

## Lightweights flex their muscle

The low weight of fiber composites combined with their very high strength and stiffness is making them the material of choice for more and more demanding light-weight design applications – in aeronautics, the automotive industry, construction, piping and even sports equipment.



Production of the wing leading edge nose assemblies of the Airbus A380 at Stork Fokker in the Netherlands. The composite sheets are made from carbon fibers and Fortron® PPS from Ticona.

Nature has perfected the art of lightweight construction for millions of years. Every honeycomb, every bone is stiff and strong and located precisely – and exclusively – where the load is high. Areas that bear lighter loads are all trimmed consistently to reduce weight. Material and component developers have long recognized nature as an ideal teacher. They have very successfully emulated nature's designs for many years now, in order to satisfy the most demanding applications with a minimum of raw material. One means of achieving this is through fiber composites – or "composites" for short – where fibers made of glass or carbon are embedded in a thermoplastic matrix. Composites are stiffer and stronger than nonreinforced plastics. They offer a weight advantage of up to 25 percent over aluminum – and up to 60 percent over steel. The interest in composites is correspondingly high in all industries where weight is a critical factor – especially in aeronautics.

Along with low weight and reasonable raw materials costs, two further aspects are of key importance to industry in the replacement of established metallic or thermoset materials: rational processing and broad design latitude. Ticona has a very wide range of products to offer here, ranging from Fortron® PPS as basic material, Celstran® LFRT pellets or Celstran® LFRT composites in the form of tapes and semi-finished products. They can be combined with virtually any polymer (e.g. PP, PA or ABS) as a matrix material and with a variety of reinforcement fibers (glass, aramid, carbon, etc.).

### **Celstran® LFRT: Thermoplastic composites**

Celstran® LFRT long-fiber-reinforced pellets provide impressive results, not only with their specific technical properties, but also with short cycle times and broad design latitude – using established processing techniques. Moreover, so-called "tapes" (unidirectionally reinforced semi-finished products) are in increasing demand among processors: available in a variety of standard sizes as well as

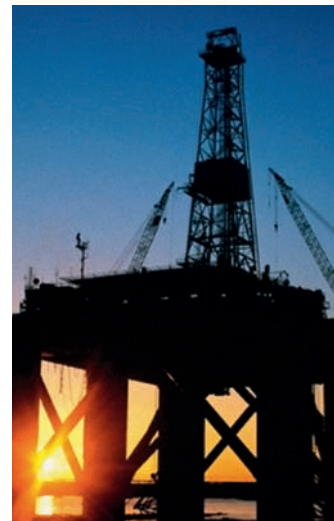
customized dimensions, tapes based on different polymers and reinforcement fibers can also be processed easily and particularly cost-efficiently. Ticona's latest customer-friendly semi-finished products are rods developed especially for metal replacement applications.

### **Lightweight construction in many fields**

The advantages of composites are readily apparent – not only in the air, but also on the ground: in automotive construction, fiber-reinforced Celstran® LFRT grades from Ticona are used for different structural components such as instrument panels and door modules.

In bridge construction, the low weight of composites permits the prefabrication of very large components, which can be installed subsequently at the construction site. Load-bearing assemblies made of composites are perfectly able to compete with concrete or steel bridges: depending on fiber content, their strength in the direction of the fibers is comparable to that of steel. Unlike traditional materials such as steel, reinforced concrete or wood, they neither corrode nor weather, thereby guaranteeing long service life and low maintenance costs.

Fiber-reinforced plastics are also suitable for use in wind turbines, shipbuilding and piping systems. With their excellent processing characteristics, short cycle times and low creep, they are the material of choice for use in the fabrication of rotor blades for wind turbines, for example. In addition, components such as these have a long service life – after which they can also be easily recycled. Fiber-reinforced Celstran® LFRT can be used as a substitute for metal and metal alloys in the production of pipes for flowlines, pressure lines and underwater pipelines: In oil and gas production, piping systems made of PPS also offer significant advantages over metal pipes. With aramid reinforcement, for example, they are up to 90 percent lighter than metal, permit rapid, inexpensive installation and prevent paraffin build-up.



Pipes made of Celstran® LFRT composites offer high strength and require little maintenance.

Composites dampen vibrations better than steel and concrete, and their corrosion resistance lowers operating costs in the construction of bridges and buildings.



That's why pressure losses are up to 50 percent lower, which means piping with smaller diameter can be used. In sum, the greatest possible efficiency in terms of performance and costs – from installation right through to maintenance.

Today composites are even used in sports equipment. A leading manufacturer of golf clubs, for example, is marketing three new models with shafts made of carbon-fiber-reinforced Fortron® PPS. This composite increases the stability of the golf club on impact and improves energy transmission, thereby optimizing precision and range. With their wide range of extraordinary property profiles, composites made from Ticona polymers give the start signal for the cost-efficient implementation of many demanding lightweight structural design solutions.

### Fortron® PPS – proven in the aeronautics industry

Composites based on the polyphenylene sulfide Fortron® PPS from Ticona are already commonplace in aircraft construction. Inherently flame-retardant, this thermoplastic combines high hardness and impact strength with excellent resistance to heat, chemicals and fuels. It maintains its properties across a very broad range of temperatures – from minus 40°C to plus 240°C. Ideally suited for subsequent thermoforming and welding processes, these composites consist of alternating layers of Fortron® PPS films and carbon fiber mats, which have been baked into an inseparable sandwich in an autoclave.

Current aircraft applications include the large area profile components of the wing leading edge nose assemblies for the Airbus A380 jumbo airliner and the A340-500/600 series. With a length of

26 meters, the wing leading edge nose assembly of the A380 weighs just 200 kilograms – about 20 percent less than a comparable assembly made of aluminum. Moreover, the design latitude that resulted from conversion to composite construction made an entirely new forming technique possible: the new 'J nose' is more aerodynamic than the conventional 'D nose' made of aluminum and also leaves room to house electrical cables, de-icing systems and other equipment.

### Will composites soon make up half of all parts?

A total of more than 1,000 separate parts used in the Airbus A380 are made of PPS composites. Integrated into seat backrests, the new type of lumbar support made of Fortron® PPS weighs all of 150 grams. "A comparable support made of aluminum would weight nearly twice as much," says Peter Radden, Technical Marketing Manager Composites at Ticona.

"With 555 seats in all, that amounts to a weight savings of 72 kilograms." For airlines that want to reduce fuel consumption, extend carrying capacity and range, and ensure economical operation, every kilogram truly does count – even in a large, heavy commercial jetliner that weights about 550 tons at takeoff.



Fortron® PPS makes it possible to reduce weight economically with these seats too.

# Aircraft manufacture

## Major breakthrough for PPS composites

Gulfstream G650: Fortron® PPS composites used in primary structural aircraft components for the first time

Arnt Offringa smiles. For good reason. Stork Fokker has written another chapter in its 90-year history and the evolution of aircraft manufacturing. In an interview with "inform", the R&D director takes a look at the most recent successes and explains what developments may be expected in future. In his view, thermoplastic composites and innovative technologies will be at the cutting edge of these advances.



*Thanks to high-performance composites in the form of prepregs and new welding methods, we can produce large, strong, homogeneous structural components without the usual additional costs for drilling and riveting work.*

**Inform: The new business jet from Gulfstream, the G650, recently completed its first flight. Can you briefly describe what part Fokker has played in this?**

A. Offringa: Among other things, we developed the G650's rudder and elevator. When it flew for the first time on November 25, 2009, the event marked the maiden flight of the world's first aircraft to rely on PPS thermoplastic composites for these control surfaces. This is a very major breakthrough in the aircraft industry. Until now, those assemblies had been made from a combination of thermosets and metal.

**Inform: Why are aircraft manufacturers using the new material combination instead of thermosets?**

A. Offringa: There are two key reasons for using thermoplastic composites. Firstly, they save time and handling costs in production, because they eliminate the very labor-intensive riveting and bonding operations required in individual component assembly. The second advantage of thermoplastic composites – which, in the case of the G650, are based on Fortron PPS polyphenylene sulfide – is that they can be used to produce large profile sections that are some 20 per cent lighter than those made from conventional materials such as metal and light alloys. All manufacturers today want to and must design lighter aircraft to cut fuel consumption per passenger.

**Inform: Thermoplastic composites have been used for quite some time in aircraft construction. What have been the important milestones in your opinion?**

A. Offringa: These composite materials have been used since the mid-1980s, although only in very small quantities at first. The material primarily employed in those early days was a carbon fiber-PEEK (polyetherether ketone) composite. Dassault and Airbus used it, for example, in the vertical fin. At the end of the 1980s, PEI composites, i.e. polyetherimide, also arrived on the scene. They were used in applications such as floor panels inside the Airbus "Beluga" super



With the Gulfstream G650, aircraft control surfaces made of thermoplastic composites will take off for the first time in the history of aircraft construction. Aircraft manufacturer Stork Fokker uses Fortron® PPS to manufacture the rudder and elevator of the new business jet from Gulfstream Aerospace.

transporter and in aircraft manufactured by Fokker and Dornier. And in 1995, Gulfstream brought out an aircraft that relied on a carbon fiber-PEI composite in primary structural components.

### **Inform: And when did the first aircraft fly containing a carbon fiber-PPS composite?**

A. Offringa: That was the Fokker 50 in about 1997. It had a landing gear door made from PPS composites. But this had been preceded by discussions since 1992/93 between TenCate Advanced Composites, the Technical University of Delft in the Netherlands and Ticona. At about the same time, the developments that would later lead to the new wing leading edge nose on the A340 500/600 started at Airbus in the UK. Profile sections based on composites from TenCate and Fokker made it possible to design a new wing leading edge nose shape, the "J nose". This has several advantages over the old "D nose" shape produced from aluminum. The components are reinforced with curved ribs made from PPS-carbon fiber composites in a way that makes them exceptionally stiff in the direction of flight but able to accommodate wing vibrations in the transverse direction. In addition, the "J nose" is aerodynamically shaped and designed to house electric cables, deicing equipment and other systems. Instead of the usual five aluminum components, only two structural elements are now required for the wing leading edge nose.

### **Inform: What was the next crucial step?**

A. Offringa: The next great milestone without any doubt was the A380, the largest passenger plane today. Around 25 percent of the aircraft structure and components are produced from composites. And in the next generation of aircraft, the content of composites will double. For example, the A350 is expected

to take off for the first time in 2011 with over 50 percent of its total weight made up of fiber-reinforced composite materials. And also in the Dreamliner, the Boeing 787, which is due to make its maiden flight in 2009, half of the components are produced from composite materials. A measure of the trust now placed in lightweight structures can be seen in the advance orders: over 860 for the Dreamliner and nearly 500 for the A350.

### **Inform: What has driven this development over the past years?**

A. Offringa: This rapid development has been driven by the significant advances made in technologies and materials but also, of course, by economic and ecological pressures. Metals such as aluminum weigh more and, as I have already said, are more costly to process.

### **Inform: How then are these large profile sections produced from thermoplastic composites?**

A. Offringa: PPS composites (so-called prepregs) are produced from Fortron® films, PPS matrix material and reinforcing fibers at a temperature of about 300°C under high pressure. Specialized suppliers to the aircraft industry such as Ten Cate or also Airbus itself manufacture ribs, stiffeners and other elements from the prepregs. The individual components are welded together to form a strong, inseparable unit. This process eliminates the need for costly drilling and riveting operations and achieves higher strength and safety – while at the same time reducing weight. It also saves time and money.

**Inform: In the Gulfstream 650, you are going a step further because here thermoplastic composites are being used in exterior primary structural aircraft components. Does a new technology or material lie behind this?**

A. Offringa: New technology, yes, new material, no. Because of its specially suitable property profile, Fortron PPS is the only thermoplastic, apart from PEI, PEKK and PEEK to be approved for aircraft composite structures by the US Federal Aviation Authority and other national authorities. Components made from PPS composites remain hard, impact-resistant, stiff and dimensionally stable, even when exposed to temperature variations of more than 100°C. Fortron® PPS is also resistant to aggressive media such as aviation fuel, engine and hydraulic oils, solvents and antifreezes. With its inherent flame retardancy, the material also meets the very high safety standards

example, to weld PPS ribs to large, flat PPS components. Now we have moved forward another step and the relevant components are in serial production.

**Inform: Is this another reason for the surge in the use of fiber-reinforced thermoplastics in aircraft construction and does it even spell the end for aluminum? Which material will win out your opinion?**

A. Offringa: Aluminum will certainly have to give an enormous amount of ground. But in the near future, it will not disappear completely – even though Bombardier, for example, has developed an all-composites fuselage structure for the Learjet LJ85. Tape technology has a future as a production process simply because it offers important advantages. In this technology, long tapes are ultrasonically compressed and shaped. Other parts can be directly joined to the tapes in a fully automated process. Once again, this saves



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specified by the aircraft industry, such as the FST (fire, smoke and toxicity) requirements.

**Inform: So essentially something has changed in the technology or processing ...**

A. Offringa: That's right! The PPS components for the rudder and elevator of the Gulfstream 650 are produced using a welding method that is new to aircraft construction, known as induction welding, which has been developed by the Dutch KVE Composites Group. In simple terms, this is a very precise welding method, in which the components are only welded at the points where it is necessary. This method is used, for

time. For this reason, this is the technology of the future in my opinion. In terms of materials, however, there will probably still be some departure from the present route. I am firmly convinced that the future lies "between" the properties of PPS and PEEK. Although it is an excellent material, PPS comes up against certain limits here and there. PEEK is a very good but also very expensive material with a very high melting point in an autoclave. If we could succeed in producing a combination that exploited the advantages of both materials, we would have the perfect basis for new tapes.

**Inform: Have you set up special research or partner programs to help translate the increasing but very complex know-how surrounding lightweight construction from theory to practice in a quicker and more targeted way?**

A. Offringa: We are conducting research in many directions. But we cannot cover or take forward everything on our own. We are therefore cooperating, for example, with Boeing, TenCate Advanced Composites and the University of Twente in the Netherlands. We plan to establish a "Thermoplastic Composites Research Center (TPRC)" to accelerate innovations based on affordable, lightweight, eco-friendly thermoplastic composite technologies. And Airbus, too, is working in this area with the Dutch aircraft industry and therefore with us under the auspices of TAPAS, the "Thermoplastic Affordable Primary Aircraft Structure" project. This does not mean, of course, that all knowledge is thrown into one pot and mixed up. A couple of secrets remain because our aircraft manufacturing competitors are also pushing ahead with innovations and lightweight construction, so we are all eagerly awaiting future developments.

**Inform: Can you reveal to us nevertheless what new things the near future might bring in aircraft construction?**

A. Offringa: It is certainly no secret any more to say that not only in the new A350 fuselage brackets but also in the new military transport plane from Airbus Military, the A400m, the fuselage ice protection plates are to be produced from this material. The horizontal tail is also in the development engineers' sights.

All in all, and this is not just my opinion, the future lies in the production of thermoplastic composites by the new tape technology I have already mentioned. This will allow more compact design and require less material, so that further considerable weight reductions can be achieved. In addition, tape technology will open up whole new design opportunities. For example, large structural components can be produced more cost-effectively.

**Inform: Will these developments exhaust the future of thermoplastic composites?**

A. Offringa: By no means. Then we can really take off in the aircraft industry and develop far more than the 1000 structural and non-structural interior and exterior parts installed on the A380, for example. Our designers' eyes light up at the very thought, as no doubt do those of the material manufacturers, to whom rosy times will certainly come. And, of course, there are other industry sectors that benefit from good lightweight construction materials. And I'm not thinking just of the automotive industry here. For wind farms, trains, buses or trucks, high-performance composites are also the lightweight material of choice.

**Inform: Thank you very much for the interview.**

The interview with Arnt Offringa was conducted by Henning Küll, Communications Manager Europe, Ticona.

**Further links**

- ▶ [www.airbus.com](http://www.airbus.com)
- ▶ [www.fokker.com](http://www.fokker.com)
- ▶ [www.gulfstream.com](http://www.gulfstream.com)
- ▶ [www.kve.nl](http://www.kve.nl)
- ▶ [www.tencate.com](http://www.tencate.com)

Delivery of the first Gulfstream G650 is currently scheduled for 2012. It logged its maiden flight in late November 2009.





Fortron® PPS is an ideal high-tech thermoplastic for production with short cycle times. PPS is recyclable and consumes relatively little energy during processing.

## PEEK

Polyether ketones (PEK) are high-temperature-resistant thermoplastics. The best known and most important representative of this group is polyetherether ketone (PEEK). Its melting point is 335 °C.

Polyether ketones are resistant to virtually all organic and inorganic chemicals. They are also resistant to hydrolysis up to about 280 °C. On the other hand, they are not resistant to UV radiation, concentrated nitric acid, general acid-oxidizing conditions and some halogenated hydrocarbons. With a typical price per kilo for prepregs of about 350 € (April 2009), PEEK is one of the most expensive engineering plastics.

## PEI

Polyetherimide (PEI) is a high-performance thermoplastic belonging to the high-temperature-resistant plastics group (up to about 200 °C).

Polyetherimide is inherently flame-retardant with low smoke development. 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.

## Fortron® PPS

Specific properties of polyphenylene sulfide and its compounds: inherent flame retardancy, excellent hardness, stiffness and dimensional stability, high heat resistance with continuous service temperatures of up to 240 °C, very good chemical and oxidation resistance, minimal water absorption, good electrical properties, low creep and excellent mechanical properties.



Braided cable sleeves made of Fortron® PPS are used in many applications in aircraft construction.