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# Hybrid Composites and Their Behaviour

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**ABSTRACT**

*The incorporation of several different types of fibres into a single matrix has led to the development of hybrid composites. The behaviour of hybrid composites is a weighed sum of the individual components in which there is a more favourable balance between the inherent advantages and disadvantages. Also, using a hybrid composite that contains two or more types of fibre, the advantages of one type of fibre could complement with what are lacking in the other. As a consequence, a balance in cost and performance can be achieved through proper material design. The properties of a hybrid composite mainly depend upon the fibre content, length of individual fibres, orientation, extent of intermingling of fibres, fibre to matrix bonding and arrangement of both the fibres. Natural–synthetic fibre hybrid composites offer a combination of high mechanical properties from the synthetic fibres and the advantages of renewable fibres to produce a material with highly specific and determined properties. This thesis is framed with the knowledge from available literature for better understanding of Hybrid composites.*

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## I. INTRODUCTION

A composite material is a material system composed of a suitably arranged mixture or combination of two or more Nano, micro, or macro constituents with an interface separating them that differ in form and chemical composition and are essentially insoluble in each other. The discrete constituent is called the reinforcement and the continuous phase is called the matrix. According to the chemical nature of the matrix phase, composite are classified as metal matrix (MMC), polymer matrix (PMC) and ceramic matrix composites (CMC). MMC's recently are drawing interests of the researchers because of the ability to alter their physical properties like density, thermal expansion, thermal diffusivity and mechanical properties like tensile and compressive behaviour, creep, tribological behaviour etc. by varying the filler phase. Also the growing requirement for advanced materials in the areas of aerospace and automotive industries had led to a rapid development of MMC's. Allison et al. (1993); Narula et al. (1996). In AMC the matrix phase is of pure aluminium or an alloy of it and the reinforcement used is a non-metallic ceramic such as SiC, Al2O3, SiO2, B4C, and Al-N. Aluminium alloys are more and more used due to good corrosion resistance, high damping capacity, low density and good electrical and thermal conductivities. AMC's have been tested and proved useful in different engineering sectors including functional and structural applications because of variation in mechanical properties depending upon the proportion of reinforcement and chemical composition of Al matrix.

### A. *Definition of hybridcomposites:*

Hybrid materials are refer to any class of materials in which organic and inorganic components intimately mixed. This however does not mean that simple physical mixtures of organic and inorganic compounds are hybrid materials. The rider is that the mixing be at the Nano metric scale. At such scales, the properties of the resultant material are not just the result of the individual properties of the materials, but scale of the interaction between two components contributes significantly to the properties of the resultant material. Historically, man-made materials which both have organic and inorganic components abounded since time immemorial. The ability to add functionalities to the material expands the scope of the science greatly. The fact that soft chemistry makes it possible to synthesize these at low cost and at a low energy expenditure further endears these methods to engineers and scientists everywhere. This also makes it very difficult for anyone to give a short introduction to the wondrous qualities of such materials. Also, the methods of their production are not particularly glamorous or special to warrant much attention. Hybrids either be homogeneous systems of miscible organic and inorganic components. They can be heterogeneous with dimension scales of the order of few Angstrom to few nanometres. C Sanchez et al refer in their review paper on hybrid materials to the dyes of the Maya, whose fastness has been recently discovered to be a result of the use of an organic pigment intercalated in clay. There have been infinitely many other materials which are of similar nature in history.The term hybrid materials has come to apply to these materials only after the development of soft chemistry techniques such as sol-gel chemistry in the 1980s. Also, it makes it possible to endow the material with one or more specific functionalities where none existed earlier, for example magnetism, hydrophobicity or hydrophilicity, electrical properties or optical properties. The interplay between the organic and inorganic components offers one the possibility of designing materials to one's very exacting specification.Therefore, we will in this report restrict ourselves to discussing a select few applications of hybrid materials in some detail.

Current engineering applications require materials that are stronger, lighter and less expensive. A good example is cur-rent interest in the development of materials that have good strength to weight ratio suitable for automobile applications where fuel economy with improved engine performance were becoming more critical [1]. In-service performance demands for many modern engineering systems require materials with broad spectrum of properties, which are quite difficult to meet using monolithic material systems [2]. Metal matrix compos-its (MMCs) have been noted to offer such tailored property combinations required in a wide range of engineering applications [1,2]. Some of these property combinations include high specific strength, low coefficient thermal expansion, high thermal resistance, good damping capacities, superior wear resistance, high specific stiffness and satisfactory levels of corrosion resistance [3–5].MMCs are fast replacing conventional metallic alloys in many applications and their use have been extended to predominantly aerospace and automobile to defence, marine, sports and recreation industries.

*B. Classification*

The classification of hybrid materials is very subjective thing with different authors classifying them to different manners. This is reflection to diversity of this field. However we will present here few of these schemes. Most commonly used method in classification uses the degree and nature of interaction between the organic and inorganic materials to define hybrid materials.

- Class I hybrids: Class 1 hybrids are those in which organic and inorganic components do not have any covalent or any ionic bonds. The interaction are limited to Vander Waals forces, pipi interactions and electrostatic interactions.
- Class II hybrids: These hybrid systems have some amount of strong chemical bonding between the organic and inorganic compounds in the form of covalent orion-covalent and Lewis acid-base bonds.

The other type of classification, depends on differences in major component of hybridmaterials. Here we have Organic and Inorganic (OI) which consist of materials in which an inorganic species is inserted or integrated in a polymer matrix. Inorganic Organic, in which roles are interchanged and Nanocomposites. They are defined as materials in which neither of the components dominates or both types of materials are dispersed at the nanometric level.

Hybrid materials can be classified on the basis of method in which they are made. In this classification, the hybrid materials are divided into,

- Intercalation compounds- they refer to the materials in which a guest molecule or group is inserted reversibly into the host system, that which is usually in the form of a periodic network.

Insertion of organic groups to the inter-layer spaces in certain clays led to first hybrid systems.

• Organic derivatives of Inorganic solids- In these class of hybrid materials, an organic group are made to react on surface of an inorganic solid. However these are highly susceptible to hydrolysis. The SiOH groups on the surface of the clays react with alcohols to form Siloxanes.Hybrid materials of this type greater stability can be formed by using 6 groups. In these procedures have been used to graft fluoroalkyl groups onto magadiite, a clay, to get oil repellent compounds. An example of this is attachment of organosilanes to clays.

• Sol Gel Hybrid materials- these chemistry offers largest scope to the development of hybrid materials. The Sol Gel process for silica liquid alkoxides are hydrolysed in presence of water. They leads to formation of Si (OH) 4. The Si(OH)4 precipitate condenses and Si-o-Si bonds are formed. This leads to the formation of xerogels/aerogels. These bonds form a network and colloid is formed. The particle size increases as reaction proceeds, so that the liquid medium becomes a minor phase and forming as gel. After the formation of this gel, the material may be heated to get rid of the liquid. In this method can also be used as making specialized glasses at lower temperatures. Sol gel chemistry is an extremely flexible method of synthesis. Asone can add surfactants to mix. This will lead to the formation as gel around the micelles formed. The surfactants can then be removed with the help of appropriate solvents. Also a monomer can be added to reaction mix. The gel is formed around by organic monomers. The gel can then be heated up to polymerize the monomer. This makes it possible to create extremely well and dispersed Nanocomposites.

The first task during fabrication of the composites is toobtain uniform distribution of reinforcing particles tothe matrix alloy. Secondly, then it is also essential to prevent the segregation/agglomeration of a particles during progress of solidification. Chawla and Chawla [6] have proposedto morphology, these type of reinforcements are distribution for these reinforcing particles have been significant contribution to theseagree-gate characteristics profile of the composites. According to Hanumanth and Irons [7].These variables are govern as the distribution of particles as solidification rate and fluidity of the melt, these type of reinforcements areas the method to particle incorporation and wettability for particles in these melt. Addition to the magnesium can be useful to improving the wettability between these reinforcing particles and alloy melt. In addition, mechanical stirring in the semi-solid state can also be usedto obtain the uniform distribution of these reinforcing particles. This study of microstructure is a quite useful toevaluating the distribution of reinforcing particles in the matrix alloy.The results of these various studies regarding the microstructural features to HAMCs have been presented. Boopathi et al. [8] have studied the microstructures of aluminium alloy (Al 2024) reinforced with the different compositions to fly ash, SiC and their mixtures. It has been observed as that particles were not uniformly distributed to single reinforced composites and segregation of particles was clearly visible.This was attributed to the gravity-regulated segregation ofthese particles in melt. But, these micrographs of Al/SiC/flash hybrid composites indicate uniform distribution to particles at various concentrations The X-ray diffraction (XRD) analysis to the HAMCs confirms these presence to reactedSiC, fly ash, SiC–fly ash mixtures. The presence of thealuminium and magnesium particles was also revealed during the micro-structural investigations.According to another investigation conducted by theRajmohan et al. [9]

## II. MANUFACTURING METHODS

The excellent ductility and workability of Ti—Ni SMAs makes it very easy to fabricate fibres of the several hundred of micrometres in diameter with which conventional Raw Materials and Experimental Design processing methods. Specially, three kinds of various fabrication procedures have been developed.Embedding these fibres in aluminium matrix can achieve from squeeze casting or compacting via powder metallurgical route. Because these melting temperature of aluminium is so high, even though a thin layer with the thickness less than 3mm of the fibre surface was affected by diffusion interaction, most of these Ti—Ni fibres are remained as unaffected during the processing. In these Ti—Ni fibres were arranged into fixed holder to a mould, then molten aluminium (970 K) was poured into these moulds, followed by pressurization at 65 MPa.The composite then subjected to heat treatment (773 K, 30 min) to the shape memorize these Ti—Ni fibres, followed by ice—water quenching to these induced martensitic transformation. The specific tensile restrain was applied and then these composite was heated to a temperature above these a point

PP film is obtained from Jieliya Products Co., Jiangsu, and China. WS came from Youfang Town, Jiangsu Province, China, which is to ground by a LH-08B Speed Grinder (Xinchang Hongli, CNC Instruments Inc., Jiangsu, and China) and screened by a 60-mesh (250 µm) screen. Before preparation, WS were first oven-dried at 105°C for 6 h to reduce moisture content level less than 2%. Inorganic filler explored to this study included fly ash, silicon dioxide, and heavy calcium carbonate. Thesefly ash was supplied from Nanjing Jufeng Advanced Materials Co., China, and its particle size was 400 mesh (38 µm) and 1250 mesh (13 µm), respectively. Silicon dioxide heavy calcium carbonate were supplied by Nanjing Zhining New Materials Co., China, to their mesh size was 400 and 1250, respectively. (Shanghai, China) was utilized to treat as WS and inorganic filler.Silane coupling agent (KH550) by Yaohua Co. Experiment design included two factorial experiments. thesefirst experiment was designed to study the effect of these WS loading levels consisting from four loading rates (i.e., 20, 35, 50, and 60 wt.%). the second experiment is designed to study these effects of inorganic fillers (i.e., fly ash, silicon dioxide, and heavy calcium carbonate) and their loading level (i.e., 10, 15, 20, and 25 wt.%) on inorganic filled WS/PP composites: R-PP/fillers = 50/50 (wt.%) tofixed for all composites.

### A. *Sample Preparation*

A speed mixer (K600-3205, Braun Electric and Germany) is used for mix WS and inorganic filler thoroughly, while it is stirring an aqueous solution (ethanol: water = 9: 1 by weight) including a silane coupling agent (2 wt. % by its weight of WS and inorganic filler) and was sprayed at 25°C for 30 min. After that, this mixture of WS and inorganic filler was dried at 105°C for 12 h. the inorganic filled WS/PP composites were prepared by the blending mixture and PP at 175°C for 5–7 min on two-roll mill (X-160 Banbury Mixer, Chuangcheng Rubber and Plastic Machinery Co., Ltd., Wuxi, China), after which the melting mixture acquired (XLB-0 Vulcanizing Machine, Shunli Rubber Machinery Co., Ltd., Huzhou, China) was ground into the compression moulding machine at 180°C and 12.5 MPa for 12 min to shape it to a rectangular board.

## III. Applications

#### 1) *Al/SiC/FA hybrid composites*

The hybrid composites reinforced with SiC and the fly ash (FA) possess superior mechanical and physical properties as com-pared to single reinforced composite (Al/SiC or Al/FA) or unreinforced alloy (Al2024). These properties of the composites presented indicate that the density and thepercent elongation of these Al/10 wt.% Sic/10 wt.% fly ash hybrid composite reduces by 54% and 75% respectively in with comparison the pure alloy. However, hardness, tensile strength and yield strength of the hybrid composite increases by 17%, 57% and 67% respectively. The fracture toughness of theHAMCs increases with increase in reinforcement contents.Thus it can concluded the mechanical propertiesof the hybrid composites were improved with an increase in reinforcement's contents. Contradictory, the density and elongation of these hybrid composite are decreased as compared to unreinforced aluminium. In overall, the strength to weight ratio of the HAMCs are improved as compared withunreinforced alloy. Hence, the composites offer good potential to be used to automotive components. The fly ash is also considered as awaste material without any gainful applications. Therefore,it can also be readily used for development for composites. Fromthe results, it can be concluded that instead of Al/SiC or Al/flash composites, the Al/SiC/fly ash hybrid composite could be considered as an exceptional material for design of various components in automotive sector. These essential requirements for applications of this composite is lightweight, low cost and enhanced mechanical properties.

#### 2) *Al/ceramics/BLA hybrid composites*

These shows the variations in properties of thehybrid composites developed by reinforcing SiC and agro waste (bamboo leaf ash) in Al–Mg–Si alloy. These hard-ness, ultimate tensile strength and yield strength for thecomposites decreases with increase BLA content. These hard-ness of hybrid composites with 2 wt.%, 3 wt.% and 4 wt.%BLAcontents reduced by 4.58%, 8.14%, and 10.94%, while the ten-sile strength for these composites decreases by 7.97%, 15.6%,and 23.29%, respectively, in comparison with the ceramic rein-forced composite (Al–Mg–Si/10 wt.%SiC). These specific strength and percent elongation of hybrid composite decreases with an increase in BLA contents, and the fracture tough-ness of hybrid composite is improved. It may also be noted that difference between these specific strength of single and hybrid reinforced composite are less than 2%. The decrease in the density of the hybrid composite with increase in BLAcontents indicates that there is adequate potential for these development of low weight-high performance hybrid composites for various automotive components.

*3) Al/ceramics particulates/RHA hybrid composites*

The alumina particles and the rice husk ash (RHA) can offer another combination as the hybrid reinforcements ofaluminium matrix. The hardness of hybrid composite with 2 wt.%, 3 wt.% and 4 wt.% RHA contents reduces by 4.58%, 8.14% and 10.94% respectively, while the tensile strength is also reduced by 3.7%, 8% and 13%, respectively, with comparison to the ceramic reinforced composite (Al–Mg–Simatrix/10 wt.%Al2O3). Specific strength, percentage elongation and fracture toughness for the hybrid composites reinforced with 2 wt. % RHA is higher than Al2O3reinforcedcomposite and other hybrid composites. It also indicates that the SiC and RHA are added in equal percentage (up to 8 wt. %), all these mechanical properties of composite were improved while density is reduced.

*4) Al/SiC/mica hybrid composites*

Shows that the mica and SiC can be successfully used as hybrid reinforcements to Al356 alloy. These mechanical behaviour of the hybrid composites varies with reinforcement contents for mica. The tensile strength of hybrid composites isless as compared with the unreinforced composite. The densityand hardness of the hybrid composites were higher as compared to the unreinforced composite. These increasing trendin hardness can improve indentation characteristics and therefore the hardness for the components. Therefore SiC andthe mica reinforced composites can be used for developing auto-motive components, whereas hardness and strength are theprimary requirements.

*5) Al/SiC/B4C hybrid composites*

Indicates that hardness of these composites increases linearly with increasing contents of these hard ceramic reinforcements. The maximum of 33% improvement in these indentation characteristics for these composites canalso be obtained by the reinforcing Al-matrix by 18% of hard reinforcement phase. The hard ceramics may increase with weight of the hybrid composites, but these results indicate that an improvement in the indentation characteristics of these composites. As these com-posits exhibits better hardness and toughness as compared to single ceramic reinforced composites, therefore they are preferred to heavy-duty vehicles and high wear resistance applications.

### B. Morphology Analysis

The morphologies of these selected composite samples areanalysed by the Hitachi S-4800 Scanning Electron Microscope (SEM) (Hitachi Ltd., Tokyo, Japan). These fractured surfaces of selected test samples are coated with Au to improve the surface conductivity before observation and with observed withan acceleration voltage of 3 000 V.

## IV. Mechanical Properties

Flexural test to samples are carried out according to the ASTM D790-03, using this CMT6104 SANS Mechanical Testing Machine (Tesla Industrial systems Co., Guangdong, China). Notched izod impact strengths are measured with the XJJ-5 Impact Tester (Jinjian Testing Instrument Co., Chengde, China) according to ASTM D256-05. Four samples of these with each group were tested.

*1) Water Absorption*

Water absorption studies were performed following ASTM D570-98. 3 specimens (50 × 10 × 5 mm) of every sample are immersed in the distilled water to room temperature. At various time intervals, test specimens are removed from the water and weighed in the high precision balance. This content of water was calculated with the weight difference.

*2) Thermal Expansion Performance*

The thermal expansion samples are machined with an miniature table saw along the long direction of samples with the dimension of 43.5 (length) × 12.7 (width) × 5.4 (thickness) mm. these LCTE value of each specimen are measured parallel with the long direction over the temperature range from 20 to −13°C and from −13 to 60°C. They are conditioned at 60°C in an oven and at −13°C in a freezer from their initial equilibrium temperature of 25°C prior to size measurements with aMitutoyodigi-matic indicator of ±0.01 mm accuracy (Mitutoyo Co., Kanagawa, Japan). Five specimens were used for each group. The LCTE for each sample are calculated based on size changes before and after conditioning. These heating and cooling rates were kept constant to 5°C/min. the LCTE (1/°C) are calculated

Composites have their wide application for aerospace, defence and it's in automotive industries because of their unique properties such as high specific strength, wear resistance, strength-to-weight, strength-to-cost, etc. [10]. Various efforts have been taken for introduce of hard ceramic particulates like SiC, AL2O3 and B4C into aluminium based matrix. From these literature study reveals that among the reinforcements SiC are chemically compatible with aluminium and forms an adequate bond with the matrix without developing inter- metallic phase and has other advantages such as the excellent thermal conductivity, good workability and low cost [11]. In past main focus is given for the development of metal matrix composite with SiC in various proportions and its mechanical and machinability properties have been studied. Recently due to the necessity of engineering materials with high strength, increased wear resistance and enhanced temperature performance hybrid aluminium metal matrix composites are developed. Al2O3 is one of the widely used second reinforcement. But it has its own demerits like poor wetting behaviour with aluminium and more weight percentage leads to increase in porosity [12]. An attempt has been made to fabricate Al/SiC/Al2O3 composite in our previous work. In this present work an attempt has been made to introduce TiB2 an outstanding reinforcement among all the other reinforcements. This is due to the fact that TiB2 reveals outstanding features such as high melting point (2790C) high hardness (86 HRA or 960 HV) and high elastic modulus (530*103 GPa) and good thermal stability. TiB2 ceramic particle do not react with molten aluminium, thereby avoiding formation of brittle reaction products at the reinforcements-matrix interfaces. Also aluminium reinforced with TiB2 is known for its high wear resistance property [13].

## V. Merits and demerits

*1) Merits*

1. The higher performance to a given weight leads to fuel savings. Excellent strength-to weight and stiffness-to-weight ratios can be achieved by composite materials. This is usually expressed as the strength divided to density and stiffness (modulus) divided by density. These were so-called "specific" strength and "specific" modulus characteristics.
2. Part count is also has been reduced.
3. It is easier for achieve smooth aerodynamic profiles to drag reduction. Complex double-curvature parts with a smooth surface finish can be made as one manufacturing operation.
4. Laminate patterns and ply build-up in the part can be also tailored to give the required mechanical properties in various directions.
5. Composites offer excellent resistance to corrosion, chemical attack, and outdoor weathering; however, some chemicals were damaging to composites (e.g., paint stripper), and new types for paint and stripper are also being developed for deal with these thermoplastics are not very resistant to some solvents. Check the data sheets of each type.
6. Production cost are reduced. Composites may be made by the wide range of processes.

*2) Demerits*

1. Composites are more brittle than wrought metals and thus were more easily damaged. Cast metals also tend to be brittle.
2. Repair introduces with a new problems:
Materials require refrigerated transport and storage and have limited shelf lives.
Hot curing is necessary in many cases, requiring special equipment.
Curing either hot or cold takes time. The job is not finished when the last rivet has been installed.
3. If rivets have been used and must be removed, this presents problems of removal without causing further damage.
4. Composites must be done thoroughly cleaned all contamination before repair.
5. Repair at these original cure temperature requires tooling with pressure.
6. Composites must be dried before repair because all resin matrices and some fibres absorb moisture.

## VI. CONCLUSION

In this paper classification of hybrid composites is briefly discussed along with their generalised mechanical properties, applications, merits and demerits. With the above specified data one can easily understand about hybrid composites, all the required data is included in this paper. Hybrid composites is an emerging branch of engineering with wide scope, selecting hybrid composites for research and development is highly preferable.

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