

Processing, Mechanical Testing and Analysis of a Polymer Matrix Composite as a Substitute of Metallic Bracket

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ABSTRACT: This project work aims at reducing the weight of the aerospace or automotive structural components such as brackets by use of composite materials to increase the performance of the overall aeroplane or passenger car by replacing conventional metal alloys with composite materials for structural components. Major concern when using composite materials is structural integrity. Polymer Matrix Composite Materials such as E glass, S-glass, Aramid fibre, carbon fibre with resins give high structural integrity. Depending upon cost and budget, in this project S- glass fibre and Epoxy resin composite test specimen has been prepared and tested for tensile strength and properties such as young's modulus, Yield strength, UTS, Poisson's ratio have been determined. A cad model of simple structural angle bracket has been designed and Finite Element Analyses has been carried out for simple load cases with properties of Aluminium metal. Later same bracket is FE analysed with composite material properties obtained from physical testing of S-glass and Epoxy resin composite. Theoretical validation for FE analysis of angle bracket with aluminium metal properties has been also provided in this work to support Finite Element Method.

KEYWORDS: Polymer Matrix Composite Material, FEA Analysis, Structural Bracket, Optistruct.

I. INTRODUCTION

Composites are the materials prepared of two different materials of different chemical and physical properties. There are different categories of composites like Particlestrengthened (Reinforced), Fibereinforced and Structural for example Laminates and Sandwich panels. Most commonly used polymers are fiber reinforced. There are mainly two types of fibre reinforced polymers. Metal matrix composites (MMCs)and Polymer matrix composites (PMCs).

Composites are being used more and more in every field of Engineering because of their Equivalent Mechanical strength and stiffness to that of Conventional Metals. The project aims at the study of composites that are increasingly finding applications in the AEROSPACE and AUTOMOTIVE Industries because of reduction in the cost of final Product.

Fuel chargesreporton the behalf of more than 35% of an airline's expenses. This volatile cost, along with fossil fuels being a limited natural resource, has put added pressure on aircraft manufacturers to deliver new levels of fuel efficiency. Analysts believe 35,000 new aircraft will remain needed over the succeeding 20 yonks in order towards substitute ageing units furthermore to relate civilian flight demands of civilian.

The automotive industry is globally driven by environmental and safety standards and requires increased longevity due to extended warranty and lower costs of production. Consumers are demanding less frequent maintenance, more comfortable driving experiences, and better fuel economy, with no deterioration in performance. The reduction of the vehicle weight, driven by the desire for lower CO emissions and improved mileage, results into miniaturization of components and functional integration which are at the forefront of the automotive industry's efforts

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

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The work in this paper is divided into several chapters but there are mainly three phases. 1) Fabrication and evaluation of Mechanical Properties of the S-Glass and Epoxy Composite. 2) Theoretical Validation and FEA Analysis of Structural Bracket with Aluminium and S Glass and Epoxy Composite material. 3) Comparison of results, discussions and Conclusion.

II. LITERATURE SURVAY

1. Composite Materials in Aerospace Applications by Nikhil V Nayak (September 2014) describes applications various types of composite materials being developed employed in aerospace industry for the increased stability and performance. It also highlights nature of behaviour of composite material and design challenges while working with them.
2. Experimental Study of Effect of Fiber Orientation on the Flexural Strength of Glass/Epoxy Composite by Sandeep M.B, D.Choudhary, Md.Nizamuddin inamdar, Md.Qalequr Rahama describes the test specimen preparation for testing of flexural strength of E-glass and epoxy composite with different orientations.
3. Analysis and Optimization of Engine Mounting Bracket by Mohali Deshmukh and Prof. K R Sontakke (May 2015) explains the different static and dynamic loads that an engine mounting bracket experiences and analysis procedure for determining safe stress levels and also to optimize the overall bracket.
4. Modeling and Analysis of Bracket Assembly in Aerospace Industry by P. Thameem Banu, and Dr. R. Satya Meher describes design of CAD model of aerospace bracket assembly that is used for placing components for various purposes like carrying fuel and air. It also highlights the Analysis of bracket assembly that is done by assuming loads as pressure loads.

III. SPECIMEN PREPARATION AND TEST RESULTS

For the preparation of the specimen S-glass and Epoxy were selected. The test specimen was prepared as per ASTM standard D3038D / D3039M. Three samples of each specimen were prepared. The following Table 01 gives the recommended geometric dimensions of the test specimen.

Fibre Orientation	Width	Overall length	Thickness	Tab length	Tab thickness
	mm	mm	mm	mm	mm
0- Unidirectional	15	250	1	56	1.5
90- Unidirectional	25	175	2	25	1.5
Balanced and Symmetric	25	250	2.5	25	1.5

Table 01. Geometric Dimensions of the Test Specimen.

Following pictures show the prepared test specimens of different orientations. 3 specimens of each orientations were prepared.

International Journal of Innovative Research in Science, Engineering and Technology

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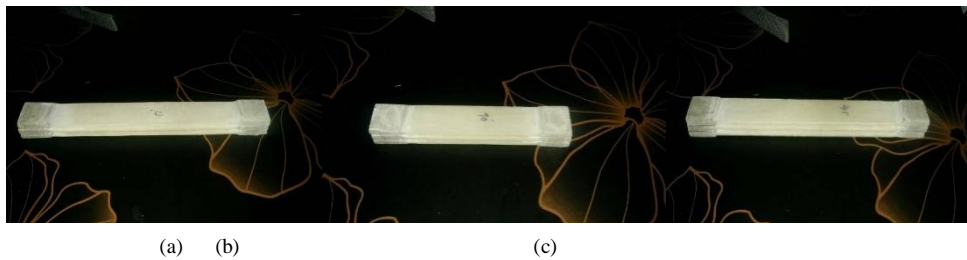


Fig. 01. Fabricated Specimens (a) 0 ° Orientation Specimens (b) 90 ° Orientation Specimens (c) 0 and 45 ° Orientation Specimens

The specimens prepared were tested in UTM as per ASTM standards. Results obtained such as UTS (Ultimate Tensile Strength), Displacement and strain etc. are obtained and are tabulated in the following table 02

	Sample no/coding	Peak Load	Break Load	Peak Disp	Braeak Disp	Initial Area	Final Area	Reductionin Area	Engg UTS	Strain
		N	N	mm	mm	sq mm	sq mm	%	Mpa	
Orientation 0	1.a	6031.300	6031.31	10.302	10.302	48.227	39.937	0.172	125.06	0.2080
	1.b	5089.8	4619.1	8.639	8.69	56.452	48.031	0.149	90162	0.175
	1.c	5236.9	49.035	9.428	9.513	56.195	47.213	0.1	93.192	0.19
Orientation 90	2.a	7296.4	7296.41	10.862	10.862	76.496	62.382	0.18	95.382	0.22
	2.b	6168.6	6168.6	10.862	10.862	75.223	61.72	0.18	82.004	0.219
	2.c	7855.4	7767.14	11.999	12.059	75.313	60.604	0.195	104.3	0.243
Orientation 0 & 45	3.a	7218	98.07	12.941	15.419	90.112	68.873	0.236	80.1	0.308
	3.b	9875.6	490.35	15.3	39.579	82.742	59.28	0.284	119.36	0.396
	3.c	7806.4	1677	11.965	13.866	93.343	73.077	0.217	83.631	0.277

Table 02. Test Specimen Results

It can be observed from the table that unidirectional laminas have great strength compared to 0° and 45 ° lamina but their strain is slightly less than the former. So unidirectional laminas can be used where there is application of high strength and unsymmetrical angular lamina can be used where specific strain application are in need.

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Following pictures show the results obtained after physical testing of the test specimens

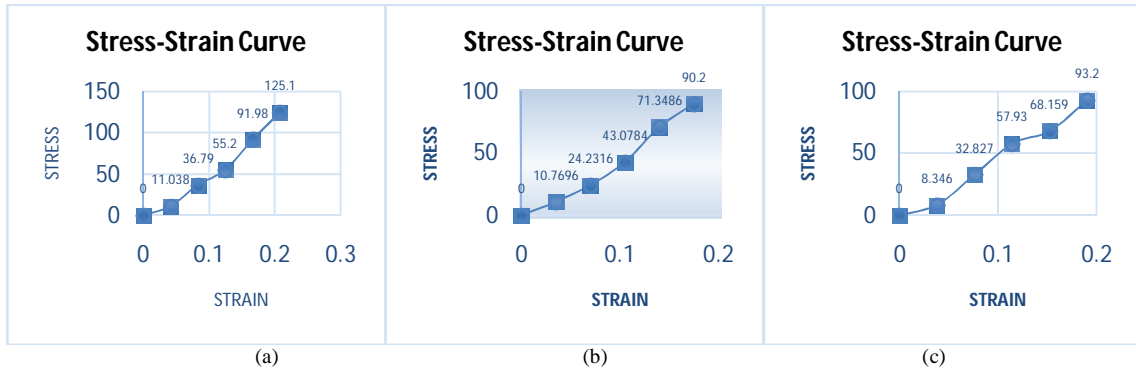


Fig. 02 Specimen Test Results (a) Sample 1.a Results (b) Sample 1.b Results (c) Sample 1.c Results

It can be seen that 0° unidirectional lamina has Ultimate Tensile Strength of 125.1 Mpa for sample 1.a.

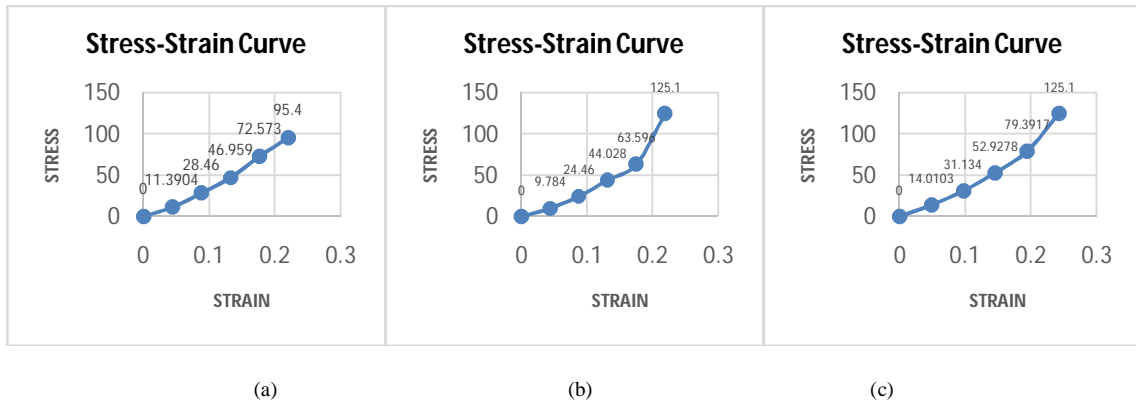


Fig. 03 Specimen Test Results (a) Sample 2.a Results (b) Sample 2.b Results (c) Sample 2.c Results

It can be seen that 90° unidirectional lamina has Ultimate Tensile Strength of 125.1 Mpa for sample 2.b.

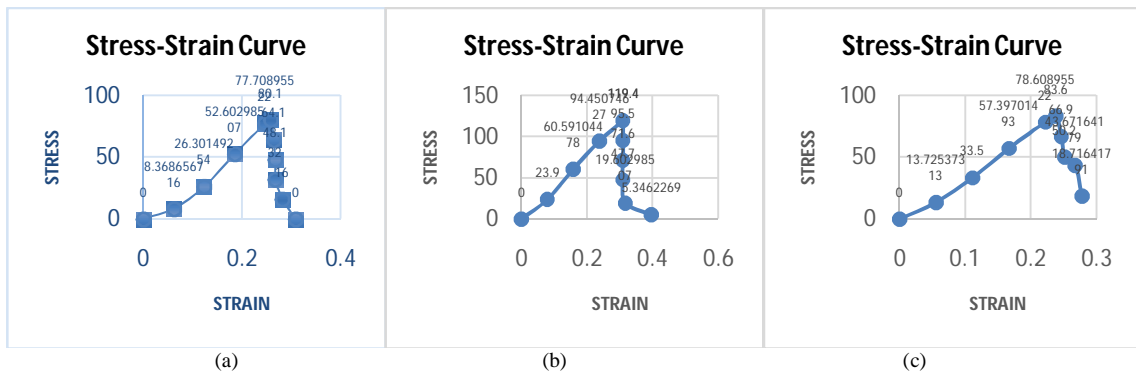


Fig.04 Specimen Test Results Graphs (a) Sample 3.a Results (b) Sample 3.b Results (c) Sample 3.c Results.

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It can be seen that 0° and 45° lamina has Ultimate Tensile Strength of 119.4 Mpa for sample 3.b.

IV.SIMULATION AND RESULTS

A structural bracket used to support structural loads has been FE analysed with mechanical Properties of Aluminium 6061 and S glass and Epoxy Composite with the help of computer aided softwares. For CAD modelling NX Unigraphics, for Analysis Hypermesh and Optistruct has been used. A maximum deflation of 0.0351 and 1.89 mm and Von Mises Stress of 81.92Mpa and 65.53 Mpa are observed with Aluminium and S Glass Epoxy Composite.

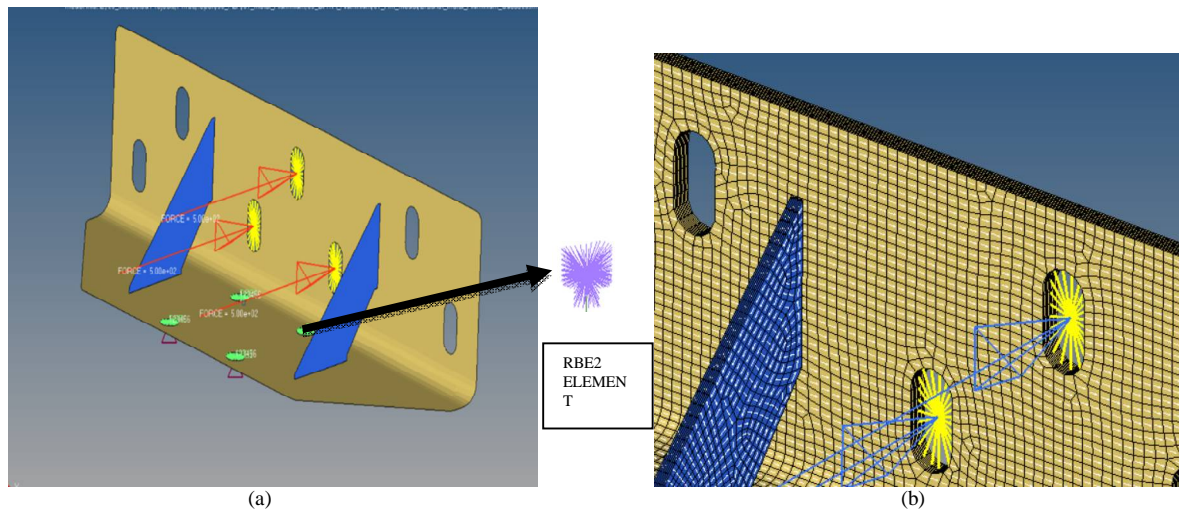


Fig 05 Loads and Boundary Conditions (a) Showing force and constrained points (b) Showing Material orientation and load application in Composite Material.

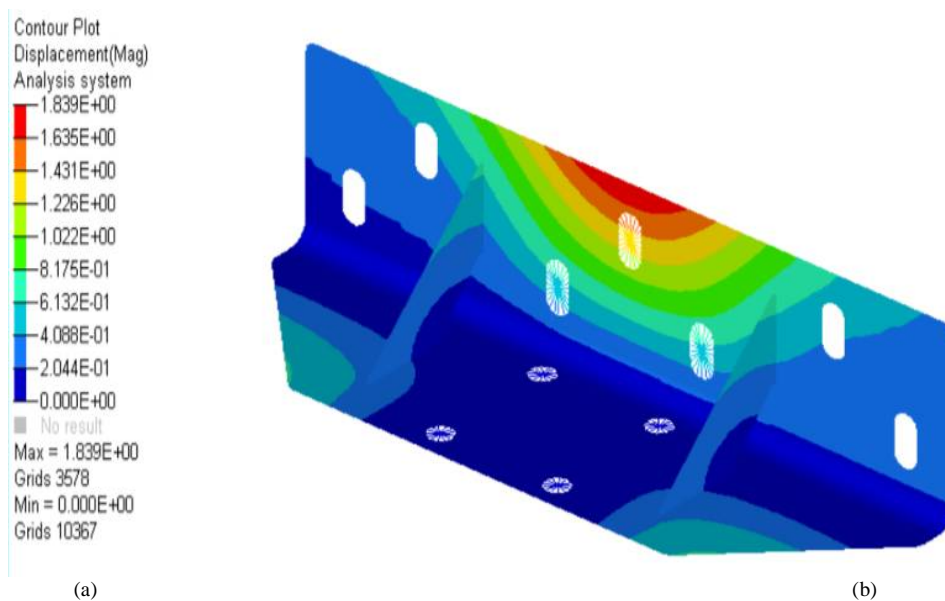


Fig 06 Displacement Plot (a) Numerical Values of Displacements for Composite (b) Graphical Representation of Distribution of Displacement for Composite

International Journal of Innovative Research in Science, Engineering and Technology

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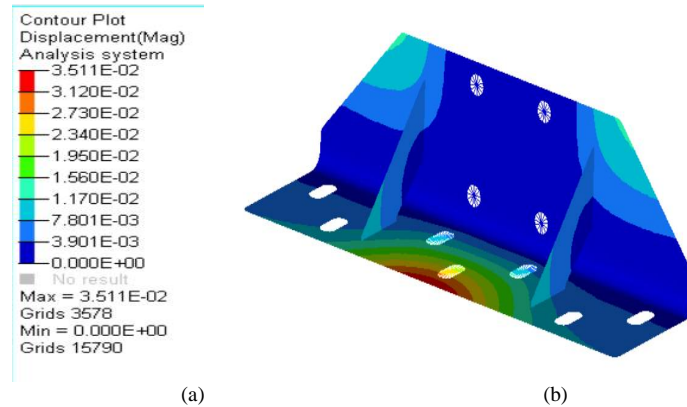


Fig 07 Displacement Plot (a) Numerical Values of Displacements for Aluminium (b) Graphical Representation of Distribution of Displacement for Aluminium

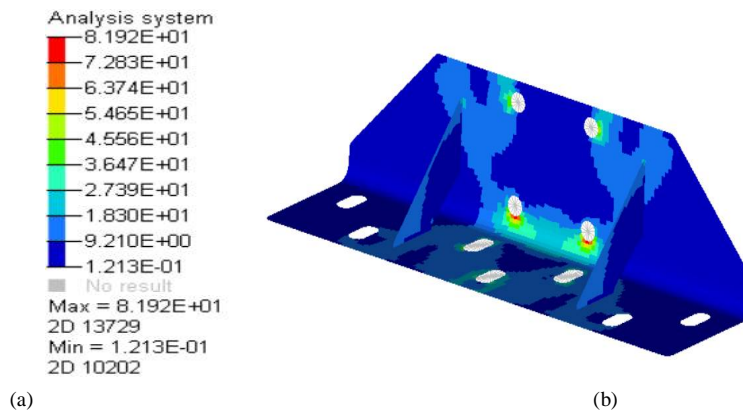


Fig 08 Stress Plot (a) Numerical Values of Stresses for Aluminium (b) Graphical Representation of Distribution of Stresses for Aluminium

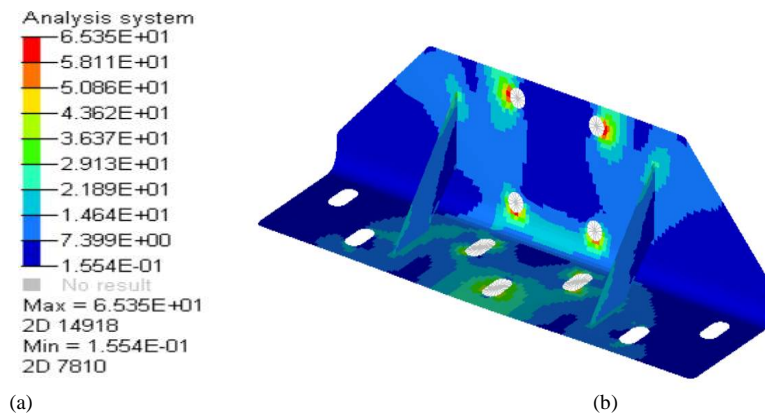


Fig 09 Stress Plot (a) Numerical Values of Stresses for Composite (b) Graphical Representation of Distribution of Stresses for Composite

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V. THEORETICAL VALIDATION

Theoretical Validation for the FE analysis is provided here. Results obtained from FE analysis are nearly matching theoretical calculations. The following Figures show the CAD modelling drafting of the structural bracket.

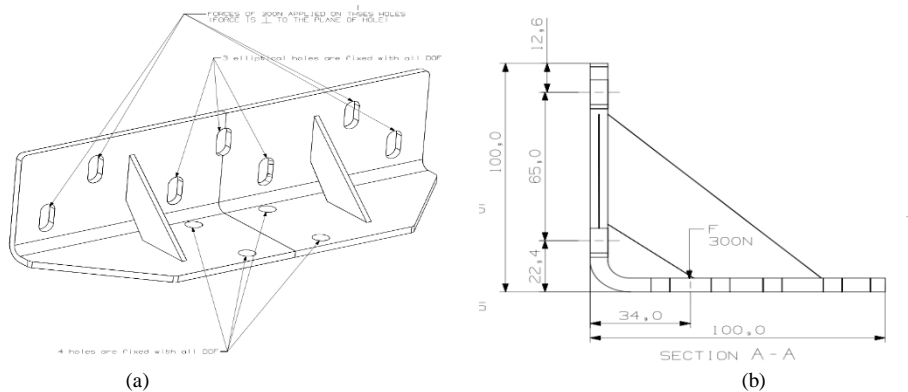


Fig 09 (a) CAD model Drafting of Structural Bracket (b) Sectional View at the Rib area

1. Stress

We know that bending moment and stress are related by following equation.

$$\frac{Mb}{I} = \frac{\sigma}{y} = \frac{E}{R}$$

Where M_b is the Moment of Bending. I is Area Moment Of Inertia. σ is Stress due to Bending. Y is distance of fibre away from Neutral axis. E is Young's Modulus. R is the radius of curvature.

Bending Moment

$$M_b = 34 \times 500$$

$$M_b = 17000 \text{ N-mm}$$

Consider $\frac{Mb}{I} = \frac{\sigma}{y}$ We know that Area moment of Inertia is given by $I = \frac{bd^3}{12}$

Cross Section dimensions are $b = 100 \text{ mm}$, $d = 6 \text{ mm}$

$$\text{Therefore } I = \frac{100 \times 6^3}{12} = 1800 \text{ mm}^4 \text{ At } y = 3 \text{ mm}$$

$$\frac{17000}{21600} = \frac{\sigma}{3} \Rightarrow \sigma = \frac{17000 \times 3}{1800} \Rightarrow \sigma = 28.33 \text{ Mpa}$$

Applying notch sensitivity index at holes we get $\sigma = \sigma * 3 \Rightarrow \sigma = 28.33 \times 3 \Rightarrow \sigma = 85 \text{ Mpa}$

2. Deflection

We know that deflection of cantilever beam with load at end is given by $U = \frac{PL^3}{3EI}$

Substituting the values we get.

$$U = \frac{500 \times 34^3}{3 \times 70 \times 10^9 \times 1800}$$

$$U = 0.05198 \text{ mm}$$

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ANALYTICAL AND FEA RESULT COMPARISON:

		Aluminium 6061	S Glass/Epoxy	Hand Calculation
Displacement δ mm	Max	0.03511	1.839	0.05198
	Min	0	0	-
Stress σ N/mm ²	Max	81.92	65.53	85
	Min	0.121	0.155	-

Table. 03 Analytical and FEA Results comparison

VI. CONCLUSION

Looking at the results it can be concluded that composites materials made up glass epoxy polymer matrix can be used instead of conventional metals. They satisfy all the structural strength requirement. As PMCs help in reducing the weight and increasing the performance. They are durable and properties such as toughness and strength can be custom-made to match the applications they are required for. PMCs can be used in corrosive environment since they have excellent corrosion resistance compared to metals. With increase in the research on the composite materials and finding of more strength and durable composites, components made up of conventional metals can be replaced with composites.

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