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Advanced Composite Material for Aerospace Application-a Review

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Abstract

For the Aerospace Engineering there are huge progress of material science and engineering with the technological challenges in terms of the development of sophisticated and specialized materials e.g composite materials. At present composites material are becoming important in Aerospace engineering due to its increased strength at lower weight, stiffness and corrosion resistance. This paper investigates the composite materials used in Aircraft structure and also reviews the advanced composites as structural materials. Progressive development allows their application in new areas for further uses in future.

Keywords: composite materials, aerospace applications, latest research & developments.

INTRODUCTION

Aerospace Engineering has actual the promoter for the development of advanced engineering materials. The advanced material development depends on their properties such as, Strength, stiffness, damage tolerance, density, and corrosion resistance, at ambient and high temperatures. At present life cycle costing has been recognized as an tool to assess the economic acceptability of the material (exception to aerospace engineering).

A reduced take-off weight of an aircraft, space vehicle or satellite directly affects the amount of fuel burned, causes enormous economical and ecological benefits with light weight design.

COMPOSITE MATERIALS

A composite material is made when two or more different materials are combined together to create a superior and unique materials. The stronger material referred as reinforcement and the weaker material is referred as matrix. The reinforcement provides the strength and rigidity which helps to support the structural loads. The matrix or the binder help to maintain the position and orientation of reinforcement and more brittle, but when these two materials are combined which is light weight ,stiff, strong and tough.

ORIGINS OF COMPOSITE MATERIALS

The rapid development and use of composite materials beginning in the 1940s had three main driving forces. Military vehicles, such as airplanes, helicopters, and rockets, placed a premium on high-strength, light-weight materials. While the metallic components that had been used up to that point certainly did the job in terms of mechanical properties, the heavy weight of such components was prohibitive. The higher the weight of the plane or helicopter itself, the less cargo its engines could carry.

Polymer industries were quickly growing and tried to expand the market of plastics to a variety of applications. The emergence of new, light-weight polymers from development laboratories offered a possible solution for a variety of uses, provided something could be done to increase the mechanical properties of plastics. The extremely high theoretical strength of certain materials, such as glass fibers, was being discovered. The question was how to use these potentially high-strength materials to solve the problems posed by the military's demands.

One may conveniently speak of four generations of composites:

1st Generation (1940s): Glass Fiber Reinforced Composites

2nd Generation (1960s): High Performance Composites in the post-Sputnik era

3rd Generation (1970s & 1980s): The Search for New Markets and the Synergy of Properties

4th Generation (1990s): Hybrid Materials, Nan composites and Biomimetic Strategies.

The First Generation (1940s): Glass Fiber Reinforced Polymers (GFRPs)

While it seems obvious that making whole components (wings, nose cones, helicopter rotors, etc.) out of these high strength materials would be the answer, this was not the solution. These materials, while strong, were also brittle. Because of this, when they failed, they did so terribly. The theoretical high strengths could be severely undermined by flaws in the material, such as a micro crack on the surface. Also, the stress-to-failure varied widely between what should have been identical components, because the number of flaws and their sizes were different for each manufactured piece. Since the number of flaws generally scales with the size of component, the only solution was to use short fibers of the high-strength materials to minimize the flaws in the system. But what use were short glass fibers? By themselves they seemed to be laboratory curiosities at most, with no real applications.

An addition of Materials Properties

However, engineers soon realized that by immersing fibers in a matrix of a lightweight, lower-strength material, they could obtain a stronger material because the fibers stop the propagation of the cracks in the matrix. A polymer with insufficient strength or stiffness to act as an airplane wing could be reinforced with these new, fibers to produce a stronger, stiffer, lighter-weight product. The polymer "matrix" provided an environment for the fibers to reside in their original form - single, independent needles - and protected them from scratches that might cause them to fracture under low stress. The fiber "reinforcement" added strength to the more fragile polymer material by shouldering much of the stress that was transferred from the polymer to the fiber through their strong interfacial bonds.

The reinforced plastics emerged from engineering milieu rather than from scientific research. While solid-state scientists focused on the relation between structure and properties, industrial researchers were more concerned with the relations between functions and properties. The predominance of function over structure inspired composite materials, i.e. materials made of two or more heterogeneous components.

At the same time, chemical companies were conducting research into new polymers. Phenolic, urea, and aniline-formaldehyde resins were developed in the early 1930s , along with the unsaturated polyester resins patented in 1936 that would come to dominate the composites field. P.Castan in Switzerland received the first patent for epoxy resins in 1938, and soon licensed the patent to Ciba. While these new thermoplastic and thermosetting resins were being investigated for stand-alone applications - packaging, adhesives, low-cost molded parts - their potential use as a matrix for stronger materials was also kept in mind in order to expand the market of plastics. Mixing polymers with various additives - such as chargers, fillers, and agents of plasticity was already a well established tradition in chemical industries.

The increasing importance of polymers in industry is evident in the founding of the Society of the Plastics Industry in 1937, followed by the Society of Plastics Engineers in 1941. The emergence of scientific societies can indicate a level of widespread interest in a subject - a critical mass of sorts - that moves people from different companies and universities to gather together to exchange information about the latest findings.

The Beginnings of the Reinforced Plastics Industry: GFRP

Typically, the glass fibers were added to the polymer melt, which was then poured into a mold. Engineers and technicians had to learn the best ways to add the fibers so they were evenly distributed throughout the matrix, instead of clumped together. High pressure was applied to the early resins to get them to cure, but this caused some problems: the glass fibers were easily damaged at high pressures. To alleviate this problem, Pittsburgh Plate Glass developed some low pressure allyl polyester resins in 1940, and in 1942 Marco Chemical Company in Linden, New Jersey, was hired to investigate other low-pressure curing resins. In 1942 the first fiberglass laminates made from PPG CR-38 and CR-39 resins were produced.

The earliest applications for GFRP products were in the marine industry. Fiberglass boats were manufactured in the early 1940s to replace traditional wood or metal boats. The lightweight, strong fiberglass composites were not subject to rotting or rusting like their counterparts, and they were easy to maintain. Fiberglass continues to be a major component of boats and ships today.

In 1942, the U.S. Navy replaced all the electrical terminal boards on their ships with fiberglass-melamine or asbestos-melamine composite boards with improved electrical insulation properties.At the Wright-Patterson Air Force Base in 1943, exploratory projects were launched to build structural aircraft parts from composite materials. This resulted in the first plane with a GFRP fuselage being flown on the base a year later.

Another significant advancement was the development of tooling processes for GFRP components by Republic Aviation Corporation in 1943. The ability to cut and trim components to size reduced waste and added flexibility to the manufacturing of complex components.

Pre-impregnated sheets of glass fibers in a partially-cured resin, or pre-pregs, made manufacturing of components easier. By placing the fibers on a plastic film in a preferred orientation, adding the resin, pressing, and then partially curing the resin, flexible sheets of a precursor material could be produced. Pre-pregs eliminated the early production steps for manufacturers trying to avoid the resin and glass fiber raw materials. These sheets could be cut to shape, stacked, and consolidated into a single piece by pressure and heat.The first commercial composites were called glass fiber reinforced plastics and, remarkably, they still dominate the market today, comprising about 90% of the composites market.

Second Generation (1960s): High Performance Composites in the post-Sputnik Era:

GFRP technology spread rapidly in the 1950s. In France, a new Saint-Gobain factory in Chambery was opened in 1950 for the production of glass fibers; by 1958 they were producing composite helicopter blades for the Alouette II. Fiberglass-polyester was used to produce the sleek body of the Corvette sports car, and fiberglass-epoxy composites were used in applications ranging from printed circuit boards to

Winchester shotgun barrels. However, new demands emerged for the military space programs and new fibers which prompted the search for new high modulus fibers. The conjunction of the world geopolitical situation and materials research prompted the emergence of a general notion of composites.

The major world event was the launch of the Soviet Sputnik satellite in 1957 and the space race that it prompted. Spacecraft that would have to break the Earth's gravitational grip while carrying men and payloads into space required even lighter, stronger components than GFRPs. Also, the heat generated during re-entry of a spacecraft into the Earth's atmosphere could exceed 1500°C, which was beyond the temperature limits of any monolithic or composite material then known, especially low-melting point polymers. In 1956 Cincinnati Developmental laboratories added asbestos fiber to a phenolic resin for use as a possible re-entry nosecone material. Scientists also began looking at metal matrix composites (MMCs) for a solution.

MMCs typically use an inorganic, ceramic fiber or particulate phase to add heat resistance to light-weight metals and to lower their coefficient of thermal expansion. The reinforcement can also add strength and stiffness, but toughness tends to be lower in an MMC than in its corresponding monolithic metal. Other than experiments with steel wire reinforced copper, little research had been done in the area of MMCs at that time. The space race thus provided an impetus for the development of the carbon and boron fibers that had recently been discovered.

Carbon and Boron

Developments in the lab interacted with major world events in the 1960s to prompt the use of new stronger reinforcement fibers: graphite (carbon) fibers were produced using rayon as the starting compound, and Texaco announced the high stiffness and strength of boron fibers they had developed. While carbon and boron fibers were developed around the same time, carbon took the lead in the 1960s due to its superior processing capabilities and its lower cost. In Japan, A. Shindo developed high strength graphite fibers using polyacryonitrile as the precursor in 1961, replacing the rayon and pitch precursors used previously. Graphite fibers were of use only in polymer matrices at this time. Because of the reactivity of carbon with aluminum and magnesium, the use of graphite as reinforcement for metal matrices was not possible at first. It took the invention of air-stable coatings for carbon fibers that prevented a reaction between the carbon and the metal to make graphite-aluminum and graphite-magnesium composites a reality.

Boron fibers, whose strength exceeded that of carbon, found a place in military applications where their high cost was no concern, but made no inroads into other markets. Boron had three problems: It had to be deposited on a tungsten wire that was used as a substrate; such an arrangement was expensive; and the filament could not be bent in a tight radius. In 1969 boron-epoxy rudders were installed on an F-4 jet made by General Dynamics. Boron also reacted with the metal matrix above about 600°C, so coatings had to be devised before boron-reinforced MMCs became viable.

Aramid Fibers

In 1971 DuPont introduced the world to Kevlar, a fiber based on an aramid compound developed by Stephanie Kwolek back in 1964. Aramids belong to the nylon family of polymers. Their key structural features are aromatic rings (basically benzene rings) linked by amide groups. Kwolek had been working on petroleum-based condensation polymers in an effort to develop stronger, stiffer fibers. The looming possibility of an energy shortage had convinced DuPont that light, polymer-based fibers for radial tires could replace the steel belts then in use, reducing the overall weight of the car and saving fuel.

Kwolek normally melted the polymers she produced, and then had a co-worker spin the polymer into thin fibers. But in 1964 she made a polymer that would not melt, so she went searching for a solvent to dissolve the material. After many tries, the polymer dissolved, but the resulting solution looked like cloudy water, instead of the thick molasses-like solutions she was used to dealing with. Still, she wanted to spin it to see what kind of fibers she would obtain. Her co-worker in charge of the spinning process at first refused, claiming that the mixture was too thin to spin, and that particulates in the solution would clog up his machine. But Kwolek persisted, and eventually the fibers produced from her aramid solution turned out to be five times stronger than steel. They would be used in such applications as bulletproof vests and helmets for law enforcement officers. A slight variation in the positions of the amide groups between the aromatic rings produced Nomex, a fire-resistant fiber that is blended with Kevlar to produce protective gear for firefighters.From reinforced plastics to the generic notion of composites

With the use of a variety of fibers and the use of a variety of matrices, a general notion of composites emerged in the 1960s. A composite was a material combining two heterogeneous phases, whatever their nature and origin. The design of composite materials led scientists and engineers to turn their attention towards the interface between two phases. Because the mechanical properties of heterogeneous structures depend on the quality of interfaces between the components it was crucial to develop additive substances favoring chemical bonds between the fiber and the matrix. Composites thus favored a new orientation of materials research in which chemists had to play a major role.

Third Generation: The Search for New Markets and for the Synergy of Properties (1970s & 1980s)

Whereas space and aircraft demands had prompted the quest for new high modulus fibers in the 1960s, composites made with such expensive fibers had to find civil applications in the 1970s, when space and military demands declined. Sports and automobile industries became the more important markets. A new approach of materials design made possible by the use of computers favored the quest for a synergy of properties.

Carbon fibers were used extensively in sporting goods beginning in the 1970s, with graphite tennis rackets and golf clubs replacing the wooden racket heads and steel club shafts of their predecessors. The lighter weight and higher strength of graphite enabled tennis rackets with tighter strings to be swung at a higher velocity, greatly increasing the speed of the tennis ball. The increased stiffness of a golf club shaft transferred more of the energy of the swing to the golf ball, making it go farther. The increased cost seemed to be no problem for avid golfers and tennis players.

Metal Matrix Composites

After the race to the moon was over, aerospace engineers began designing reusable spacecraft such as the Soviet MIR space station, Skylab, and the Space Shuttle; and all were subject to extreme and repeated temperature swings. This required the optimization of the metal-matrix composites (MMCs) that had first been investigated at the beginning of the space race. These MMCs had to have the combined properties of high strength, high-temperature resistance, and low coefficient of thermal expansion (CTE) so the material would not expand and contract much during the regular thermal cycling periods. New fibers such as SiC had been developed in the mid-1970s, and coatings for carbon and boron fibers now made them viable additives for metallic matrices.

Addition of a ceramic reinforcing phase such as SiC fibers to a metal matrix, such as aluminum, produces a composite with a CTE below that of the matrix metal itself. Experimentation showed that the value of the CTE could be controlled by varying the amount of SiC added, so now engineers could tailor the thermal expansion properties of the composite to meet their needs. In addition, long, continuous fibers of SiC, carbon, or boron can dramatically increase the modulus of the component over that of the unreinforced matrix. Adding 30% continuous carbon fiber to aluminum can more than double the modulus of the metal.

By the mid-1990s, a variety of MMCs had found uses in spacecraft applications: carbon-reinforced copper was used in the combustion chamber of rockets, SiC-reinforced copper was used in rocket nozzles, Al_2O_3-reinforced aluminum was used in the fuselage, and SiC-reinforced aluminum was used for wings and blades. The antenna boom on the Hubble Space Telescope is made of a graphite-aluminum composite.

The cost of producing MMCs has prevented them from entering into other marketplaces. A notable exception is again in the area of sports equipment, where MMCs such as Duralcan (Al reinforced with 10% Al_2O_3 particulates) and Al reinforced with 20 % SiC particulates are used in bicycle frames for lightweight, high strength, very expensive mountain bikes.

Ceramic Matrix Composites

The development of ceramic matrix composites (CMCs) awaited the development of high temperature reinforcing fibers, such as SiC, because low-melting fibers would be destroyed at the high processing temperatures required for ceramic sintering. Yajima's development of Nicalon™ SiC fibers in 1976 was thus a major step.

Brittle ceramics need a reinforcing phase that will add to the toughness of the material, which is measured as the area under the stress-strain curve. In ceramics the fiber sometimes acts as a bridge over a crack, providing a compressive force to the leading edge of the crack to keep it from spreading. But the fiber can also absorb some of the crack propagation energy by "pulling out" of the matrix. Coatings have been developed for fibers that aid in this pulling-out process.

Alumina is the ceramic typically used in artificial hip prostheses. Prevention of brittle fracture of a hip implant is obviously of great interest to the patient. By adding SiC whiskers to alumina matrices, the toughness of the implant increases by as much as 50%. SiC-reinforced alumina is also used in long-lasting cutting tools for wood and metal. Graphite fibers in a carbon matrix produce another important class of CMCs: carbon-carbon composites. The excellent heat resistance and toughness of these materials allow them to be used as brakes on aircraft.

The ultimate goal of some ceramic engineers has been the production of an all-ceramic engine for use in automobiles. For a while there was hope that a CMC such a zirconium-toughened alumina would have the toughness to withstand the mechanical pounding such an engine would be subjected to, but so far such a composite has eluded researchers.

Initially Glass Fiber reinforced Plastics were conceived as an ingenious addition of the properties of each component. Thin glass fibers are quite strong but they are fragile. Plastics are relatively weak but extremely versatile and tough. Let's marry them! The expectation was just to obtain an addition of the properties of the various components: 1+1=2 However, gradually materials engineers realized that more could be obtained than the addition of the properties of the individual components. That the end product could be more than the sum of the properties of its components. How could 1+1= 5? Such a "miracle" can be achieved thanks to a synergy between the reinforcing fiber and the matrix when their combination reveals new possibilities and generate innovations. Let us take a simple and familiar example to illustrate such synergetic effect.The old chrome-steel bumpers of the automobile cars of the 1950s have been replaced by composite bumpers. The main reason for this change was that plastics saved weight and could offer comparable mechanical characteristics when adequately strengthened. Similar substitutions occurred in many other items (skis, tennis rackets, and window-frames). In the case of the bumper, however, the material substitution acted as a driving force generating a complex dynamic of change. The introduction of plastics in place of chrome steel did not immediately entail the cost reduction that was expected because this change involved heavy financial investments for R&D, for tests and trials and new equipment. Eventually, the innovation costs were largely paid off, because the plastic material had opened new avenues for change. Plastics, whether reinforced with fibers or not, are molded. Unlike metals, they can be shaped in the process of hardening the resin. Whereas with metals manufacturing and shaping the material are two successive operations, in the case of composites they became one and the same process.

Car designers were consequently free to redesign the bumpers in accordance with the current styling of cars. The bumpers were curved and molded along the line of the shell. The protective element became integral part of the body of the car. Instead of a separate part that had to be manufactured independently and then welded to the car, the shield is like a protective second skin wrapped around the body.

Such synergetic effects could only be reached through a close cooperation between car designers, physicists, chemists, chemical engineers and computer scientists. The lesson to be learnt was that the traditional linear approach - "given a set of functions let's find the properties required and then design the structure combining them" - should give way to a systems approach. The systems approach has been made possible by the use of computer simulation in industrial design. Computer simulation allows a to and fro and mutual adaptation between structure, properties, process, and end users.

Therefore such examples of synergy prompted a new paradigm for composite technologies. Whereas in the 1970s, composites had been defined by the association of a matrix and reinforcing fibers, in the 1980s, the synergy effect became part of their standard definition. For instance Philippe Cognard, the author of a French textbook intended for training materials engineers wrote: "A composite is a material whose assembly of constituent elements generates an effect of synergy within the properties of these elements. This bi- or tri-dimensional assembly is constituted by two or more basic elements that can have all possible kinds of forms: matrices, fibres, particles, plaques, sheets...It allows us to obtain a resilient material, all of whose elements are strongly and durably attached together." However, few composites answer this ideal definition. Such synergetic effects are neither frequent nor predictable. Each composite is itself an adventure.

Fourth Generation (1990s): Hybrids and Nanocomposites

In the 1990s, both academic and industrial researchers started to extend the composite paradigm to smaller and smaller scales. From the macroscopic scale to the molecular scale: Hybrid materials.

Hybrid materials mix organic and inorganic components at the molecular scale. Historically it was the study of biomineralization that focused the attention of materials scientists to the possibilities of such hybrid structures. Thus a new design strategy emerged that is known as biomimetism. Mollusk shells, bones, wood, most materials made by living organisms' closely associate inorganic and organic components. Biological macromolecules form an intimate mix or composite of proteins and mineral phases at all level of composition, starting from the nanoscale up to the macroscopic scale. For instance nacre is a kind of sandwich material made of layers of calcium carbonate crystal alternating with organic layers of proteins.

In the design of hybrid materials the main target is to mimic also nature's process that is to get a spontaneous association of molecules into stable structures. Molecular self-assembly is a common standard process in biological systems. In order to perform molecular self-assembly materials scientists have to overcome thermodynamic issues involved in the aggregation of molecules. They rely on all sorts of non-covalent interactions - such as hydrogen bonds, or van der Waals interactions - linking together molecular surfaces into aggregates. Like nature uses proteins as templates in order to manufacture stable structures, materials scientists also use templates, generally an inorganic porous matrix in which they insert organic molecules or enzymes.

Remarkably, strategies of hybridization apply to all families of materials: not only to polymers but also to cements and materials for electronics or medical uses. Hybridization intensifies the need for multidisciplinary cooperation: molecular biologists, chemists, chemical engineers, mechanical engineers, electronic engineers and physicists have to collaborate. Thus hybrid materials constitute a composite field of research requiring the knowledge and the know-how of various disciplines. For instance they use the skills in intercalation processes accumulated by the solid-state chemist as well as the synthetic skills of the polymer chemist, their experience in the design of composites and multiphase systems using polymer blends, copolymers, and liquid crystal polymers. Scientists from these various specialties have to learn the language of other disciplines instead of defending their own territories.

Nanocomposites

Smaller and smaller: since micro synthesis has been successful in making computer components, materials scientists have aimed to go beyond the micro scale and to build up materials atom by atom (that is at the nanoscale: less than 100 nanometers) in order to make complex materials that can function as devices or micro machines. Again biological systems provided the model. As George Whitesides put it: "for the nanometer scale there is no richer storehouse of interesting ideas and strategies than biology". Much money and effort has been spent on nanocomposites. However, a major problem lies in the impossibility of extrapolating from the micro- to the nanoscale: At the latter, quantum effects become the norm.

Summary: The Impact of Composites on Materials Research Composites had a direct impact on materials technology and indirectly reoriented materials science and engineering.How composites changed materials technology:

Material by design

A distinct advantage of composites, over other materials, is the flexibility of design. By using many combinations of resins and reinforcements, one can design a composite to meet specific strength requirements. Advanced composites for aerospace industry are thus tailored to perform a specific set of functions in a specific environment. Composites opened up the era of materials by design when high modulus continuous fibers such as aramid or carbon fibers were introduced. They are not randomly oriented like short fibers, but carefully aligned into a unidirectional tape. Making such composites is a laborious process with many steps, the end product is more expensive than the standard materials used in mass-production. However they offer higher performances for a specific use.

Crossing Boundaries: Because they associate various families of traditional materials in one single structure, composites encouraged the hybridization of independent industrial traditions. Glass companies and textile industry began to cooperate on the production of fiberglass in the 1950s. Glass manufactures and chemical companies, and also metallurgy and ceramics technologies, had to learn from each other to manufacture composites.

Systems approach*:* The technology of composites helped develop a systems approach in materials research. In order to design composites with more than the sum of the properties of their individual components, a parallel synergy should be created between the various experts involved in the design of the composite material and cooperation between customers and suppliers.

Performances and Process: Whereas metallurgy and solid state physics had focused the attention of materials scientists on the relation between structure and properties, performance and process entered the game with R&D on composites (together with R&D on electronic materials). High performances are the driving force in advanced composites. And processes are so important in automotive industry that materials are labeled after their fabrication process rather than by their composition. Composites undoubtedly generated a new way of thinking.

Surface and Interfaces: Composites turned the attention of materials scientists to the interface between two phases. Because the mechanical properties of heterogeneous structure depend upon the quality of the interface between the reinforcing fiber and the matrix, interfaces and srufaces became a prime concern of materials science and technology. Surface science thus emerged as a new field of research. As Bernhardt Wuensch emphasized in a recorded discussion: "worrying about interfaces was the beginning of composites and the beginning of Materials Science and Engineering"

Biomimetism: Wood and bones are natural composites whose functions and properties challenge the most advanced materials designed by human art. Biomimetism thus became one of the favorite strategies to design molecular and nanocomposites.

THE USAGE OF COMPOSITE MATERIALS IN AEROSPACE INDUSTRY:

Composite materials can provide a much better strength-to-weight ratio than metals: sometimes by as much as 20% better. The lower weight results in lower fuel consumption and emissions and, because plastic structures need fewer riveted joints, enhanced aerodynamic efficiencies and lower manufacturing costs. The aviation industry was, naturally, attracted by such benefits when composites first made an appearance, but it was the manufacturers of military aircraft who initially seized the opportunity to exploit their use to improve the speed and maneuverability of their products.

Weight is everything when it comes to heavier-than-air machines, and designers have striven continuously to improve lift to weight ratios since man first took to the air. Composites materials played a major part in weight reduction, and today there are 3 main types in use: carbon fiber, glass and aramid – reinforced epoxy. There are others, such as boron-reinforced (itself a composite formed on a tungsten core). Composites are versatile, used for both structural applications and components, in all aircraft and spacecraft, from hot air gondolas and gliders, to passenger airliners or fighter planes.

The types have different mechanical properties and are used in different areas of aircraft construction.

Carbon fiber for example, has unique fatigue behavior and is brittle, as Rolls Royce discovered in the 1960’s when the innovative RB211 jet engine with carbon fiber compressor blades failed catastrophically due to bird strikes. In an experimental program, Boeing successfully used 1500 composite parts to replace metal components in a helicopter.

The use of composite-based components in place of metal as part of maintenance cycles is growing rapidly in commercial and leisure aviation. Overall, carbon fiber is the most widely used composite fibre in aerospace applications.

THE FUTURE OF COMPOSITES IN AEROSPACE INDUSTRY

With the increasing fuel costs and environmental lobbying, commercial flying is under sustained pressure to improve performance, and weight reduction is a key factor in the equation. Beyond the day-to-day operating costs, the aircraft maintenance programs can be simplified by component count reduction and corrosion reduction. The competitive nature of the aircraft construction business ensures that any opportunity to reduce operating costs is explored and exploited wherever possible.

The development of new composite material

New materials can be defined as materials which have yet to be applied in an 'as-designed' application in aviation. Some of these materials, particularly metal matrix composites (MMC) and ceramic matrix composites (CMC) have seen some in-flight testing and are approaching military use but have yet to gain wide ranging acceptance by OEMs for various reasons.

Ceramic matrix composites (CMCs)

It is a material with the excellent thermal properties and with improved mechanical properties and with improved mechanical properties, overcoming the limitations of monolithic ceramic (i.e. toughness) and displaying other benefits. The possible applications of CMCs in aviation are generally in the hot section of the aero engines and include turbine disks, combustor linear, and turbine aerofoils.

Metal matrix composites (MMCs)

These consist of an aluminum or titanium matrix with oxide, nitride or carbide reinforcement and have many advantages over monolithic materials. But they are not as tough, are more expensive and are difficult to machine. Possible applications include highly loaded surfaces such as helicopter rotor blades, turbine fan blades and floor supports.

Carbon Nanotube technology

Carbon nanotubes have been being looked forward to as the next generation of new and advanced materials. System designers are now seeing the possibilities of using these in new applications for electronics and shielding of large scale aircraft. Carbon nanotube technology has many applications for aerospace and defense electronics. It is EMI shielding, for example, carbon based composite aircraft often get residual current from lightning strikes. They use metal to protect the aircraft, but residual current is still present. This light weight material is being used for EMI shielding and shielding internally. It enables better shielding for basically the weight of a coat of paint, and allows you to shield the internals of a carbon fiber based airplane.

Carbon nanotubes have at least the tensile strength of carbon fiber, but they are quite flexible. They don't have the same brittleness, so the strain to failure is different. They are able to be in a fabric like format where they can be put into the composite themselves, or be the composites themselves. One can imagine that the surface of a wing would be both structural, it would de-ice itself, it could be the antenna, it could report back to the aircraft and say 'we are or we are not integral', you have enormous numbers of multifunctional applications that carbon nanotube technology can bring to aircraft and spacecraft.

Shape memory metals (SSMs)

When SSMs are heated they revert to pre-deformation shape. They usually consist of copper/nickel based alloys, though other materials can be used. The simplicity of SSM actuators is that they can be used for hybrid applications such as variable jet intake and morphing variable geometry chevrons where traditional systems are too large and complex when compared with the savings possible.

Core materials

Aerospace sandwich structure consists of two skin face sheets attached to a core using adhesive. There are many materials utilized in the development of a core. The most common type of core is a honeycomb. Depending on the design parameters of the part, the aerospace industry may utilize either metallic or non-metallic honeycomb material. A honeycomb core is made from materials such as aluminum, fiberglass or Nomex. The honeycomb sandwich construction can comprise an unlimited variety of materials and panel configurations. The composite structure provides great versatility as a wide range of core and facing material combinations can be selected. Honeycomb-cored sandwich panels increase part stiffness at a lower weight than monolithic composite materials. By imitating the natural geometric structure of a beehive, the honeycomb core imparts strength and light weight to sandwich panels, while supporting the prepreg skins. The honeycomb sandwich structure composite has high compressive strength in the direction of the cell walls and high shear strength in the plane perpendicular to the cell walls. Commonly, the bond between the honeycomb core and the prepreg skins is created by a film adhesive layer. A surfacing film is often co-cured with the composite sandwich panel to improve the appearance of the part and to provide a smooth, uniform, and nonporous surface.

Reinforced carbon-carbon (RCC) is a composite material consists of carbon fiber reinforced in matrix of graphite, often with silicon carbide coating to prevent oxidation. It was developed for the nose cone and leading edges of the space shuttle and for the nose cone of intercontinental ballistic missiles.

Aerospace Main design Driven for Composites:

Aeronautics: - Design primarily driven by strength & fatigue.

Space: - Design primarily driven by Stiffness to avoid coupled resonant response (e.g between a Satellite and its launcher) and long term on orbit environment.

Common: - Mass optimization to maximize the embarked by load (aerospace), reduce fuel Consumption (aircraft). The different design needs address the choice of different composite Materials (fibers resin systems) for aircraft and space structures.

Advantages for space Applications

- Specific Strength/ Stiffness: Light weight.
- Low coefficient of thermal expansion.
- Tailor able Thermo-Mechanical properties in terms of (i) Fibers (type,diameter,UD,fabrics)

(ii) Resin systems – Polymeric matrix (iii) Mix Resin / fibers

Drawback for space Applications

- Material cost (recurring & nonrecurring, storage and expiring)
- Low thermal and electrical conductivity (improved with conductive fiber)
- Properties of structural laminates tends to deteriorates due to environmental conditions

(transportation,pre-launch,launch)

- Strong concurrent design to manufacturing & tooling required.
- NDI-more complex wrt metals, wide variety of defect logy.
- Repair: Complex to recover structural integrity, impact damage visibility.

Resin Matrix Typologies: The composite resin systems typology as follows;

(i) Epoxy -for normal use where high stability and release of chemical does not affect the performance , maximum working temperature of 150 *C-180*C curing system.

(ii) Cyanate Ester-Working temperature of 150*C-180*C superior thermal stability,low out-gassing,low moisture absorption, radiation resistance.

(iii) Bismaleimidic- Upto about 250*C, find application in re-entry and exploration vehicles(low-medium heat applications).

(iv) Polyimide- Upto about 330*C find application in re-entry and exploration vehicles(low-medium heat applications)

Equipment Racks in manned structure (Epoxy CFRP) for internal structure.Thermal De-coupling washers (GFRP) for MDPS (Micro Meteoroids & Debris protection system)panel attachment points for external of space manned application.

CPD- Coarse painting device (Epoxy CFRP &Metals) for solar emission measurement.

Satellite Structure –Typical structural configuration:

- Sandwich (mostly for high stiffness application e.g Satellite primarily structures).
- Inserting and potting for equipment fixation.
- Bracket & machine parts under skin embedding.
- Connection of panels via angular shapes cleats.
- Perspective of high multi-functional panels.
- The satellite structural is typically based on a sandwich panels assembly: Al honey with CFRP Skins.

Composite in space Unmanned Applications

- Solar arrays (Sandwich structure)
- Antenna Reflectors (Sandwich structure)
- Truss structures(tubular structure)

RESULTANT CONCLUSIONS

Composite materials are becoming more important in the construction of aerospace structures. New generation large aircraft are designed with all composite fuselage and wing structures and the repair of these advanced composite materials requires an in-depth knowledge of composite structures, materials and tooling. The carbon nanotube technology itself is the greatest challenge for being able to drive scale to volume and decrease cost.

For example it is great to have a cable that’s 69% lighter weight, but we have to be able to produce this in a format and in a cost that can be broadly used by aircraft engineers. So the future is driving up the output, decreasing cost and eventually getting broadly used across the entire industry. The future of the composite industry looks set for continued expansion, with mergers and acquisitions likely, long term growth guaranteed, and exciting new innovative products and applications always on the horizon.

Research is also ongoing to improve repair techniques. Recyclability and the bonding between fibers and matrix maerials.Moreover, standards are being set-up for the testing and computerization of mechanical and corrosion property. Since the development of new fire retarding elements, the availability of polymers with higher temperature ratings, the relative ease of fabrication, and fair cost. MMC and CMC parts, tends to indicate that important progress has been made towards reduction of processing and manufacturing costs. So it is important to realize that the use of composites requires an integrated approach between user and designer/manufacturer to ensure functionality.

REFERENCES

[1] F.P. Gerstle, Composites," Encyclopedia of Polymer Science and Engineering, Wiley New York, 1991

[2] Carter ,F.C., and Paul,D.E. Material science and engineering. Ohio, ASM International, 1991 351 pp..

[3] Ashby, M.F., and Jones,D.R.H. Engineering materials-an introduction to their properties and applications. Oxford, pergamon Press,1985. 277 pp.

[4] HarrisS,B. A perspective view of composite materials. *Mat* & *Design,* vol 12, no. 5. 1991.pp. 259-271.

[5] *Materials Edge,* no. 50. Ju!. 1993, p. 4.

[6] PIGLIACAMPJI.,J. Organic fibers. Engineering materials handbook *1*, Composites . Dostal, c.A., *et al.* (eds.). Ohio, A.S.M.International, 1989. 983 pp.

[7] A. Brent Strong, Fundamentals of composite manufacturing: Materials, methods and application, Society of manufacturing Engineers, ISBN-10 0872638545, ISBN-13 9780872638549, 640 pages, 2008.

[8] L. Werfel man, The composite Evolution, Aero Safety World, pp 17-21, March 2007.

[9] T. Edwards, Composite materials revolutionize aerospace engineering, Ingenia Magazine Online, Issue 36, 24 p, September 2008.

[10] B. Hayes, L. M. Gammon, Optical microscopy of fiber-reinforced composites (ASM International), 223 p,2010.