A Review on Recent Applications and Future Prospectus of Hybrid Composites

Gururaja M N, A N Hari Rao

Abstract: Hybrid composite Materials have extensive engineering application where strength to weight ratio, low cost and ease of fabrication are required. Hybrid composites provide combination of properties such as tensile modulus, compressive strength and impact strength which cannot be realized in composite materials. In recent times hybrid composites have been established as highly efficient, high performance structural materials and their use is increasing rapidly. Hybrid composites are usually used when a combination of properties of different types of fibres have to be achieved, or when longitudinal as well as lateral mechanical performances are required. The investigation of the novel applications of hybrid composites has been of deep interest to the researchers for many years as evident from reports.

This paper presents a review of the current status of hybrid composite materials technology, in terms of materials available and properties, and an outline of some of the trends, obvious and speculative, with emphasis on various applications including some details of smart hybrid composites.

Keywords: Hybrid composites, strength, stiffness, tensile modulus, smart hybrid composites

I. INTRODUCTION

There is a steady increase both in the number of applications being found for fiber reinforced plastics and, concurrently, in the variety of fiber/resin systems that are available to designers. Some of these systems are useful, however, only in highly specialized situations where limitations such as high cost and brittle fracture behavior are considered secondary to such qualities as low density, high rigidity and high strength. By mixing two or more types of fiber in a resin to form a hybrid composite it may be possible to create a material possessing the combined advantages of the individual components and simultaneously mitigating their less desirable qualities. It should, in addition, be possible to tailor the properties of such materials to suit specific requirements. There are many situations in which, for example, a high modulus material is required but in which the catastrophic brittle failure usually associated with such a material would be unacceptable. In the case of a strut member, a high initial modulus followed by limited yielding of the material and accompanied by the smallest possible reduction of load carrying capacity is usually desirable.

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Hybrid fiber reinforced materials can be made in two separate ways either by intimately mingling the fibers shown in Fig 1 in a common matrix, or by laminating alternate layers of each type of composite. In this work the latter technique has been used and the following considerations apply to this type of hybrid material. In principle several different types of fiber can be incorporated into a hybrid system [1, 2] but in practice it is likely that a combination of only two types of fiber would be of most use.

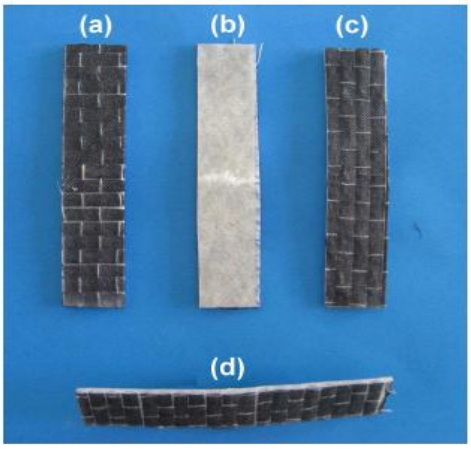

Fig 1 Hybrid laminates - Glass & Carbon

II. APPLICATION AREAS OF HYBRID COMPOSITES

2.1 Aeronautical Applications

Commercial aircraft applications are the most important uses of hybrid composites. Aircraft, unlike other vehicles, need to lay greater stress on safety and weight. They are achieved by using materials with high specific properties. A modern civil aircraft must be so designed as to meet the numerous criteria of power and safety. Glass & carbon reinforced hybrid composites are the most desired materials as a result of advanced technology that has gone beyond the design and application. In cases where high moduli of elasticity values are less important, hybrid is the natural option because of the low cost of material. The matrix material used with fiber glass & carbon fibers however, limits its use to low temperatures, usually below 121°C, although it is not a debilitating limitation for the fiber, as its properties can still be used and maintained at temperatures beyond 426 to 482°C. Fiber epoxy composites have been used in aircraft engine to enhance the performance of the system. The pilot's cabin door of aircrafts has also been made with hybrid resin composites and these are now used in other transport systems. The boron-graphite hybrid materials were initially designed for fighter aircraft components and their use in commercial aircraft has been very less.

The newer materials which have widened the horizons of the aircraft designer are, of course, carbon fiber in its various forms and to a lesser extent, Kevlar. These materials, with high specific strength (ultimate strength/density) and, equally, if not more important high specific stiffness (modulus/density), offer possibilities to the aircraft designer undreamed of fifteen years ago. In spite of this it has been the cheaper, less structurally attractive glass which has made the major inroad. This is particularly true in the case of sailplanes - few are now built which do not have nearly all the structures built in this hybrid material, but their design requirements are such that this is possible, great emphasis being placed on attaining a smooth exterior profile which, with the combination of GRP and other materials, is feasible. Coupled with this is the fact that these machines are virtually custom-built by hand at low volume production rates. The greatest interest in reinforced plastic structural materials must lie in those forms of reinforcement which are unwoven (or, at least, have essentially uncrimped or untwisted Fragments), the filaments being as straight as possible, thus imparting to the composite single layer the maximum strength and stiffness in the filament direction. They all have low transverse and shear strengths but, of course, with the material correctly layered and oriented to match the specified load pattern, these properties can be tailored [3] & [4]. A simple example of this tailoring would be for, say, HM CFRP, where the shear modulus for the layer is, 1/5 of that of aluminum alloy, but, when built as an angle ply at ±45 °, is approximately double (Fig 2) whilst at the same time being only 2/3's as heavy. Also of great interest for these thin walled shell structures are comparisons of forms of reinforcement needed to support compressive forces without buckling.

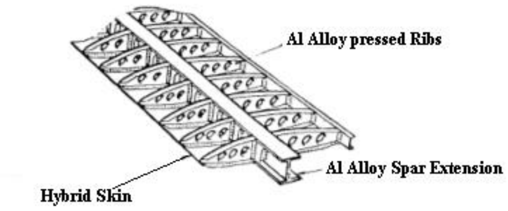

Fig 2 Sail Plane Wing with Hybrid composite skin

2.2 Hybrid Smart Memory Composites

Increasing demands on the performance of materials used in engineering applications necessitate the development of so-called adaptive, multifunctional, smart, or intelligent materials [5]. The concept of smart hybrid composites with embedded elements emerged in the late 1980's and attracted a worldwide research interest in the last decade. SMA composite materials are created by embedding SMA elements in the form of wires, ribbons, or particles into matrix materials such as polymers, fiber-reinforced polymers, metals, or ceramics shown in Fig 3. The physical properties of the matrix materials are either improved by the SMA elements or can even be actively modified by controlling the progress of the martensitic transformation (MT) in the SMA elements. Internal compressive stresses are generated in the surrounding matrix when the embedded and pre strained SMA elements are heated. These compressive stresses can strengthen the composite, improve its impact or damping properties, or change its natural vibration frequencies External shape variations of the composites can be also achieved. Intensive multi-disciplinary research on these and other subjects has been carried out in the last decade mainly, in the United States.

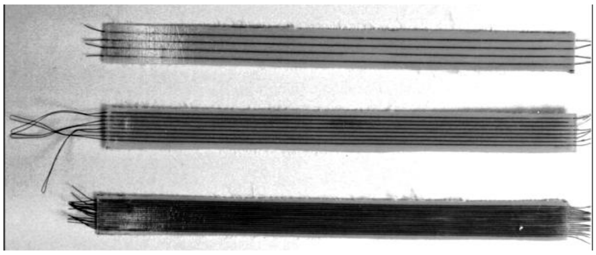

Fig 3 Three SMA composite samples with different volume fractions of thin Ni-Ti-Cu SMA wires embedded in a Kevlarâ reinforced epoxy matrix produced at EPFL, Lausanne Switzerland.

2.3 Wind Power Generation

The wind-power engineering is a priority area of energy generation due to its resource-saving and ecologically safe. The power cost primary is determined substantially by basic power element – blades. At present hybrid fibers (carbon, glass) are mainly used for fabrication of the blades shown in Fig 4 [6], whereas the works for reinforcing of epoxy matrices with basalt and other fibers are known [7]. The task of cost reduction may be solved through application of the less expensive materials in comparison with carbon fibers. For blade creation an application of new composite hybrid material is suggested on the basis of epoxy matrixes, strengthened by mullite-like crystals, as well as – on combinations of high-strength and high-modulus basalt and carbon fibers. Basalt reinforcing element of a composite was prepared on the basis of Georgian raw materials. The problem consists in a partial or total substitution of expensive carbon fiber in the material. An application of hybrid reinforcing fibers and of strengthened matrix will permit a considerable reduction of the blade cost without significant loss of physical-mechanical properties of the material.

Fig 4 Hybrid wind turbine system

2.4 Marine Applications

Ships are under constant attack, both from the elements of nature and the enemy. The vast majority of ship hulls are constructed from common carbon steels, which are obviously susceptible to corrosion, but they also create distinct thermal and electromagnetic signatures easily detectable from long distances. Nonetheless, even methods which are staples of the industry have shortfalls.

First, the construction process is very labor intensive, involving the welding of thousands of steel plates. Second, all the welding creates numerous heat affected zones, resulting in areas of stress concentrations. Next, the entire structure, and especially these heat-affected zones, are highly susceptible to corrosion and reduced fatigue life. Lastly, extensive coatings [8] are required to shield the structure from the elements. All of these factors and more ultimately translate into higher build and maintenance costs for ships. For the next generation of ships, the Navy is looking to stealthier hull technologies, specifically those which create lower magnetic, acoustic, hydrodynamic, radar, and thermal signatures. One way to accomplish this is by constructing hulls out of reinforced polymer hybrid composite materials. Hybrid composites have many advantages over carbon steel [9], including a much higher strength to-weight ratio, lower maintenance requirement, and an ability to be formed into complex shapes such as hulls shown in Fig 5. Hybrid composites hulls also offer a number of stealth benefits. Beyond the benefits of stealth, hybrid composites also have high durability and increased fatigue life.

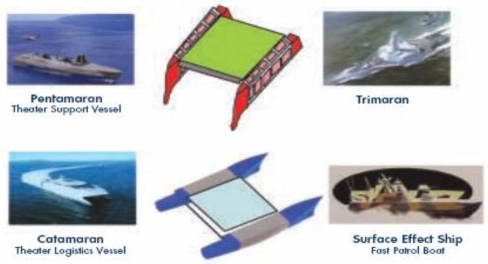

Fig 5 Application of Hybrid composites for Hull construction

2.5 Hybrid Thermoplastic Application

Thermoplastic advanced composites have long held potential for mass-producing lightweight structural parts. Unlike thermoset-based composites, which undergo time-consuming chemical cross linking during processing, thermoplastic-based composites are typically processed using only heat and pressure. The helmet shape is one that the Army has developed for its Future Force Warrior (FFW) initiative. Currently, the US Army uses helmets of a different design. These helmets, called PASGT helmets shown in Fig 6, are made using a composite comprising aramid fabric in a thermoset matrix. One overarching goal of the FFW helmet is to reduce weight compared to the PASGT helmet [10]. The construction must also be strong enough to withstand the daily wear of a soldier's activities and provide improved ballistic protection. The FFW construction that Fiber forge investigated includes a tough, stiff carbon-fiber reinforced thermoplastic shell bonded to an aramid reinforced thermoplastic composite ballistic layer. The carbon fiber shell stiffens the helmet and improves wear resistance [11]. The aramid provides ballistic performance.

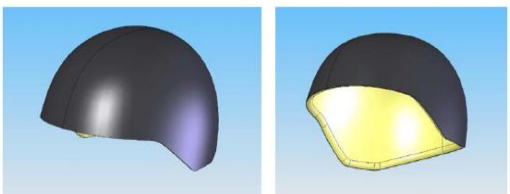

Fig 6 Hybrid Composite Helmet Design

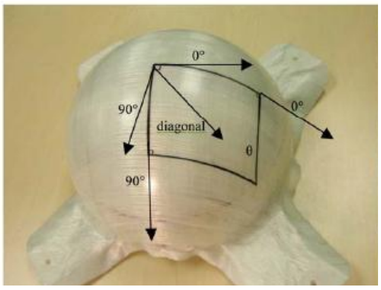

Fig 7 Hemispherical Composite 0/90 laminates Design

2.6 Hybrid for Civil Construction

In the last decade, the research and development of all hybrid FRP structures in civil engineering has progressed substantially in several countries [12]. The first all hybrid FRP bridge was constructed in Okinawa, Japan prefecture in 2001 (Ueda, 2005). This bridge is a two span continuous girder pedestrian bridge as shown in Fig 8 below, which is located in the road-park of Ikei-Tairagawa road. All the structural elements have been made with Hybrid Fiber Reinforcement Plastics (GFRP & CFRP). The all HFRP solution was chosen for this bridge due to its heavily corrosive environment where the bridge is surrounded by the ocean. It is believed that the innovative materials can be competitive to other conventional materials in the near future when life cycle cost is taken into account; there is an urgent need for research and development of this cutting edge technology. With such research and development, it is anticipated that a potential application in a road bridge can be materialized in the near future across the globe.

Fig – 8 Pedestrian Bridge in Okinawa, Japan made of Hybrid Composite

In order to propose an effective application of FRP materials from the aspect of strength and cost, the authors [13] focus on an innovative hybrid FRP bridge girder combining Glass Fiber Reinforced Plastics (GFRP) and Carbon Fiber Reinforced Plastics (CFRP). While CFRP has higher tensile strength and stiffness, it is more expensive than other constructive materials such as concrete and steel, whereas GFRP is comparatively less expensive but its mechanical properties are lower than that of CFRP. The innovative feature in this girder development is that these material properties are effectively utilized as hybrid materials.

2.7 Hybrid Composites for Telecom Applications

Need of telecommunication industries of power transmission along with data transmission is increasing, which felt the need to explore the innovative product category called Hybrid Cable.

Hybrid aerial, underground cable is very innovative and versatile cabling solution with in built power transmission required for network equipments with OFC cables. Hybrid Composite Cable is need of a day, firstly to support for Power transmission for always ON (Interrupt free) telecom needs. The telecom network elements & terminations are powered with help of this copper pair. Secondly, the Copper pair also used for critical signaling needs for railway signaling & fiber optic element for Telecom application [14]. Conventionally railway use quad cables for communication as well as signaling. Due to change in technology & increase in applications of communications for data transmission optical fiber cables are now become backbone of communication. Customer / Passenger expectations are increased for communications during traveling. On other hand railways are forced to provide services with lower investments. Railways have no choice to select only one communication media due to application & limitations of each media. New hybrid cable design Fig 9 is made such that it reduces cost of installation & total cost of two separate cables. The Copper conductors & types of fiber cable reinforcement & protection are provided based on requirement of the field.

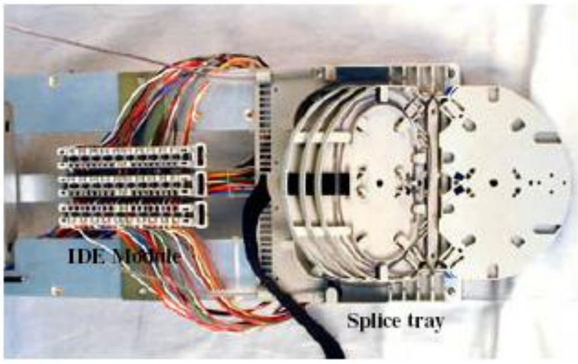

Fig 9 Hybrid Composite Cable

III. CHALLENGES, OPPORTUNITIES & FUTURE TRENDS

Several challenges must be overcome in order to intensify the engineering usage of Hybrid composites. Design, research and product development efforts and business development skills are required to overcome these challenges. In this pursuit there is an imperative need to address the following issues.

- Science of primary processing of hybrids need to be understood more thoroughly, especially factors affecting the microstructural integrity.
- There is need to improve the damage tolerant properties particularly fracture toughness and ductility in Hybrid Composites.
- Work should be done to produce high quality and low-cost reinforcements from industrial wastes and by-products.
- Efforts should be made on the development of Hybrids based on non-standard fibers & matrices.
- There is a greater need to classify different grades of Hybrids based on property profile and manufacturing cost [15].
- There is an urgent need to develop simple, economical and portable non-destructive kits to quantify undesirable defects in Hybrid Composites.

IV. CONCLUSION

The following conclusions can be drawn with regard to the various applications of Hybrid Composites:
Firstly, the details of manufacturing process of hybrid laminates is provided as applicable to various industries such as transportation industry, aeronautics, naval, automotive industries and components for the electronic industry. Considerable efforts have been focused on the applications of Hybrid composites for better understanding of the phenomena associated to the cutting edge technology. As far as the material is concerned, glass and carbon fibre reinforced composites have been equally investigated; however, epoxy resin is preferred as the matrix material. An effort towards this literature on hybrid composites will throw some light on researchers and scientists pursuing work on hybrid composite technology.

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