APPLICATIONS OF COMPOSITE MATERIALS IN THE DEVELOPMENT OF AEROSPACE INDUSTRY

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ABSTRACT: *Composites materials are intended to be used more extensively as an alternative of aluminium structure in aircraft and aerospace applications. This is due to their attractive properties as high strength-to-weight ratio and stiffness to weight ratio. Besides that it clarifies the growing interest for composite materials due to advantages of lightweight, high strength, high stiffness, superior fatigue life, tremendous corrosion resistance and low cost manufacturing. Composites have attractive mechanical and physical properties that are now being utilized in automotive industry. New fibres, polymers, and processing techniques for all classes of composites are constantly being developed. Research is also on going to improve repair techniques, recyclability, and the bonding between fibres and matrix materials.*

Keyword: Composite, Aerospace, Fibre, Resin, Matrix
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INTRODUCTION

Humans have been using composite materials for thousands of years. For example, they have manufactured bricks out of mud which is thousand year old technology. Fibre glass is one of the first modern composite which was developed in the late 1940s and is still the most common in our daily use. Composite is a term that has different meanings among engineers and manufacturers. In its general form, a composite material can be defined as a material which consists of two or more dissimilar materials which when combined are stronger than the individual component (Hossain, 2011). People have been making composites for many thousands of years. One early example is the mud bricks. Mud can be dried out into a brick shape to give building materials. It is strong if you try to squash it (it has good compressive strength) but it breaks quite easily if you try to bend it (it has poor tensile strength). Straw seems very strong if you try to stretch it, but you can crumple it up easily. By mixing mud and straw together it is possible to make bricks that are resistant to both squeezing and tearing and make excellent building blocks. Another ancient composite is concrete. Concrete is a mix of aggregate (small stones or gravel), cement and sand. It has good compressive strength (it resists squashing). In more recent times it has been found that adding metal rods or wires to the concrete can increase its tensile (bending) strength. Concrete containing such rods or wires is called reinforced concrete. Most composites are made of just two materials. One is the matrix or binder. It surrounds and binds together fibres or fragments of other materials which is called reinforcement.

Composites are materials of two or more chemically distinct constituents on a macro-scale, having a distinct interface separating them, and with properties which cannot be obtained by any constituent working individual (Agarwal et al 2006). There are basically two types of fibre: Natural fibres include those produced by plants, animals, and geological processes. They are biodegradable over time. Synthetic fibres are man- made fiber or chemical fiber whose chemical composition, structure, and properties are significantly modified during the manufacturing process (Kauffman et al., 1993). Fibres are widely used as reinforcements. Amongst the fibres available, glass, aramid, carbon fibres and lately natural fibres are in extensive use, although boron or other exotic fibres are also used in modest quantities for applications requiring very high service temperatures like the ones which we need for the skinning of the aircrafts.

Matrices are essential ingredients to embed fibres and provide a supporting medium for them. It is the ability of the matrix to transfer stresses which determines the degree of realization of mechanical properties of fibres and final performance of the resultant composites stress- strain behaviour and adhesion properties are important properties are important criteria which control the ability of the matrix to transfer stresses. A lot of research is being carried out on the basic understanding of the relationship between properties and production of tough, strong, stiff and environment resistant composites structures. This has helped in the development of composites having accepted properties. Composite materials are divided in five principal types: polymer matrix composite (PMC), metal matrix composite (MMC), ceramic matrix composites (CMC), Carbon- Carbon (CC) and hybrid composites (HC). Polymer matrix composites and especially fibre reinforced polymer (FRP) are widely utilized in manufacturing applications, including automobile and aerospace (Miller, 1998).

Prospects of Composites in Developing Countries

Composites present immense opportunities to play increasing role as an alternate material to replace timber, steel, aluminium and concrete in buildings. Their benefits of corrosion resistance and low weight have proven attractive in many low stress applications. The use of high performance FRP in primary structural applications, however, has been slower to gain acceptance although there is much developed activity. They are being used for the manufacture of prefabricated, portable and modular buildings as well as for exterior cladding panels, which can simulate masonry or stone. In exterior applications, composites are used in the manufacture of shower enclosures and trays, baths, sinks, troughs and spas. Cast composite products are widely used for the production of vanity units, bench tops and basins. Composite material properties can be converted into important financial and performance benefits during offshore operations. Studies have shown that the use of composite products can reduce offshore capital requirements, decrease maintenance costs and enable operations that otherwise are not feasible both technically and financially. During operations constitutes approximately 25-40% of the total project cost, so extended reach drilling capability is very important in offshore operations. Offshore oil and gas reservoirs are often accessed through horizontal drilling. There are other advanced composites that are currently being used in the field production applications (Fowler et al., 1998).

Application of FRP Composites in Other Areas

In the past three decades FRP composites have won an increasing mass fraction of military and civil applications. Significant investments from private and public funds were made towards research, development, testing, and fabrication and demonstration projects. Confidence in using composite materials increased dramatically (Agarwal et al 2006). This was also a period of great innovation in manufacturing, assembly and repair method development. The manufacturing industry has also become a major end user of FRP composites due to its advantages. Nowadays the manufacturing industry utilizes FRP composites based on glass, carbon and aramid fibres embedded in matrices made of polyester, epoxy and vynilester resins (Bunsell 2005). Recently basalt fibres have been introduced especially in application requiring high temperature exploitation (Serbescu 2006). The range of properties of FRP composites as well as the formability of FRP composite elements provides a large variety of load bearing and non-structural applications for manufacturing area. Linear elements, plate and shell elements and folded structures can be easily fabricated and assembled in different types of structures (Taranu 2009). 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 fibres (carbon, glass) are mainly used for fabrication of the blades, whereas the works for reinforcing of epoxy matrices with basalt and other fibres are known (Griffin 2004). The task of cost reduction may be solved through application of the less expensive materials in comparism with carbon fibres.

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 labour intensive, involving the welding of thousands of steel plates. Secondly, 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 (Bones et.al 2003) are required to shield the structure from the elements. All of these factors and more ultimately translate into higher build and maintenance costs for ship. 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 so many advantages over carbon steel (Grenestedt 2003), including a much higher strength to – weight ratio, lower maintenance requirement, and an ability to be formed into complex shapes. Need of telecommunication industries of power transmission along with data transmission are 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 equipment's 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 and terminations are powered with help of this copper pair. Secondly, the Copper pair is also used for critical signalling and fibre optic element for Telecom application (Pramod et al.2000).

Increasing demands on the performance of materials used in engineering applications necessitate the development of adaptive, multifunctional, smart, or intelligent material (Sittner et.al 2000). 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, fibre-reinforced polymers, metal, or ceramics. 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. In the last decade, the research and development of all FRP structures in civil engineering has progressed substantially in several countries (Keller 2003). 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 which is located in the road- park of Ikei- Tairagawa road. All the structural elements have been made with Hybrid Fibre Reinforcement Plastics (GFRP and CFRP). The all HFRP solution was chosen for this bridge due to its heavily corrosive environment where the bridge is surrounded by the ocean.

Application of Composite Materials in Aerospace Industry

Commercial aircraft applications are the most important uses of 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 and carbon reinforced composites are the most desired materials as a result of advanced technology that has gone beyond the design and application. NASA recently completed a major space technology development milestone by successfully testing a pressurized large cryogenic propellant tank made of composite materials. The composite tank will enable the next generation of rockets and spacecraft needed for space exploration. Cryogenic propellants are gases chilled to subfreezing temperatures and condensed to form highly combustible liquids, providing high-energy propulsion solutions critical to future, long term human exploration missions beyond low-Earth orbit. Cryogenic propellants such as liquid oxygen and liquid hydrogen have been traditionally used to provide the enormous thrust needed for large rockets and NASA's space shuttle. In the past, propellant tanks have been fabricated out of metals. The almost 8 foot diameter composite tank tested at NASA's Marshall Space Flight Center in Huntsville, Ala., is considered game changing because composite tanks may significantly reduce the cost and weight for launch vehicles and other space missions.

"These successful tests mark an important milestone on the path to demonstrating the composite cryogenic tanks needed to accomplish our next generation of deep space missions" said Michael Gazarik, NASA's associate administrator for space technology at NASA Headquarters in Washington. " This investment in game changing space technology will help enable NASA's exploration of deep space while directly benefitting American Industrial capability in the manufacturing and use of composites". Switching from metallic to composite construction holds the potential to dramatically increase the performance capabilities of future space systems through a dramatic reduction in weight. A potential initial target application for the composite technology is an upgrade to the upper stage of NASA's Space Launch System heavy- lift rocket.

SSTL's Composite Engineering Facility provides a total solution for advanced composite and bonded components and assemblies. It is established to meet the increasing demand for high performance, low cost spacecraft structures. SSTL's innovative engineering approach is tailored to the specialist multifunctional needs of their satellite structures, addressing the aggressive structural and acoustic born vibration environment of launch and the stiffness, electrical, thermo-elastic, and dimensional stability requirements of in-orbit operation. Precision composite components and structure are made from:

- Cynate-ester and Epoxy based polymer resin system.
- Various fibre reinforcements
- Integral and multi-part bonded construction

Through ESA's ARTES program SSTL developed a low cost, short lead-time primary structure for the GMP-T Geostationary platform. Stable opto-mechanical mounts, extremely stable optical benches and solar panel substrates are among many structures developed by SSTL composites facility for its own, and third party, small satellites.

DIAGRAM OF PRIMARY STRUCTURE FOR THE GMP-T GEOSTATIONARY PLATFORM

Challenges of Composites

Today, a major challenge relating to automotive composite design is the unavailability of simulation tools and a general lack of composite material characterisation. Another issue is the computational time required to model composite structure and components. Current composite material models within commercial design software require very long situation times. These times are usually too long solution times. These times are usually too long for the first phase of vehicle development, in which many different options have to be analysed over a period of just few months. For composites to be properly evaluated at these early stages, the automotive industry needs a factor of ten reductions in solution times. The commercial software developers have not yet solved this problem, so some of the more advanced research and design centres are developing in-house methodologies, which usually remain confidential (Ciaraldi et al., 1992). Manufacturing is an issue for composites in the aerospace, automotive sector when one considers the high production volumes required. One reason why composites are not widely used in mass production automotive applications is the cost of the raw materials, but the main reason is the lack of suitable manufacturing processes. Currently, the choice of manufacturing process depends strongly upon the required rate of production. A typical truck application might have a volume of between 5,000 and 20,000 parts per year; whilst for cars it might be 80,000- 500,000 parts per year, or even more. Other aspects that have to be considered are tooling costs, scrap production and cycle time. Composites can fail on the microscopic or macroscopic scale. Compression failures can occur at both the macro scale or at each individual reinforcing fibre in compression buckling. Tension failures can be net section failures of the part or degradation of the composite at a microscopic scale where one or more of the layers in the composite fail in tension of the matrix or failure of the bond between the matrix and fibres. Some composites are brittle and have little reserve strength beyond the initial onset of failure while others may have large deformations and have reserve energy absorbing capacity past the onset of damage. The variations in fibres and matrices that are available and the mixtures that can be made with blends leave a very broad range of properties that can be designed into a composite structure.

Tools for composite production are much cheaper than tools for sheet metal forming. This is because composite processes are one-shot operations (i.e one mould), whilst sheet metal forming requires five – six separate tools per component line. These savings in tool costs are very influential at low production volumes, but this competitiveness is lost at higher volumes where part costs dominate. The flaws that are present in natural fibres present a further challenge. These include areas where the fibre has a grown defect, thinning due to an increased inner hole dimension, and kink bands where the fibre direction is briefly translated sideways, leading to local strain concentrations when placed under load. Commonly, with present approaches to the manufacture of bast fibre composites, a strain of less than 0.5% is achievable. The techniques for addressing these issues are still under development, and include new approaches to tailoring the fibre interface. A second approach is to process the materials so that the reinforcement dimension is under the level of these flaws. The development of nanocellulose is being driven by the wood industry worldwide due to the excellent stiffness properties of cellulose (estimated at 130 Gpa), and may provide an entirely new class of composite in the future. Major challenges associated with dispersion and pre-treatment of the nanocellulose in its polymer and ensuring adhesion may be well rewarded with a flexibly manufactured material with good environmental characteristics.

CONCLUSION

Composites have attractive mechanical and physical properties that are now being utilized in automotive industry and aerospace on a grand scale world-wide. The use of fibre reinforced composites has become increasingly attractive alternative to the conventional metals for many components mainly due to their increased strength, durability, corrosion resistance, resistance to fatigue and damage tolerance characteristics. Composites also provide greater flexibility because the material can be tailored to meet the design requirements and they also offer significant weight advantages. Carefully designed individual composite parts, at present, are about 20-30% lighter than their conventional metal counterparts. All these studies show the excellent capability of composite materials that it can be processed to develop aerospace and satellite components for various applications.

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