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HYBRID COMPOSITES IN MODERN ENGINEERING

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Abstract

Hybrid composites are those composites which have a combination of two or more reinforcement fibers. Hybrid composites are materials of future, present industry need materials with property which don't exist in nature. But hybrid composites concept is helping material engineers to engineer new materials which can meet the requirement of the industry, Hybrid composites are usually used when a combination of properties of different types of fibers wants to be achieved, or when longitudinal as well as lateral mechanical performances are required. This paper gives a clear view on hybrid composites

Introduction:

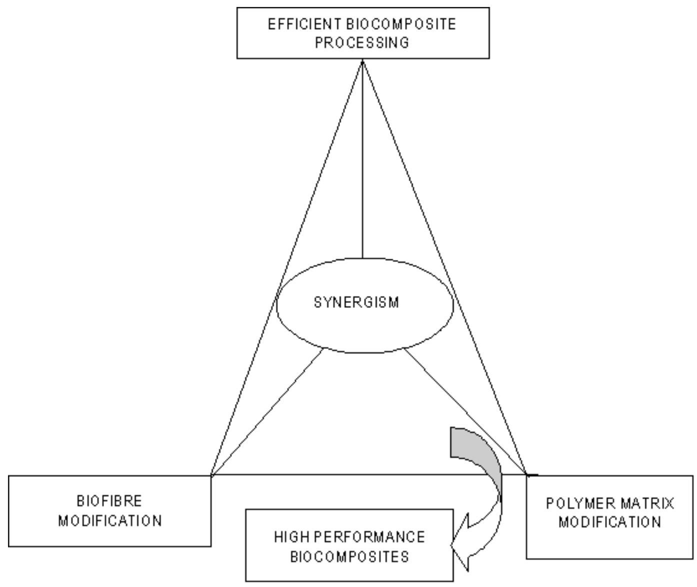
A composite material is composed of suitable arranged mixture of a material system or combination of 2 or more macro,nano or microconstituents with an interface separating them in differ form, chemical composition and are essentiallyunsolvable in each other. The continuous phase is called matrixand the discrete constituent is called the reinforcement. According to the chemical nature of the matrix phase, composite are classified as metal matrix composite (MMC), polymer matrix composite (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 thermal expansion, density, mechanical properties and thermal diffusivity like compressive behavior and tribological behavior and tensile, creep, 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 aluminum or an alloy of it and the reinforcement used is a non-metallic ceramic such as SiC, Al2O3, SiO2, B4C, Al-N. Aluminum 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.

Current engineering applications require materials that are stronger, lighter and less expensive. A good example is the 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 are becoming more critical. 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. Metal matrix compos-its (MMCs) have been noted to offer such tailored property combinations required in a wide range of engineering applications. Some of these property combinations include: high specific strength, low coefficient thermal expansion and high thermal resistance, good damping capacities, superior wear resistance, high specific stiffness and satisfactory levels of corrosion resistance .MMCs are fast replacing conventional metallic alloys in so many applications as their use have been extended from predominantly aerospace and automobile to defense, marine, sports and recreation industries

DESIGNING HYBRID COMPOSITES

Although hybrid fiber reinforced polymer composites are acquire interest, substitute conventional glass reinforced plastics with bio-composites that presents structural and functional stability during storage and use and yet are impressionable to environmental degradation upon disposal is the challenge. An captivating approach in fabricating bio-composites of higher-ranking and desired properties include efficient and cost effective chemical moderation of fiber, judicious selection if fibers, matrix qualification by functionalizing and blending and efficient processing techniques.

Other interesting concept is that of “engineered natural fibers” to obtain higher grade strength bio-composites.This concept traverse the suitable blending of bast (stem) and leaf fibers. The judicious assortment of blends of bio-fibers is based on the fact that the correct blend achieves optimus balance in mechanical properties for e.g., the combination of bast and leaf fiber is expected to provide a stiffness toughness balance in the emanate ting bio-composites.



Definition of hybrid composites:

Hybrid materials aremention to any of a class of materials in which inorganic and organic components intimately mixed. It does not mean that basic physical mixtures of organic and inorganic compounds are hybrid materials. The rider is that the mixing at very nano metric scale. Hybrids are homogeneous systems of miscible organic and inorganic components or they also can be heterogeneous with dimension scales of the order of a few Angstrom to a few nanometers. At such scales, the properties of the resultant material are not just the result of the individual properties of the materials, but the scale of the interaction between the two components contributes significantly to the properties of the resultant material. Historically, man-made materials which have both organic and inorganic components have abounded since time immemorial. C Sanchez et al in their review paper on hybrid materials to the dyes of the Maya, whose fastness has been recently locate to be a result of the use of an organic pigment intercalated in a clay. There have been infinitely numerously other materials which are of anindistinguishable nature in history. Although, the hybrid materialsapproach to appeal these materials only after the blooming of soft chemistry techniques such as sol gel chemistry in the year 1980s. The interplay betwixt the organic and inorganic components propound one the possibility of designing materials to one's very demanding specification.Also, it makes it possible to endow the material with one or more specific functionalities where none existed earlier, for example magnetism, hydrophobicity or hydrophobicity, electrical properties or optical properties. 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. The ability to add functionalities to the material expands the scope of the science greatly. 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. Therefore in this report restrict ourselves to discussing to select few applications of hybrid materials in few detail.

Introduction to the Current engineering applications require materials that are lighter, stronger and less expensive. A good example is the 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 are becoming more critical. 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. Metal matrix compos-its (MMCs) have been noted to offer such tailored property combinations required in a wide range of engineering applications. Some of these property combinations include: high specific strength, low coefficient thermal expansion and high thermal resistance, good damping capacities, superior wear resistance, high specific stiffness and satisfactory levels of corrosion resistance .MMCs are fast replacing conventional metallic alloys in so many applications as their use have been extended from predominantly aerospace and automobile to defense, marine, sports and recreation industries

Types or classification

Hybrid materials is a subjective thing with different authors classifying them in different means. This is anindication of the diversity of this field. However we will explain few of these schemes. The most commonly used method of classification uses the degree and nature of interaction between the organic and inorganic materials to define them.

- **Hybrids Class I:** In this hybrids are those in which the inorganic and organic components do not have any ionic or covalent bonds. The interaction is limited to van der Waals forces, pipe interactions and electrostatic interactions.
- **Hybrids Class II:**On the other hand these hybrid systems have few amount of strong chemical bonding in between the inorganic and the organic compounds in the form of covalent, iono covalent or Lewis acid base bonds.

The other classifications, depends on the differences in the major component of the hybrid materials. Here we have Organic-Inorganic which contains of materials in which an inorganic species is inserted or non-segregated in a polymer matrix. Inorganic Organic, in which the roles are interchanged and Nano-composites. Nano-composites are defined as materials in which neither of the components dominates and both types of materials are dispersed at the nonmetric level.

The hybrid materials can be classified as the basis of the technique in which they are made. In this, the hybrid materials are divided into,

- Intercalation compounds these introduce to materials in which a guest molecule or group is inserted convertible into the host system, which is usually in the configuration of a periodic network. The insertion of organic groups into the inter-layer spaces in certain clays led to the first hybrid systems.
- In this class of hybrid materials organic derivatives of Inorganic solids, to react the surface of an inorganic solid this group is made. An example of this is attachment of organosilanes to clays. The SiOH groups on the surface of the clays react with alcohols to form Siloxanes. Still these are highly susceptible to hydrolysis. Some can be done by using -SiX groups Hybrid materials of this type of greater stability. These procedures have been used to graft fluoroalkyl groups onto manganite, a clay, to get oil repellent compounds.
- For the development of hybrid materials Sol Gel Hybrid materials Sol gel chemistry offers the largest scope. In the Sol Gel process for silica liquid alkoxides are hydrolyzed in the existence of water. This guide to the formation of $Si(OH)_4$. The $Si(OH)_4$ precipitate condenses and Si-o-Si bonds are formed. These bonds form a network and a colloid is formed. The particle size increases as the reaction proceeds, so much so that the liquid medium becomes the minor phase and forming the gel. After the formation of this gel, the material may be heated to get rid of the liquid. This leads to the formation of xerogels/aerogels. This method can also be used to make specialized glasses at lower temperatures. Sol gel chemistry is an extremely flexible method of synthesis. One can add surfactants to the mix. This will lead to the formation of the gel around the micelles formed. The surfactants can then be removed with appropriate solvents. Also, a monomer can be added to the reaction mix. The gel is formed around the organic monomers. The gel can then be heated to polymerize the monomer. This makes it possible to create extremely well dispersed nano composites.

The first process during fabrication of composites is to acquire the uniform distribution of reinforcing particles in the matrix alloy. And next, during the progress of solidification it is also essential to prevent segregation or agglomeration of particles. Chawla and Chawla have proposed that morphology, type of reinforcements and distribution of reinforcing particles have significant contribution in the aggre-gate characteristics profile of the composites. According to Hanumanth and Irons, the variables that govern the dis-tribution of particles are solidification rate and fluidity of the melt, type of reinforcements, the method of particle incorpo-ration and wettability of particles in the melt. The addition of magnesium can be useful in improving the wettability between the reinforcing particles and the alloy melt. In addi-tion, mechanical stirring in the semi-solid state can also be used to obtain the uniform distribution of reinforcing parti-cles. The study of microstructure is quite functional in evaluating the conveyance of reinforcing particles in the matrix alloy. The solution of various studies regarding the microstructural features of HAMCs have been presented as. Boopathi et alresearch the microstructures of alu-minum alloy (Al 2024) reinforced with different compositions ofSiC, fly ash and their mixtures. It has been perceive that the particles were not consistently distributed in single reinforced composites and segregation of particles was clearly noticeable.This was attributed to the gravity-regulated segregation of the particles in the melt. But, the micrographs of Al/SiC/flyash hybrid composites represents uniform distribution of par-ticles at various concentrations The X-ray diffraction (XRD) analysis of the HAMCs confirms the presence of reacted fly ash, SiC,SiC–fly ash mixtures. The presence of magnesium and aluminium particles was also revealed during the micro-structural investigations.

Stir casting

Usually the particulate reinforcement is distributed into the aluminum melt by mechanical stirring in a stir casting process. In the year 1968, S. Ray incorporated alumina particles into aluminum melt by mixing molten aluminum alloys incorporate ceramic fleck. Ray (1969). In this Precess mechanical stirring is a key element.

Composites with till 30% volume fractions can be satisfactory formanufacturing using this method. Luo (1995); Saravanan et al. (2000). With the stir casting process a problem associated is the separation of reinforcing particles due to settling of particles during solidification. The dispensation of the particles in the final solid depends on mixing strength, wetting condition of the particles with the melt, rate of solidification and relative density. The mechanical stirrer geometry, positioning of stirrer in the melt, temperature melt, and the properties of the particles added regulate the dispensation of particles in molten matrix. Harnby et al. (1985); Girot et al. (1987).

A recent progress in stir casting process is a 2 step mixing process or double stir casting. In this process the initial matrix material is heated to over its liquidus temperature. The melt is then cooled down to a temperature in between the solidus points and liquidusto a semi-solid state. By attending and mixing at this point the preheated reinforcement particles. The slurry is heated again to a fully liquid state and thoroughly mixed in double stir casting compared with conventional stirring the resulting microstructure has been found to be more uniform. The strength of this two-step mixing method is mostly due to its capability to break the gas layer around the particle surface which otherwise impedes wetting between the particles and molten metal. The mixture of the particles in the semi-solid state helps to break the gas layer due to the high melt viscosity of the abrasive action. Su et al. (2012) outlined a new three step stir casting method for fabrication of nano composite particle reinforced. Initially the reinforcement and Al particles are blend using ball mills to break the initial collection of nano particles. The composite powder is then assimilate into the melt with along mechanical stirring. After adequate stirring the composite slurry is solicited using an ultrasonic probe or transducer in order to increase the distribution of particles reinforced. Kumar et al. (2013) used a three phase induction motor for electromagnetically stirring the aluminum melt and showed upgrade in particle matrix interface bonding with a small grain size structure.

The major benefits of stir casting process is its applicability to mass production. Comparing to other fabrication methodologies, stir casting process costs as low as one third to one tenth for largeproduction of composites metal matrix. Maruyama (1998); Surappa et al. (1981). Due to the above reasons, stir casting is the most prominently used commercial method of producing aluminum based composites.

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Mechanical properties.

The mechanical properties of a composite depend on many factors such as reinforcement type, reinforcement of quantity, size, shape etc. As they are employed in different areas the proper perception of the mechanical behavior is thus essential. Kamat et al. the year 1989 evaluated the mechanical properties of al2024/ al2O3 composite and observed that ultimate tensile strength and yield of the composite improved with raise in volume fraction of al2O3 particles. Azim et al. in year 1995 investigated its mechanical properties and fabricated al2024/ al2O3p composite. The authors perceived that yield strength of the composite improved while ultimate tensile strength and ductility dropped with improvement in volume percentage of ceramic material. Tee et al. in year 1999 developed in situ Al-TiB2 composite stir casting. They perceived that the tensile and the yield strength of the composite was 2times that of unreinforced matrix but the ductility showed a less value. Alaneme et al. in year 2013explore the mechanical and corrosion behavior of SiC bamboo ash reinforced hybrid composite alloy Al-Mg-Si.The author reported that the ultimate tensile strength, hardness and yield strength values of the composite decreased with increase in percentage weight of bamboo leaf ash while the fracture toughness of the hybrid composite was superior. Corrosion resistance of the hybrid composite was superior in basic solution as compared to acidic solution. Azim et al. (2002) studied the mechanical and wear properties of the stir cast AlSi18CuNi/ Al2O3p composite. They observed that the composite with 2% by weight Al2O3 possessed a tensile strength and hardness values of 505 MPa and 123Hv over that of unreinforced matrix alloy. And wear resistance also increased in case of the composite. Kok (2005) fabricated Al2024/ Al2O3p composite and studied its mechanical properties. The author has divulge that the tensile strength and hardness of the composite with improving the weight percentage of the reinforcement.

Yar et al. in year 2009 produced Al "A356.1" matrix composite reinforced with nano particle of MgO. The authors contemplate that the compressive strength andhardness of the composite was more compared to the matrix alloy. Amirkhanlou et al. in year 2010 evaluated the hardness and collision energy of the Al, A356/SiCp composite and noticed that the hardness and the bang energy of the composite was higher related to the pure alloy. Sajjadi et al. in year 2011deliberated the mechanical properties of the stir cast Al, A356/ Al2O3p composite. The author has betray that the hardness and compressive strength of the composite improves with increasing the weight percentage of Al2O3 and also by reduce the particle size. Su et al. in year 2012 studied the tensile strength of nano particle Al2O3 reinforced Al (2024) matrix composite using 3 step casting method and observed that yield strength and tensile strength of the composite was superior to pure matrix alloy.

Kakaiselvan et al. (2011) produced Al (6061-T6)/B4C composite and investigated its mechanical properties. They observed that the hardness (fig 1 a) and the tensile strength (fig 1 b) of the composite are linearly increasing with increasing weight percentage of the B4C particulate.

Tribilogical properties

Aluminum–matrix composites have attracted much attention and wide acceptance due to their high specific strength and superior wear resistance. Tribological behavior of Aluminum metal matrix composites has been investigated by several researchers due to their application as bearing material, brushes, contact strips etc. Wilson et al. (1996) investigated the high temperature dry sliding wear behavior of Al(A356)/SiC, Al(A356)/(SiC+ Graphite) and Al(6061)/Al2O3 composite. The authors observed that addition of ceramic particles improves the seizure resistance of the composite at higher temperature compared to pure alloy, SiC being more effective than Al2O3. The hybrid composite own better resistance to guide wear compared to other 2 composites at higher temperature regimes. Shipway et al. in year 1998 studied the impact of load and TiC content on the dry sliding wear manner of Al (A356)/TiC, Al-4Cu/TiC, and Al pure/TiC composite. The masterfinalized that the composite had decreased wear rates related to pure alloys, Al (A356)-10%TiC presenting the highest resistance of all. Tee et al. in year 2000studied the dry sliding wear behavior of Al-4.5% Cu-Tib2 and in situ Al-Tib composites improved by stir casting method. The master has divulged that wear losses of both composite decreases with improving in volumefraction of Tib2. Also the wear resistance of the Al-Tib2 composite was higher than Al-4.5% Cu-Tib2 composite.

Sahin et al. (2003) investigated the abrasive wear behavior of SiCp reinforced aluminum matrix composite. The authors observed that wear rate increased with increasing applied load, sliding distance and abrasive size for SiC emery paper while it decreased with sliding distance for Al2O3 paper. Kok (2006) investigated the wear behavior of Al (2024)/ Al2O3p composite and evaluated the influence of sliding distance, Al2O3p content, size of reinforcement and abrasive grit size, on the abrasive wear properties. The masterdivulge that the volume loss of pure alloy is much higher related to composite material. The wear losses improves with increase in sliding distance and grit size. Also the volumetric wear losses decreases with the improving in particle weight and size fraction ofAl2O3 particles. Hosking et al. in year 1982 studied the wear behavior of 2024 Al/ Al2O3 composite and observed a decrease in wear rate of the composites with the increase in the volume fraction of Al2O3 particles at constant particle size. Also with the increase in particle size wear rate lowered at constant volume fraction.

Suresha et al. (2012) investigated statistically the dry sliding friction behavior of hybrid aluminum matrix composite reinforced with combined SiC and Graphite particles. The authors concluded that load in the most important factor affecting the friction coefficient of the hybrid composite followed by sliding speed. The coefficient of friction increased with increase in load and sliding distance. The author also revealed that the average friction coefficient of the hybrid composite is quite low compared to pure alloy. Pramila Bai et al. (1992) studied the dry sliding wear behavior of A356-Al-SiCp composite and have revealed that the wear resistance of the composite increases with increasing weight percentage of SiC particle from 15 to 25. Das et al. (2007) supervise a relative study on the abrasive wear manner of aluminum alloy based composite reinforced with zircon sand and alumina. The authors observed an increase in wear resistance for both the composites with decrease in particle size of the reinforcement. The author also revealed that wear resistance of zircon sand reinforced composite was better than Al2O3 reinforced composite. Fig 5 shows that wear rate is constant with increase in sliding distance.

Hybrid composites based on thin-film shape-memory alloys

The development of shape-memory alloy thin films for microelectromechanical systems (MEMS) is one of the most important attempts which have been directed towards the engineering applications of shape-memory alloys during the past decade. Owing to the extensive use in IC micro fabrication technologies, silicon is particularly preferable as the substrate to fabricate and pattern SMA thin films in batches. Ti—Ni, Ti—Ni—Cu and other kinds of SMA films have been deposited onto both single-crystal silicon and polysilicon substrates.

From a thermodynamically point of view, Ti—Ni is unstable as compared to Si. As a result, interface diffusion and chemical interactions may occur and titanium and nickel silicides may be formed on post-deposition annealing, especially at higher temperatures, of the SMA films. A thin buffer layer of niobium or gold can prevent the interdiffusion. In particular, a buffer layer of SiO& has proved to be an effective diffusion barrier and an excellent transition layer favoring the interface adherence

The delamination of the deposited SMA films from silicon arising from the evolution of the intrinsic residual stress, must be prevented. Wolf and Heuer reported that the adherence of Ti—Ni to a bare silicon wafer can be improved if it has been cleaned and etched with a buffered oxide etchant (H&O#NH"F #HF) prior to deposition. Also, modest heating of the substrate under vacuum to around 473 K, prior to deposition, can minimize contamination and improve adherence. Krulevitch et al. Alsoreported that in situ heated Ti—Ni—Cu SMA Films adhere well to bare silicon. The adherence of Ti—Ni film to both bulk SiO& and thermal oxide coated silicon (SiO&/Si) were reported to be excellent. A 50—300nm thick layer of Ti—Ni with parent B2 phase which remains untransformed was observed adjacent to the interface. The untransformed interlayer, which may be due to the effect of the strong (1 1 0) B2 texture, contributes to the interface adherence by accommodating the strain through a gradient or by absorbing the elastic energy. In some cases, electrical isolation of the film is needed. Wolf and Heuerreported that deposition of a 0.1m polysilicon layer on SiO& prior to deposition of Ti—Ni resulted in a well-bonded interface.

The structure of the composite films should be properly designed to achieve optimal performance. Owing to the mechanical constraints via the interface, the substrate stiffness, determined by the film/substrate thickness ratio, has a significant effect on the transformation characteristics of the SMA layer and on the output energy of the composite multilayers. The stress and its evolution in the bimorph films is governed by Equations 1 and 2 in [9]. While, the tip deflection, %, of the diaphragm cantilever is given by

$$\delta = \frac{3E_s\sigma_{rec}t_s t_f(t_s + t_f)l^2}{E_s^2 t_s^4 + E_f t_s(4t_s^3 t_f + 6t_s^2 t_f^2 + 4t_s t_f^3) + E_f^2 t_f^4}$$

Where l is the cantilever length and "()* the recoverable stress and the other symbols are defined in the same way as in Equations 1 and 2 in. The optimum SMA film thickness for maximum cantilever deflection depends on the relative stiffness of the SMA film and the underlying beam. The behavior of the film depends on the film thickness and approaches bulk behavior as the film becomes a few micro meters thick. However, more complaint actuating films must be slightly thicker for maximum tip deflection. Up to now, some novel micro devices using the SMA/Si diaphragm have been patterned and fabricated, such as micro valves and micro actuators, micro robot arm and micro gripper.

Shape-memory polymer hybrid

Composite laminates advanced composite laminates such as carbon fiber reinforced plastics (CFRP) have a relatively low damping capacity that can be improved by hybridizingCFRP with aramid or glass fiber-reinforcedplastics (GFRP), or adding other polymeric damping materials to them. The latter approach has been proved to be more effective than the former. Because shape-memory polymers (SMPs) have a high-damping capacity, and the glass transition temperature, ¹', where the loss factor tan # reaches a maximum value, can be easily controlled, they can be utilized to improve the damping capacity of the laminates. Accordingly, Fukuda et al. designed an SMP hybrid composite by sandwiching the shape-memory polymer between layers of CFRP or GERP composite laminates. Three kinds of shape-memory polymer films, named by SMP-L, SMP-M and SMP-H, having approximately the same maximum value of loss tangents (maximum tan #"1.0) at 299, 334 and 365 K, respectively, were prepared. The interleaved composite laminates integrating an SMP film about 100 m thick between four plies of CFRP and GFRP prepare sheets were cured in a hydraulic press. The SMP/CFRP composite with a thickness of about 2mmand the SMP/GERP composite with a thickness of about 1.5mm were cured at 393 and 443K for 4 h, respectively. The loss tangents were measured at a frequency of 1Hz in the temperature range from 283—393 K. It was found that the tan # of CFRP and GERP was significantly improved near the ¹' of each SMP. The amount of improvement for CFRP was superior to that for GFRP: the maximum tan # for SMP/CFRP composite was about 400 times that of CFRP, and only 30 times in the case of GFRP. Experimental results of the maximum loss tangents and the corresponding peak temperatures, ¹%, for the SMP and their hybrid laminates are summarized in Table I. In addition, it was found that within the frequency range 0.1—10 Hz, the change in frequency had no remarkable effects on the tan # of the laminates. Tensile tests results indicated that the tensile strength and modulus of SMP/GFRP laminates were almost the same as those of GFRP, but in the case of CFRP, a reduction of about 15% in the strength and modulus was observed.

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Conclusion

In this paper all basic data about hybrid composites is clearly presented, one can clear idea about hybrid composites after going through this paper, hybrid composites truly a manmade wonderful materials, with their flexibility to get Tylor made these materials continuously expand their scope and life. Research works related to hybrid composites is strongly recommended and profitable.

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