



Plastics in aerospace

Introduction

The introduction of the “plastic fantastic Boeing 787 “Dreamliner” has been widely reported by the press and to read the reports it would be easy to assume that this is the first time that plastics have been used in an aerospace. However, nothing could be further from the truth. The 787 is undoubtedly a milestone in the use of plastics in aerospace, but it is by no means the first, nor will it be the last major advance in aerospace technology that is made possible by advances in plastics. Plastics are an “enabling” technology, a technology that makes other advances possible. Over the past 90 years, the development of plastics has enabled the aerospace industry to make the rapid advances that have changed the world we live in and brought the whole world closer together.

Even at the start of the aerospace industry, polymers were present (albeit natural ones). For example, the glue used to assemble “Wright Flyer 1” (the Wright brothers' first powered airplane) was “horse hide” glue. Horse hide and other animal glues have been used for at least 5,000 years as adhesives for wood and all are basically a long-chain polymer (collagen).

The use of plastics in aerospace became widespread just before and during World War II when there was both an urgent demand for materials to replace scarce resources and when new plastics were being discovered and brought into production. Applications ranged from PMMA (acrylic) windshields to the use of PVC for fuel-tank linings and other waterproofing applications.

Since those early times, the development of new engineering polymers has almost always been accompanied by new aerospace applications and this is still true today. The first “all-plastics” was flight tested in the 1980's and the “Dreamliner” simply brings the use of advanced composites into mainstream of commercial flight. Equally, plastics are a major component of the proposed HOTOL sub-orbital space-craft and will take plastics once more into space.

To illustrate this, Figure 1 shows the growing use of plastics in commercial aircraft.

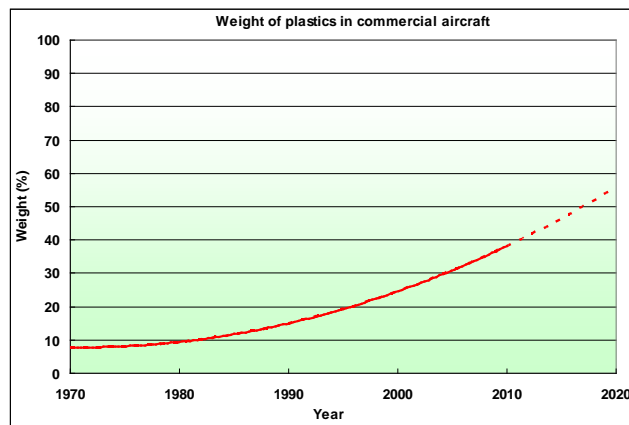


Figure 1: The development of plastics in commercial aircraft

In 2010, plastics are estimated to make up nearly 40% of the weight of commercial aircraft and as with automotive applications, this is forecasted to continue to increase in the future.

Why use plastics?

Plastics are used in aerospace applications for a variety of reasons. While cost savings are a key reason, there are many areas where the unique properties of plastics make them the only suitable materials for the application.

Strength to weight ratio

Weight is a key factor in any aerospace application and determines the efficiency and design of any aerospace component. Plastics have an excellent strength to weight ratio and can be used to reduce weight while still fulfilling the function. Reducing weight has a direct impact on performance and efficiency – a weight reduction of 1 kg can reduce lifetime operating costs, primarily in fuel costs, for a commercial airplane by more than \$2,000. Thus, even small weight reductions can be very cost-effective. In military applications, weight reduction will lead to improved performance and can be the “difference” between success and failure.

Plastics are used to reduce weight in areas as diverse as the main structure to the cutlery and bottles used for serving meals.

Part count and manufacturing operations reduction

Many of the applications of plastics enable part count reductions through the use of integral clips and fastenings or the production of finished large volume parts in a single process. This not only reduces weight and eliminates manufacturing steps, but also reduces the manufacturing time. Plastics can reduce other manufacturing operations through their unique properties. For example, plastics for interior appearance parts can be made integrally colored to eliminate painting.

Flexibility

Plastics are flexible and resistant to damage from engine induced vibration in all types of aerospace applications.

Electromagnetic transparency

Many plastics materials are transparent to wide ranges of the electromagnetic spectrum and allow plastics to be used for radomes and other structures where radar or other electromagnetic transparency is needed. This property can be used for stealth structures that are difficult to detect using conventional sensors.

Corrosion resistance

The use of plastics can greatly reduce maintenance costs associated with potential corrosion problems. Corrosion prevention is a major issue for structures manufactured from metal and the use of plastics reduces any corrosion issues and reduces maintenance costs by 30%.

Smooth contours

Plastics products can be easily formed into complex curved structures and parts to improve aerodynamics and reduce drag. When used for major airframe structures, the reduced drag is also accompanied by reduced weight – a double benefit from a single class of materials.

Market sectors

The aerospace market is not homogenous, but is composed of several but very different large sectors. These are broadly outlined in Figure 2:

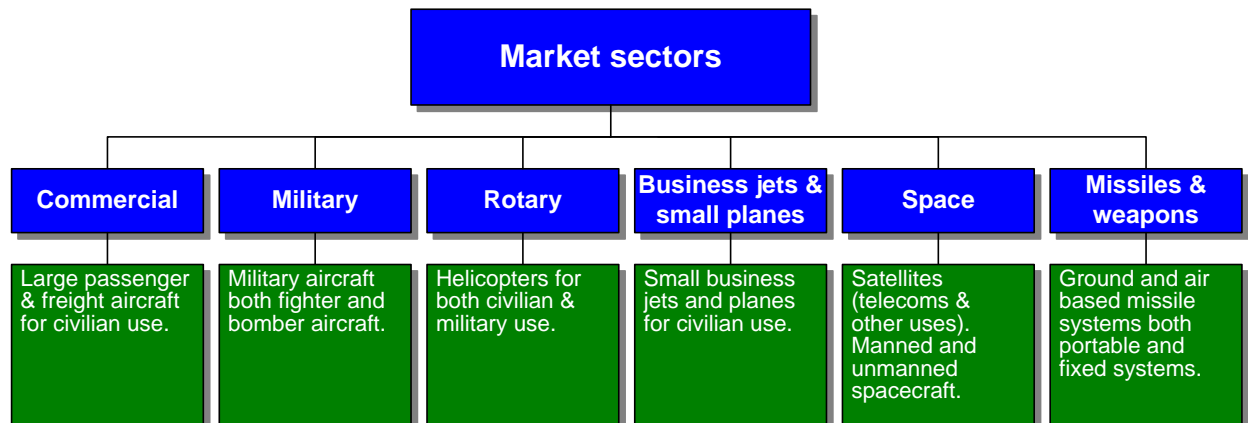


Figure 2: Typical market sectors for plastics applications in the aerospace industry

- **Commercial:** Large passenger and freight aircraft for civilian use is one of the pioneering application areas for plastics. The passenger and freight industries are extremely competitive and most carriers operate on low margins. Opportunities to reduce weight (and hence operating costs) or maintenance issues are highly sought after by operators. Increasing the use of plastics can provide both benefits and aircraft manufacturers are strongly motivated by potential sales to increase the plastics content of modern commercial aircraft.
- **Military:** Formula 1 and other racing cars act as “test-beds” for innovative ideas that, if successful, make their way into the cars we drive each day. Similarly military aircraft (both fighters and bombers) act as “test-beds” for innovative aerospace structures and developments. The jet engine was originally developed for military purposes, but was rapidly taken up by civilian airplanes and changed the face of civilian travel. Similarly, new developments in the application of plastics are often first seen in military aircraft where the demands are extremely high.
- **Rotary:** Helicopters for both civilian & military use are particularly weight sensitive, subject to high vibrational loads and required to carry high payloads. Most rotary aircraft make extensive structural and mechanical use of plastics to meet these almost contradictory requirements.

- **Business jets and small planes:** Small business jets and planes for civilian use are a growth market throughout the world. The rapid introduction of new composite materials and designs maximizing the benefits of these are increasing design flexibility, market size, and the volume of plastics in civilian aerospace applications.
- **Space:** Satellites for telecommunications and many other applications, as well as manned and unmanned spacecraft, all make extensive use of plastics in construction, wiring and heat shields. Plastics have already been to the Moon and Mars and they will undoubtedly also be present when man lands on other planets.
- **Missiles and weapons:** Ground and air based missile systems both portable and fixed systems.

Application areas

Plastics are used in every area of aerospace and some of the typical application areas are shown in Figure 3. Plastics are used in every one of the market sectors for every type of aerospace component.

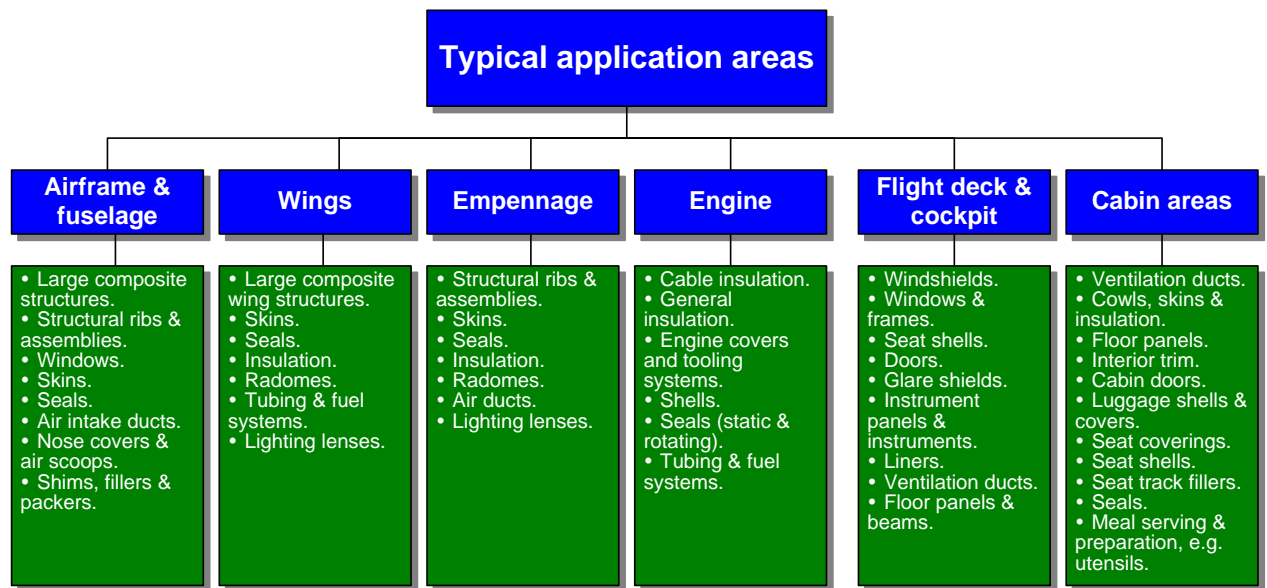


Figure 3: Typical application areas for plastics in the aerospace industry

These applications are common for most of the typical market sectors.

Plastics used in aerospace

Thermoplastics

Unreinforced and reinforced thermoplastics are used extensively in all areas of the aerospace industry, but in most cases, the majority of plastics used in aerospace applications can be classified as engineering or “performance plastics. The use of commodity plastics is limited in aerospace applications (see the previous Zeus Newsletter on “The Periodic Table of Thermoplastics” for the definition of the various types of plastics).

Figure 4 lists some of the major thermoplastics used in aerospace applications. These can be used as either unreinforced or reinforced, but are almost invariably engineering plastics.

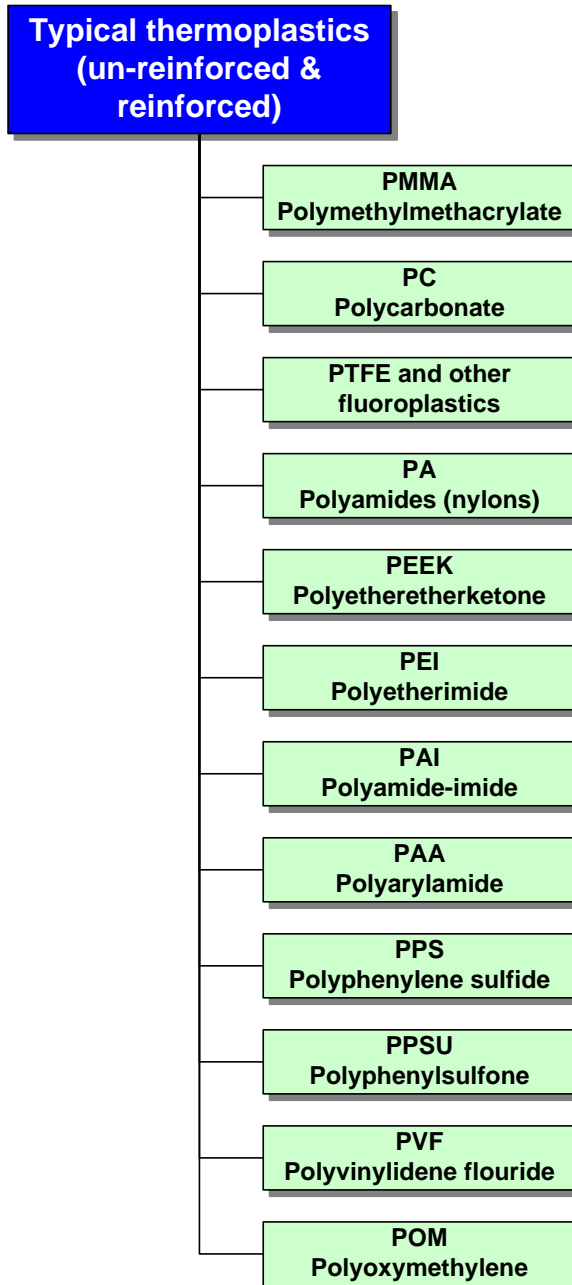


Figure 4: Typical thermoplastics (reinforced and un-reinforced) used in the aerospace industry

In some cases, the development of performance plastics has actually led to a substitution of high-strength composites with fiber reinforced thermoplastics. Thermoplastics can reduce the labor intensive fabrication of composites while achieving the required mechanical performance and the demanding flame, smoke and toxicity requirements (FST) of the aerospace industry.

Composites - Reinforced plastics

The major use of plastics in aerospace applications is in the area of high strength composites. These high-strength composites are produced using a wide variety of fibers, resin systems, and production methods. The actual choice of composite system and production method depends on the specific application. High-strength and high-heat resistance composites are

used for fuselage sections, stabilizers, ceiling beams and skin sections. Some of the fibers and matrix materials used are shown in Figure 5.

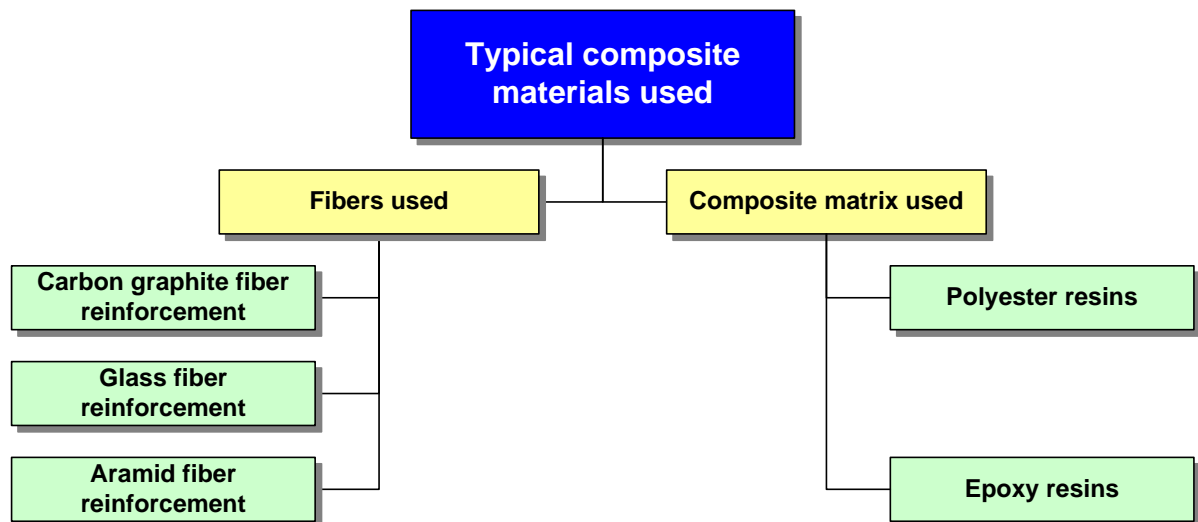


Figure 5: Typical composite materials plastics used in the aerospace industry

Composites are used extensively in the Boeing Dreamliner and Airbus 380 where they account for a large proportion of the weight of the aircraft. However the use is not restricted to commercial aircraft and is also used for military aircraft, and business jets. Composites are predicted to play a major part in space applications due to the weight reduction potential.

Potential concerns

Fire, smoke and toxicity

One of the main issues for plastics in aerospace is the area of the response to fire. This is not a simple flammability issue, but is a combined issue of flame, smoke, and toxicity (FST). Compliance with FST regulations is mandatory and one of the key issues in the use of plastics. Engineering plastics generally have better FST response than the commodity plastics and this is one reason why most plastics in aerospace applications are engineering plastics.

Fracture and failure issues

The very stiffness of composite materials is also a concern to aircraft designers. High-strength composites can suffer invisible damage due to impact that can affect their long-term performance. Materials designers have developed composites that yield to reduce impact damage and also act to prevent any potential cracks from spreading.

Recycling

Almost all of the materials used in aerospace can be easily recycled using currently available technology. However, for composite materials, the recycling technologies are still new and developing rapidly. One of the most promising technologies is the use of pyrolysis, high temperature processing without the presence of oxygen. Pyrolysis of composites leads to the formation of:

- Gases: these can be used as a process fuel.

- Oils and waxes: these can be further recycled and processed into various chemicals.
- Char and other products: these consist of a basic char material, the fillers, and also the fibers used in the composite. The fibers produced can be recycled to produce new composite materials.

Pyrolysis offers an opportunity to take waste composite materials and to recycle these into valuable feedstock for new composite materials.

Standards in aerospace

The aerospace industry makes extremely high demands on any component in terms of both quality and performance. This is reflected in the plethora of performance standards generated for plastics. Some of these are external” in that they are generated by standards or other organizations for general use, but many are “internal,” which means they apply only to a specific company’s requirements. Companies such as Airbus, Boeing, General Dynamics, and Bell Helicopters have all developed internal standards for plastics performance and while these are similar in many respects, they often differ in vital areas.

The aerospace industry uses several overall quality management standards (ISO 9001:2000 and the aerospace specific AS 9100B) for the quality systems. Mechanical performance standards dominate in many areas, such as structural components for airframe and assemblies. Whereas, the performance standards for internal (cabin) applications set demanding requirements for flame retardant properties, smoke gas density, and toxicity.

Future applications of plastics in aerospace

Nanocomposites

Nanocomposites offer huge benefits for plastics in aerospace and the potential in this area is only recently being explored. Nanotechnology has exciting potential in areas as diverse as:

- Lighter and stronger materials – nanotechnology has the potential to increase strength and heat resistance in both conventional thermoplastics and composites.
- Self-clean coatings – nanotechnology can be used to produce self-cleaning coatings for flight surfaces to reduce drag and improve fuel efficiency. Similar technology can be used for easy clean fabrics and materials for interior trim.
- Abrasion resistant coatings – aerospace glazing can suffer from abrasion during use and nanotechnology can produce abrasion resistant coatings to prolong life and visibility.

Light weight remotes

The growing use of remote controlled surveillance craft has been enabled by the ability of plastics materials to reduce weight and to increase flight times. This is a relatively new area for aerospace and the use of plastics has been an enabling technology for this area.

Rapid manufacturing

The limited numbers of products required in aerospace applications makes tooling costs a major element of the total cost of production. Rapid manufacturing techniques are now being developed for the production, not simply of prototypes, but also for the series production of parts. Rapid manufacturing allows rapid testing and development to achieve the best design for virtually non-existent tooling costs.

Summary

The recent media coverage of the launch of the 787 Dreamliner might encourage some to think that plastics are new to the aerospace industry, but the reality is that plastics, in their myriad shapes and forms, have always been an essential element in the development of the industry. Plastics are one of the classic enabling technologies and as the capabilities of plastics and the processes expand, so do the uses of plastics in aerospace.

How Zeus Can Help

Capitalizing on more than 40 years of polymer experience, Zeus continues to focus on producing the highest quality products that meet or exceed industry standards. We are committed to continuous improvement and our AS9100 certification better aligns our products with the aerospace industry. Zeus' products can be found in applications where materials are exposed to critical environments in aviation programs worldwide. Our spiral wrap, convoluted tubing, and heat shrink products are widely used in wire harness applications. Zeus Sub-Lite-Wall® (~0.002") heat shrink offers seamless coverings to composite forming mandrels or bladders that expand with heat and pressure for composite manufacturing aids. Our portfolio also includes products that are ideal for fiber optic, hydraulic, wire coating, and sealing applications.

With a technical inside and outside sales force backed up with engineering and polymer experts, Zeus is prepared to assist in material selection and can provide product samples for evaluation. A dedicated R&D department staffed with PHD polymer chemists and supported by a world-class analytical lab allows Zeus an unparalleled position in polymer development and customization.

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The *Zeus Polymer Minute*

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