

Introduction to Industry 4.0

Assignment 2: Introduction to industry 4.0 Essay

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Advance Composite Materials in Aircraft Industry

“Future of Lightweight”

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Abstract

Composite material had played a very vital role from housing early civilizations to enabling future innovations. Composites have various benefits & the main amongst them are resistance, design flexibility, durability, light weight, and strength. Use of composite is seen in our day to day life like the products used in construction, medical equipment's, oil / gas. Aerospace, automotive and many more. This essay gives an information about the pros and cons of fiber composite materials, product development, and applications of fiber composites, designing, manufacturing & properties.

In aviation new materials have been necessary in improving am product in aircraft industry. This updating in material properties has helped us to travel quickly and low cost around the world, by improving the performance and operations of modern aircraft. Composite technology continues to advance and incorporate new type like nanotube forms to accelerate and extend the usage of composite. This new material is introduced in the last part of this essay.

Introduction

There are many good reasons for aircraft manufacturers to use composites and for airlines to want composites to be used. The aerospace industry is looking for alternative materials to reduce fuel consumption and improve safety and performance. Many composite materials achieve relatively greater strength characteristics compared with traditional metallic materials, reducing aircraft weight and thus reducing fuel cost per passenger carried. Composites are more resistant than metal to fatigue from repeated take off/landing cycles, resulting in fewer costly inspections over the aircraft's lifespan and more time spent in the air making money.

Advanced composite materials can address all the demands asked for in aerospace materials, and its demand in the aerospace is increasing.

Composite materials are important to the Aviation Industry because they provide structural strength comparable to metallic alloys, but at a lighter weight. This leads to improved fuel efficiency and performance from an aircraft. This essay will investigate and describes outline & justification with industry examples.

- Role of composites a significant milestone for aircraft production.
- Composite structure for Airbus product.
- Composite panels structure in SAFRAN Aerospace industry.
- Pros and cons of composite material for future development projects.
- The Implications for society and our planet.

The essay will begin by basics of composite, its structure, classification, and major monolithic CFRP and thermoplastics applications. Further different types of composite material for future projects.

In aerospace engineering , quality control is an important, which demands high safety. Quality control for aerospace materials begins with the inspection of the raw materials and further leadsto monitor the production processes and characterization of the final structural parts. All these essential steps of quality control for aerospace composites

What is composite?

Composite are combinations of two or more different materials ***macroscopically*** combined together to achieve certain property which they cannot achieve alone.

Composites are rapidly replacing the aluminum traditionally used for aircraft industries specially in seating interiors.

Many aircraft seat manufacturers have initiated producing composite based seats because they are lighter, cheaper and stronger

Classification of composite

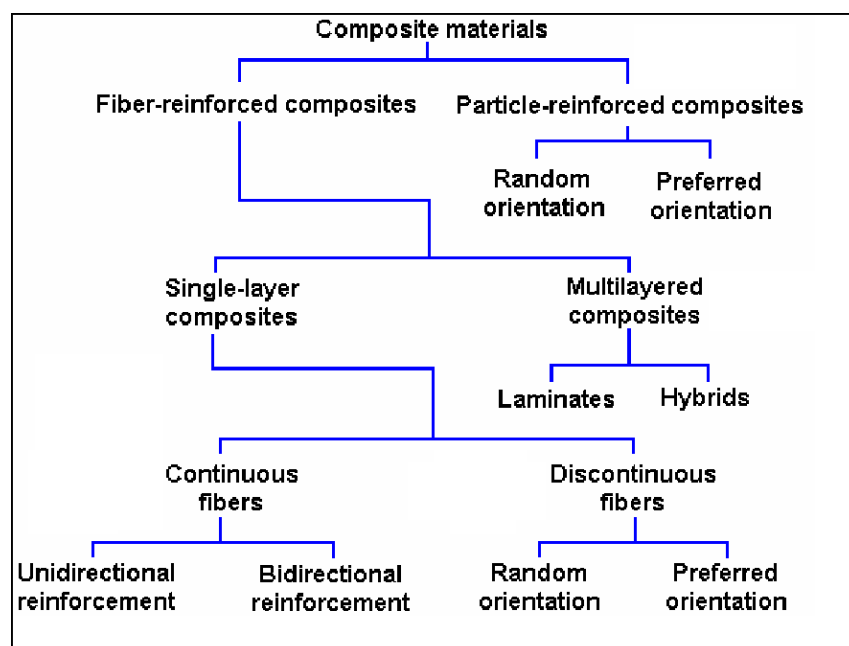
Composite may be a laminated or reinforcement type -

Laminated: Two or more layer of different material bonded physically to each other

Reinforced Composite: These composite have particles or fibre imbedded in matrix

Generally fiber / particle are harder and stronger than matrix. Matrix: Soft metals/ Polymer. Polymer is long chain structure having repetition of a simple chemical unit for a very largenumber of times.

Fig. 1 Classification of Composites



Stronger composite material is referred to as reinforcement and the weaker material is commonly normally referred to as the matrix. The reinforcement provides the strength and rigidity which is very important to support structural load.

Benefits of matrix is shape of the structure. Polymer a long chain structure of a simple chemical unit for very large number of times. Polymers are recognized by their thermal Properties: E.g. Thermoplastic Polymers and Thermosetting Polymers



Fig. 2 Chemical units of Composites

Thermosetting polymers are polymers which set when heated. They can be cross linked by heat or combination of heat and pressure. Other may be cross linked by chemical reaction at room temperature. They can not be reheated and remelted. They are having self life after moulding they become hard and strong. E.g. Phenolic resins, epoxy resins etc.

Phenolic resin are usually very brittle, so need reinforcement to increase strength and toughness. Large number of OH groups gives excellent adhesive qualities. Hence widely used as adhesives in: Plywood, PCB, Foundry shells and cores, Brake linings and Grinding wheels. (Grit mixed with phenolic powder and moulded to desired shape)

Fiber Composite use in Aircraft.

There are many type of composite used in aerospace industry. For example, composite were first used in military aircraft & now a days it's been used in commercial as well as private aircraft. Observed that the most common composite are: reinforced with fiberglass, carbon fiber and aramid fiber. Details as explained below. Fiberglass - is a fiber reinforced polymer typically from plastic matrix reinforced by fine fiber of glass. This is very lightweight & strong. Its raw material is not so costly. Carbon-fiber-Reinforced polymer - is an extremely strong and light fiber-reinforced polymer which contains carbon fibers. The composite may contain other fibers. For example Kevlar or glass fibers can be used. Aramid Fiber - is a strong synthetic fiber used in aerospace and military applications.

Pros and Cons of composites

The maximum application of composite material are in primary structure in commercial, industrial, aerospace & marine structures.

Advanced composites do not corrode like metals – the combination of corrosion and fatigue cracking is a significant problem for aluminum commercial fuselage structure.

The major benefits of composite today is fuel efficiency gained by an aircraft, which is very important with today's increasing fuel prices. Other attributes are corrosion resistance.

Composite usage has increased across aerospace and defense verticals. Market survey shows, the total composite market is anticipated to quadruple at a compound annual growth rate of 7.3%, reaching US \$30 billion by 2026.

There are some advantages of composite materials:

The main advantage is weight reduction – savings in the range 20% - 50%

Mechanical properties can be tailored by 'lay-up' design, with tapering thicknesses of reinforcing cloth and cloth orientation. This has been adapted by SAFRAN Industry,

High impact resistance & High damage tolerance improves accident survivability.

When corrosion issues in a wet state, which would occur when two different metals are in contact are avoided. In this case nonconductive fiberglass plays an important role. There are also some disadvantages in terms of higher recurring / non-recurring / Material costs.

As mentioned before, composite materials maximize weight reduction as they typically are 20% lighter than aluminum and are known to be more reliable than other traditional metallic materials, leading to reduced aircraft maintenance costs, and a lower number of inspections during service.

A Federal Aviation Administration Advanced Materials Research Program report found that there is much saving on every pound of weight saved. Data shows tentatively US \$100-300 cost saving over the service life of that aircraft. The Boeing 787 Dream liner, with its widespread composite use in primary structures, will result in less weight and consumes 20% less fuel which is very much beneficial. This shows that fiber composite use in aircraft results in significant weight savings, increased payload capacity and reduced fuel burn, allowing airlines using these aircraft to remain profitable in today's world where the fuel prices are drastically increasing.

The less weight results in minimum fuel consumption and emissions. The assembly procedure for the plastic structure needs different rivet joints which result in low manufacturing cost & improves efficiencies. Composite materials played a major part in weight reduction. Composites are versatile, used for both structural applications and components, in aerospace industry.

For example, the types have different mechanical properties and are used in different areas of aircraft construction. For example carbon fiber 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 due to bird strikes.

In an experimental program, Boeing successfully used 1500 composite parts to replace metal components in a helicopter.

Small Summary of the above points will be that there are considerable opportunities in

aerospace for composite parts manufacturers over the next 15 years. We have to realize that the usage of composite materials in the aerospace industry is still going through a learning curve and further improvements.

Composite manufacturing process

There are different types for manufacturing processes as stated below.

Hand Layup technique :

In this process a release gel is sprayed on the mould surface to avoid the sticking of polymer to the surface. Thin plastic sheets are used at the top and bottom of the mould plate to get good surface finish of the product. Reinforcement in the form of woven mats or chopped strand mats are cut as per the mould size and placed at the surface of mould after sheet. Then thermo set resin in liquid form is mixed thoroughly in suitable proportion with a prescribed hardener (curing agent) and poured on to the surface of mat. Check for any air trap. The process is repeated for each layer of polymer and mat, till the required layers are stacked. After placing the plastic sheet, release gel is sprayed on the inner surface of the top mouldplate which is then kept on the stacked layers and the pressure is applied. After curing either at room temperature, mould is opened and the developed composite part is taken out and further processed.

Spray Layup :

This process is an extension of the hand lay-up method. A spray gun is used to spray pressurized resin and reinforcement which is in the form of chopped fibers. Glass roving is used as a reinforcement which passes through spray gun where it is chopped with a chopper gun. Matrix material and reinforcement may be sprayed simultaneously or separately one after another. Spray release gel is applied for easy removal of component. A roller is rolled over the sprayed material to remove air trapped into the lay-ups. Spray lay-up method is used for lower load carrying parts like small boats & bath tubs etc.

Pultrusion

Pultrusion is a type of continuous automated closed molding. The material is pulled through the dies. Fiber mats are unrolled from a roll and pass through a resin tank. These resin saturated fibers are guided to the hot die where the desired profile is given. Curing of the composite also takes place in this section due to heating. The cured composite profile is pulled with the help of a gripper coming from the hot dies. Finally, pultruded profiles are cut with the help of a cutter which is inbuilt after the pulling mechanism in the pultrusion system.

Resin Transfer Moulding

Resin transfer moulding is a closed moulding process. Resin is transferred over the already placed reinforcement. Reinforcement in terms of either woven mat or strand mat form is placed on the surface of lower half of the mould. A release gel is applied on the mould surface for easy removal of the composite. The mould is properly closed and clamped. The resin is pumped into the mould through ports and air is displaced through other vents. After curing, the mould is opened and composite product is taken out.

Match metal moulding (Compression Moulding)

It is a closed molding process with high pressure application. Two matched metal moulds are used to fabricate composite product. Base plate is stationary while upper plate is movable. Whole assembly is kept in between the compression moulder. Heat and pressure is applied as per the requirement of composite for a definite period of time. The material placed in between the moulding plates flows due to application of pressure and heat and acquires the shape of the mould cavity with accuracy. Curing may be carried out at room temperature or at some elevated temperature. In this process production rate is high as the mould cycle time is in few minutes.

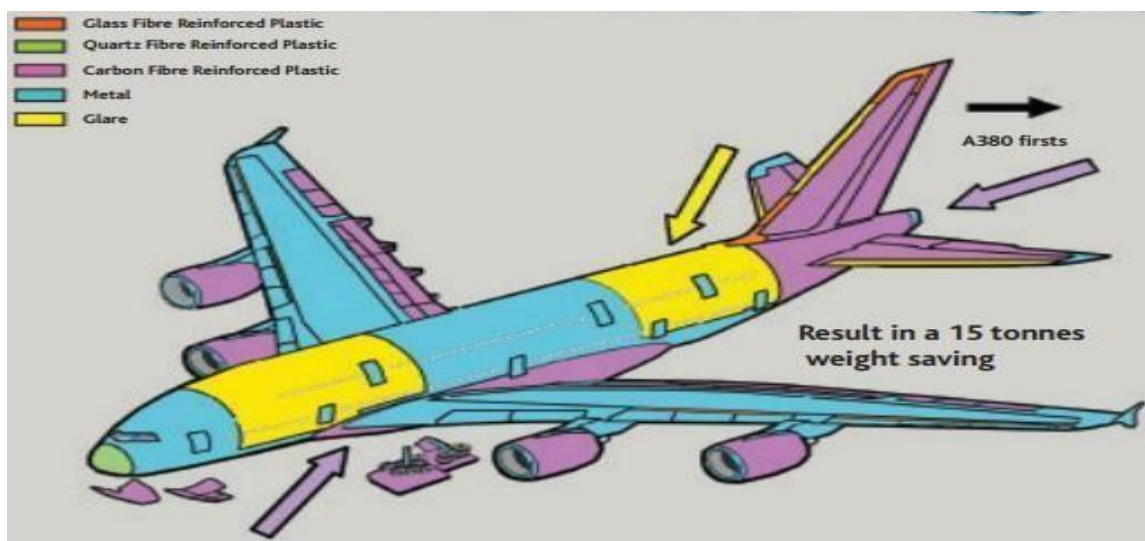


Fig. 3 Airbus material composition

Composites - Milestone for aircraft production.

In aviation innovation advance composite plays an important role. Airbus uses composites and other advanced materials in aircraft design and manufacturing, resulting economical and environmentally-friendly. The latest development in the field of aerospace materials depends upon the application. With reference for news article & analysis shows that the A380, which at 61% has the lowest percentage of aluminum by weight as shown in below image.

Innovation standards for composite environment.

Airbus was the first manufacturer to make extensive use of composites and other advanced materials for producing large commercial aircraft, beginning with the A310. Airbus pioneered the larger-scale use of composites for aviation over the course of some three decades.

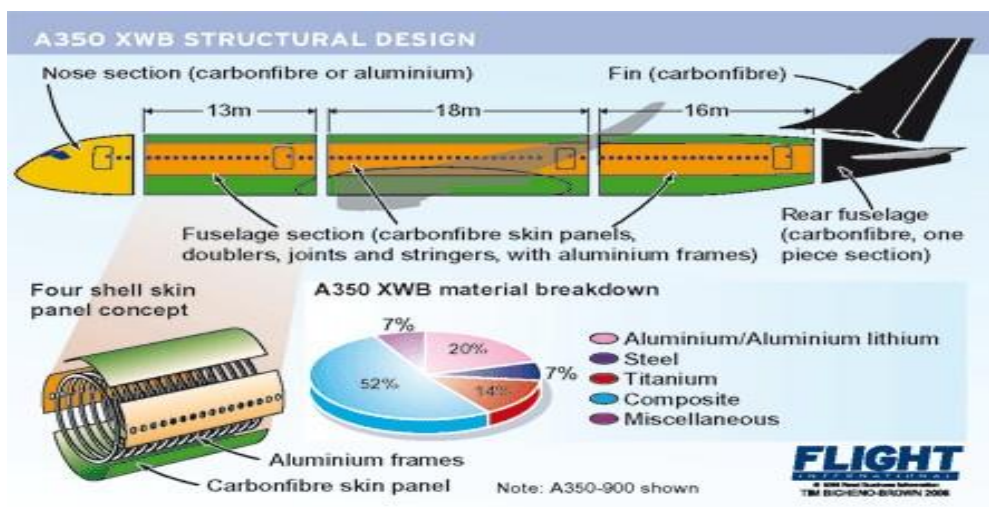
Composite structure comparisons of the Airbus product

For example, below image shows the percentage of composites and other material used in one of the aircraft to study the composition. For example, below image shows the percentage of composites and other material used in one of the aircraft to study the composition.

Its fuselage panels, frames, window frame are combinations of two or more different materials macroscopically combined together to achieve certain properties which they cannot achieve alone. Composites are rapidly replacing the aluminum traditionally used for aircraft industries especially in seating interiors.

Many aircraft seat manufacturers have initiated producing composite based seats & all furniture items with composite panels because of its lighter weight, cheaper and easy to assemble sub assembly parts with the help of inserts. This results in reduce maintenance cost for customer and also reduces the need for fatigue

Fig. 3 Composite structure of A350XWB



Composite structure of the Airbus A400M

In order to reduce weight, 30% of the A400M's structure is made of composites. These parts include most of the wing for the first time in history. Also, the horizontal and vertical stabilizers and the control surfaces, the rear cargo door and the propeller blades are made of

composite. The extensive use of composite material enables the A400M to be much lighter, enabling to enhance its performance both in terms of range and payload.

Composite structure of the Airbus A380

Aircraft Company goal is to select the most appropriate material for the specific application, which would lead to the lightest possible structure. For this purpose, composite materials are good competitors. The A380 is the first aircraft ever that boasts a CFRP (Carbon Fiber Reinforced Plastic) composite central wing box, representing a massive weight saving as compared to most advanced aluminum alloys. The upper deck floor beams and the rear pressure bulkhead are made of CFRP.

Composite structure in SAFRAN aerospace.

As mention earlier, most of the seat manufacturing are moving to build their seats with composite structure. SAFRAN has implemented the same and are using honeycomb sandwich panels as a composite for the furniture structure. Composite panels are an anisotropic materials. Composite panels used by SAFRAN is a layup, which is combination of Skin, core and insert blocks (Metal Blocks). This combination is designed based on the requirements.

SSGB and most of aero interior manufacturers are using Honeycomb sandwich panels as a composite for the furniture structure...Composite panels are an anisotropic materials
Composite panels used by SGB is a layup, which is combination of Skin, core and insert blocks (Metal Blocks), This combination is designed based on the requirements.
Skin currently used by Safran is Phenolic Pre-impregnated Glass Fibre skin. This skin is also called as prepreg. "Prepreg" is the common term for a reinforcing fabric which has been pre-impregnated with a resin system. This resin system (typically epoxy) already includes the proper curing agent. As a result, the prepreg is ready to lay into the mold without the addition of any more resin EPS number for skin details is EPS 1129.

The development of new composite materials

New materials can be defined as materials which have yet to be applied in the design process application in aviation. Some of these materials, particularly metal matrix composites (MMC) and ceramic matrix composites (CMC) have seen some in-flight testing 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 liner, and turbine airfoils.

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 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. This are mainly useful in application 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. For example, surface of a wing would be both structural, it would de-ice itself, it could be the antenna you have number of multifunctional applications that carbon nanotube technology can bring to aircraft and spacecraft.

Shape memory metals (SSMs)

When SSMs are heated they revert to predeformation 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 variety of materials and panel configurations.

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. This panels are mainly used in seat furniture which includes plinths and shroud area for seating system. They have wide application in aircraft galley design. 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.

Quality control and testing

Below details are about the major aspect related to quality control during sandwiched composites manufacturing and their maintenance, testing and repairing in service.

The common method to detect damages in sandwich panel are: Visual, ultrasonic, X-ray, back-light and moisture detectors. Major manufacturing damage and defects usually include delamination, resin-starved and resin-rich areas, cracks, blisters and air bubbles, wrinkles, voids and thermal decomposition.

This section summarizes the most common nondestructive testing techniques (NDTs) used to detect such defects in quality control inspections made during manufacturing and in-service conditions of composite sandwich structures.

No destructing testing

The most commonly used nondestructive methods to detect damages in sandwich structures applied in aerospace are as follows. Information from Aviation Maintenance Technician Handbook 2012.

- Visual inspection: This is the primary method for the in-service inspection of sandwich structure. This is suitable to detect impact damages larger than 0.5 mm. It is fast and has a large field of view, being suitable for detecting impact damages larger than 0.5 mm and cannot detect debondings, and it is not suited for defect sizing and defect depth estimation.
- Audible sonic testing (coin tapping): This is the most common technique for detecting delamination or debondings. It is performed by tapping with a round disk or a light hammer and then listening to the sound response. A clear sharp ringing means well bonded and the dull sound indicates discrepant area. The automated tap test is similar in this instead of hammer a solenoid is used. A transducer and recording system used for signals.
- Ultrasonic inspection: This technique uses sound waves with frequencies above the audible range. Ultrasonic waves are introduced into a material where they travel in a straight line with constant speed until they encounter an interface. The amount of reflected wave is captured and detects the damage. Information from this test is presented in three formats: A-scan as time function, B-scan displays a cross-section of a part and C-scan displays discontinuities.

- Radiography: Radiography involves passing X-ray radiation through a composite part and capturing an image on the opposite side. Areas with varying degrees of density and absorption exhibit different behavior in terms of absorbed radiation. It can be used to identify voids, water, impact delamination and crack-damaged cores.
- Thermography: The principle of thermography is to send a heat flow on the surface of an inspected sandwich part during a certain time and then to capture the resulting thermal response. Thermal conductivity analysis is done to detect the defected areas.
- Moisture detector: Uses radiofrequency power loss to detect water in sandwich structures.

Composites excellence aerospace companies

GE Aviation,

A world-leading producer of jet engines, already employs more than 450 people at a factory in northwest Mississippi. This factory is involved in the assembly of large front fans for jet engines as well as the production of composite components. The specific type of composite materials is known as Polymer Matrix Composites.

They are made of carbon fiber fabric and polymer resin and fabricated by using advanced technology in manufacturing processes and equipment.

Hexcel – a leading advanced composites company

A world leader in carbon fiber and composite materials for commercial and defense aircraft, helicopters, engines, HEXCEL is also a specialist in lightweight composite including engineered core parts, HexMC components and complete structures. Hexcel's composite materials bring great benefits to aircraft design. The improvement in fatigue performance with carbon fiber reinforced preregs compared to Aluminum is also a major benefit.

More than 50 % of the Boeing 787 airframe and the Airbus a350XWB is carbon fibre composite. Hexcel is a major supplier of materials to both programs and was awarded the contract to supply all the primary structure prepreg (with Hexcel carbon fiber) to the A350 XWB program. Hexcel has 40 years' experience in carbon fiber manufacture, with a vast Aerospace database and manufacturing facilities in the USA and Europe. It is an Intermediate Modulus fiber technology leader with an in-house Polyacrylonitrile (PAN) domestic supply and dedicated R&T facilities for both precursor and carbon fiber development. HexTow carbon fiber supports the World's most advanced applications including: A350 XWB, JSF, F18 E/F, A380, Eurofighter Typhoon, A400M, Boeing 787, and GENX Engines.

Blackhawk Composites

Advanced composites play a key role in aviation industry. Aircraft operators, both commercial and military, have shown that there is a demand for product upgrades, and Aftermarket providers have responded with solutions. From cowlings and fairings to storage lockers, Blackhawk Composites has complete capabilities to design, prototype and build composite components, using a wide variety of reinforcements and resin matrices, required for advanced aerospace applications, including custom solutions to meet specific performance objectives. Blackhawk Composites approved to utilize TORAY carbon epoxy composite material, the same material used on commercial jetliners and favored by the FAA. Black HOB modiodifications, a leading aircraft performance company, recently certified an engine upgrade solution for the Cessna Caravan 208B. Working with Blackhawk Composites, a design team engineered and manufactured a new composite cowling to accommodate the upgraded aircraft's larger, more powerful engine and dual port exhaust.

Composite Laminate Panels

In the aerospace industry bonded laminates are used to manufacture seats, cabin linings, galleys, storage compartments, lavatories and crew rest areas. A wide range of shapes and finishes are created by heat and pressure molding of sheet materials. Comlam manufactures sheet materials ready for forming to any customer requirement.

Laminating carbon, glass and organic fibers with thermoplastics is a significant benefit. Composite Laminate Materials be Used in following areas.

- Seats
- Cabin linings
- Storage compartments
- Galley and kitchen areas
- Crew spaces
- Lighting
- Tables, desks and work surfaces
- Decorative inserts and surround

Laminate plastic film is generally categorized into these five categories:

- Standard thermal laminating films
- Low-temperature thermal laminating films
- Heat set (or heat-assisted) laminating films
- Pressure-sensitive films
- Liquid laminate

Conclusions

Composites are one of the most important parts of aircraft's production. The recent studies show that, for example, glass fiber composites are the most popular due to their cheap price and ease of manufacturing, and will remain as the largest submarket both in volume and value of composites throughout the forecast period.

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 you 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.

Composite plays a vital part in saving the fuel saving and less carbon emission which also leads to environment safety.

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