. Mater Today Proc 2021;43:320– 5.

[3] Abdallah L, El-Shennawy T. Reducing carbon dioxide emissions from electricity sector using smart electric grid applications. J Eng 2013;2013:845051.

[4] Bajpai RP, Chandrasekhar U, Arankalle AR, editors. Innovative design, analysis and development practices in aerospace and automotive engineering: I-DAD 2014, February 22-24, 2014. Springer India; 2014.

[5] Miracle DB. Metal matrix composites–from science to technological significance. Compos Sci Technol 2005;65(15–16):2526–40.

[6] Divagar S, Vigneshwar M, Selvamani ST. Impacts of nano particles on fatigue strength of aluminum based metal matrix composites for aerospace. Mater Today Proc 2016;3(10):3734–9.

[7] Sanjeev Das, Siddhartha Das, Karabi Das, "Abrasive wear of zircon sand and alumina reinforced Al-4.5 wt% Cu alloy matrix composites – A comparative study", Journal of Science direct, pp.746-751, June 2006.

[8] L.M. Manocha. Jignesh Valand and Nikesh Patel "Nanocomposites for structural applications" Indian Journal of Pure and Applied Physics, Vol.44, pp.135-142, February 2006.

[9] Manoj Gupta, Sanjay Kumar Thakur and K. Balasubramanian "Microwave Synthesis and Characterization of Magnesium Based Composites Containing Nanosized SiC and Hybrid (SiC+Al2O3) Reinforcements", ASME Journal of Engineering Materials and Technology, Vol.129, pp.194-199, April 2007.

[10] Kestur Gundappa Satyanarayana, Fernando Wypych and Pedro Henrique Cury Camargo, "Review article- Nanocomposites: Synthesis, Structure, Properties and New Application Opportunities", Journal of Material Research Volume 12, No.1, pp.1-39, 2009.

[11] J. Babu Rao, D. Venkata Rao and N.R.M.R. Bhargava, "Development of light weight ALFA composites", International Journal of Engineering, Science and Technology, Vol. 2, No. 11, pp.50-59, 2010.

[12] Sanjay Kumar Thakur, Khin Sandar Tun and Manoj Gupta "Enhancing Uniform, Nonuniform, and Total Failure Strain of Aluminum by Using SiC at Nanolength Scale", ASME Journal of Engineering Materials and Technology, Vol.132, pp.1-6, October 2010.

[13] V.L. Kingston, Mr. John Prabhakar, Dr. N. Senthilkumar "A Study on Mechanical and Machinability Characteristics of Hybrid Metal Matrix Composites", International Journal of Engineering Research and Applications, ISSN: 2248-9622, pp. 67-70, 2014.

[14] V. Chauhan, T. Kärki, and J. Varis, "Review of natural fiber-reinforced engineering plastic composites, their applications in the transportation sector and processing techniques," J. Thermoplast. Compos. Mater., 2019, doi: 10.1177/0892705719889095.

[15] Q. Zhao and M. Chen, "Automotive plastic parts design, recycling, research, and development in China," J. Thermoplast. Compos. Mater., vol. 28, no. 1, pp. 142–157, 2015, doi:10.1177/0892705713519810.

[16] F. Gu, P. Hall, and N. J. Miles, "Development of composites based on recycled polypropylene for injection moulding automobile parts using hierarchical clustering analysis and principal component estimate," J. Clean. Prod., vol. 137, pp. 632–643, 2016, doi:10.1016/j.jclepro.2016.07.028.

[17] K. Rohit and S. Dixit, "A review - future aspect of natural fiber reinforced composite," Polym. from Renew. Resour., vol. 7, no. 2, pp. 43–60, 2016, doi: 10.1177/204124791600700202.

[18] U. Nirmal, J. Hashim, and M. M. H. Megat Ahmad, "A review on tribological performance ofnatural fibre polymeric composites," Tribol. Int., vol. 83, pp. 77–104, 2015, doi:10.1016/j.triboint.2014.11.003.