Look To Aerospace For The Materials Of Tomorrow

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Aerospace is a great industry to monitor for trends: What developments today might we be able to translate into innovations in other industries tomorrow, especially those involving materials?

One material trend that is revolutionizing the aerospace industry in terms of reducing vehicle weight and achieving fuel savings is especially interesting. Just look at the evolution of lightweight plastic and composite materials in commercial aerospace vehicles.

- In 1982, 8 percent of the Airbus A130 consisted of composites.
- Twenty years later, the use of composites in the Airbus A380 rose to 25 percent.
- In the next generation of aircrafts — Airbus A350 will be 53 percent composite and Boeing 787 will be more than 50 percent composite.

As a material supplier, Ticona has helped this exciting material revolution unfold. We've worked with various customers for more than a decade on the development of applications that use Fortron polyphenylene sulfide (PPS) as a composite matrix, starting with the Airbus series in early 2000.

Composites are conquering traditional metal domains throughout the aircraft. They’ve reached such an advanced stage of development that some complex components would actually be impossible to produce in metal. Even if these parts

could be made in metal, the costs would be prohibitive.

Today, the vast majority of composite materials for aerospace are based on thermoset materials, especially in the United States. However, thermoplastic composites have several key advantages over thermoset composites. They have been used for several years in Europe. Some thermoplastic composite parts include the fixed wing leading edge, keel beams and other components.

For the most part, though, exterior aerospace components in Europe are based on thermoset composites, and in the United States there is yet to be one thermoplastic based composite in large commercial aircraft exterior structures.

The focus on thermosets by the commercial aerospace composites industry exists for a number of reasons:

- Thermoset composites have a successful track record dating back to the '60s, making the knowledge database very mature.
- Substantial investments in thermoset composites have been made in the United States for design tools, material property databases, capital equipment, employee training and test methodologies — making a mature material value chain.
- Conversion to alternate materials and processes require substantial reinvestment and requalification costs as well as retraining of engineering and manufacturing personnel.

Since thermoset composite processes and materials are mature, cost and weight reduction associated with design optimizations are less likely to continue. As a result, it becomes difficult to meet the needs of an evolving aerospace environment with fixed structural costs.

Reinforced thermoplastic composites offer the aerospace industry opportunities to achieve weight and cost savings as well as a green solution vs. thermosets.

Thermoplastic vs. Thermoset

A rational justification can be made for using higher-cost thermoplastic composites instead of thermoset composites in aerospace applications.

From a material side, thermosets are cross-linked when heated and cannot be re-melted or re-formed, while thermoplastics are melt processable polymers that provide a more tailorable and more forgiving process.

For example, thermoplastics are heated, melted or softened, reshaped, and then cooled to a final hardened shaped, making them easy to re-work and repair. Thermoset cure also takes time, sometimes hours, while thermoplastic heating to melt takes a fraction of the comparable time and energy.

The raw materials in thermoplastics also have a near infinite shelf life and cost less

to store than thermosets, which have a typical shelf life of less than six months and require costly refrigeration, tight schedule control of material receipt and conversion to final form.

In addition, thermoplastics:

- Are typically four-times tougher than comparable thermosets, which results in more impact resistance and damage tolerance.
- Are relatively insensitive to aircraft fluids and chemical attack, and, with one exception, insensitive to moisture.
- Offer substantial reductions in flammability, smoke and toxicity performance, which is of major importance in interior components for man-rated aircraft.

From a processing standpoint, some of the existing and expensive equipment used by the industry to process thermoset composites, such as autoclaves, could be used for thermoplastic processing. However, the relatively slow and inefficient process times required for heat up and cool down would reduce process and cost efficiency options associated with thermoplastics.

Typically, thermoplastics are heated, formed and cooled rapidly, while thermosets must be held at temperature for tens of minutes or hours to achieve cure. The net result is a significant savings in process energy cost for thermoplastic composites.

Thermoplastic processes also eliminate material bagging as well as in-line consolidation techniques, kitting and debulking steps and equipment.

The shop floor space, equipment costs, tooling costs, and labor costs for all of these auxiliary processes are eliminated with a conversion from thermosets to thermoplastics.

Thermoplastics and their associated processing innovations eliminate the need for autoclave processing, which in turn reduces capital cost, floor space requirements and processing bottleneck issues.

As a green solution, the processing of thermoplastics vs. thermosets cannot be overstated. Thermoplastics can, by definition, be fully recycled, and little to no volatile organic compounds (VOCs) are released during processing.

Process scrap can also be reduced substantially with existing fiber placement technology. Based on the reduced cycle time at temperature, the process energy used for thermoplastic composites is a fraction of the comparable process energy for thermoset composites, resulting in a lower carbon footprint.

Three thermoplastics are available for use by the aerospace industry:

Polyether Ether Ketone (PEEK)

The best known and most important representative high-temperature-resistant thermoplastics — melting point is 335°C (635°F) — are PEEKs.

Applied in the industry for more than 20 years, it offers the most extensive commercially available data, and is considered the baseline for aerospace grade thermoplastic composites.

PEEKs are resistant to virtually all organic and inorganic chemicals. They are also resistant to hydrolysis up to about 280°C (536°F). On the other hand, they are not resistant to ultra-violet (UV) radiation, concentrated nitric acid, general acid-oxidizing conditions and some halogenated hydrocarbons. There are several suppliers of PEEK resin in the industry but it is one of the most expensive engineering plastics.

Polyetherimide (PEI**)**

This high-performance thermoplastic belongs to the high-temperature-resistant plastics group — up to about 200°C (392°F).

It is inherently flame-retardant with low smoke development. It is used as a composite matrix in numerous aircraft interior structures, including floor panels, pressure bulkheads, and other components. Unfortunately, PEI is susceptible to attack by anti-icing fluids, which prevents extensive use in aircraft exterior applications.

Even in the unreinforced state, it has very high strength, which can be further increased by the addition of glass or carbon fibers. PEI has high dielectric strength, is resistant to hydrolysis and very resistant to UV and gamma rays.

Polyphenylene Sulfide (PPS)

This polymer is by far the lowest cost of the three thermoplastics available for use by the aerospace industry. Successful application of PPS composites in aircraft include the undercarriage door for the Fokker 50, fixed wing leading edges for the Airbus A340 and A380, keel beams, brackets and others.

Not only is this high-performance thermoplastic extremely strong, rigid and tough, it offers inherent flame resistance, high heat resistance with continuous service at temperatures well above 200°C (392°F).

It also has very good chemical and oxidation resistance, minimal water absorption, good electrical properties, low creep and excellent mechanical properties. Dynamic creep compliance characterization of the semi-crystalline PPS shows comparable structural performance to the higher temperature amorphous polyether imide. Linear PPS is the preferred matrix approach, since it is much tougher than the branched form of the polymer.

These three candidate resins are finding increased use in commercial aerospace applications. While the long-term investment into the higher performance PEEK

material has resulted in a good database and flight history of the material, investments continue to be made in the both the PEI and PPS databases and processes, which is leading to their increased use as their cost effectiveness becomes documented.

As these resins receive more industry acceptance, the cost reduction curves for all composite materials is expected to improve.

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For Ticona technical papers and more information about Fortron PPS for thermoplastic composites, visit http://www.ticona.com/composites *[1].*

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