Recyclable pultruded thermoplastic composites profiles

Frank Chauzu,
Founder and CEO,
CQFD Composites

Thermoplastic composites and pultrusion have long faced technical challenges due to high melt viscosity, limiting their mass adoption. However, increased R&D and innovations in materials and processes are overcoming these barriers. Emerging reactive approaches, such as A-PA6, PMMA, PA11 and PPA resins, are poised to be game changers in the composite industry, enhancing recyclability and processability.

With thermoplastics, the key challenge is fibres impregnation due to the high viscosity of molten polymers, especially in thick profiles. To overcome this, CQFD Composites pioneered the "reactive thermoplastic approach" (or "in situ pultrusion"), using activated monomers instead of polymers. Monomers, with water-like viscosity, enable efficient fibres impregnation with low porosity (<2%). This process allows caprolactam polymerisation into polyamide 6 (nylon) while shaping the profile in just 2-3 min.

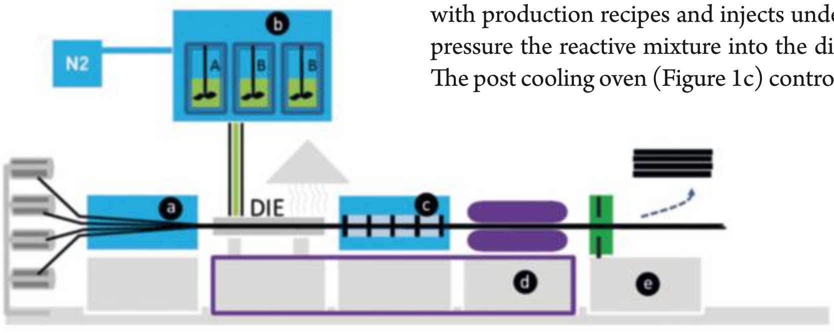

Fig. 1: Typical layout of CQFD Composites reactive thermoplastic pultrusion line

Compared to thermoset installations, 4 different types of equipment can be reported on CQFD Composites' typical pultrusion lines. The fibre oven (Figure 1a) is used to dry the fibres and get rid of the maximum humidity existing at the surface of the fibres before entering the pultrusion die. Dry fibres are introduced into the injection chamber of the die and impregnated under pressure with a reactive mixture of monomers and catalytic system. Well-adjusted dimensions are necessary to control and prevent any back flow of the resin which would turn into resin losses. The dosing (Figure 1b) unit runs under temperature up to 140°C, melts down the caprolactam and other reactive ingredients. It operates an automatic precise dosing and mixing in accordance with production recipes and injects under pressure the reactive mixture into the die. The post cooling oven (Figure 1c) controls the crystallinity of the PA6 polymer and allows reproducible properties.

These extra investments, when compared to traditional polyester/vinyl ester pultrusion, can be perceived as a drawback. In fact, A-PA6 reactive thermoplastic pultrusion of caprolactam forces the traditional pultrusion process to become fully automatised and thus fully repeatable and monitored. With such equipment, the resin is no longer used in open baths which usually raises issues related to viscosity evolution, vapours and cleaning. There is no more need for the bath cleaning operation, which requires acetone or similar solvents after a stop. For example, CQFD Composites' process only needs a few minutes to clean the die with a purge system that consumes less than half a litre of the purge liquid.

Recyclable and low carbon composite

A-PA6 reactive thermoplastic pultrusion can bring end-users several key advantages: a high stiffness and strength, a very low carbon footprint, a full recyclability and a long lasting and fibre free surface.

The A-PA6 composite profiles comply with the mechanical requirements of the EN 13 706 pultrusion standard and can

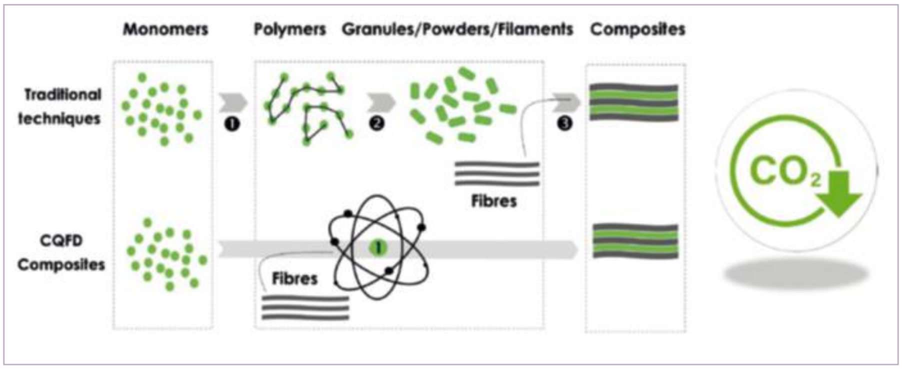

Fig. 2: Comparison between traditional thermoplastic composite processes and CQFD Composites technology

exceed them when necessary. Modulus of 60 GPa with glass fibres and 150 GPa with large tow carbon fibres are achievable in dry conditions and against all odds when using PA6, will remain as such in presence of humidity. Indeed, with specific process conditions, CQFD Composites has observed that the E modulus in traction and in flexion is almost not affected by humidity. This is an excellent news for all applications governed and designed by stiffness. And this is the case for most constructions using composite materials.

Using monomers cuts down the CO_2 emission. A-PA6 is usually accounted for around 6 to 8 kg eq CO_2/kg when a caprolactam accounts for only 3 kg eq CO_2/kg or less. And when the process allows to only use 15% of organic matrix, in only one single transformation step (Figure 2), then the final CO_2 emissions are significantly reduced compared to other thermoplastic composites solutions obtained by traditional ways (powder impregnation, stacking of polymer films, comingled, etc). For info, a nylon filament could account for more than 10 kg/CO_2. The great thing about the A-PA6 pultruded profiles is that they can be 100% recycled with existing technologies and turned down into fibre-reinforced granules (or other semi-products like plates) valuable for the whole injection and extrusion industries. No need to work on separating the fibres from the resin. In a first approach, it shows that Pultruded Recycled Granules (PRG) can be easily reused by injection moulding to create a new product with improved mechanical properties: 5 times the stiffness and 2 to 3 times the breaking strength of the virgin polymer.

With a first trial in 2009, CQFD Composites has been working on the development of surface treatments and polymer formulations to implement different thermoplastic online coatings. Plastic coatings can be offered as a less expensive and more ecological way to add: colour, choc or abrasion protection, UV protection, water repellent behaviour, improved chemical resistance or guaranty of a fibre free surface over time. To qualify the coating, intensive tests are internally carried out in accelerated ageing conditions in climatic and QUV chambers: 2,000 h under UV exposure and 3,000 h in climatic chamber, with heat and humidity, up to respectively 80°C and 85% are applied. A 10 h boiling test is added to finalise the test campaign.

To illustrate the surface ageing behaviour of the thermoplastic pultruded profiles, CQFD Composites compared 3 samples (Figure 3): samples A and B are 2 different online coated profiles, and D is a regular non treated polyester profile. None of the thermoplastic profiles have fibres on their surface after 2,000 h in QUV chamber when the polyester sample starts to exhibit visible and free fibres only after 500 h.

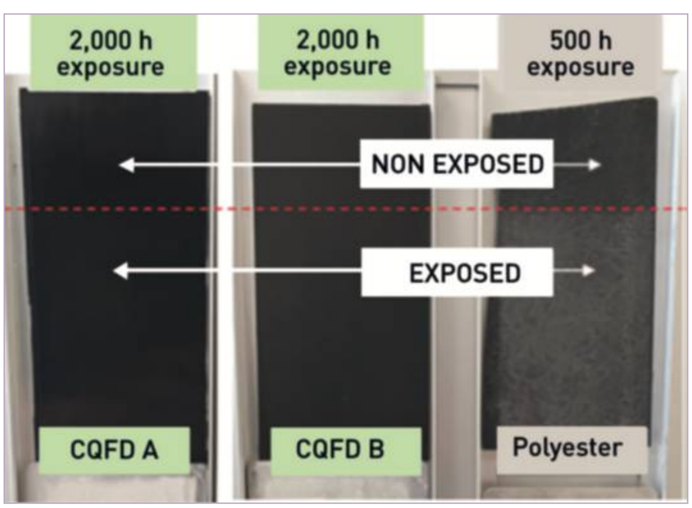

Fig. 3: Surface appearance comparison under UV exposure (TP coated vs uncoated polyester)

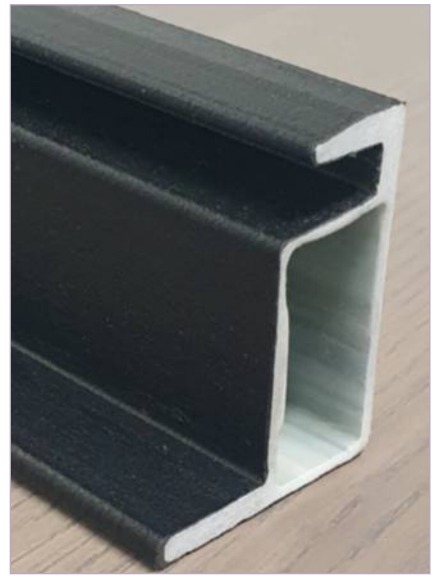

Fig. 4: EcoFrame®, a recyclable thermoplastic composite solar panel frame with UV resistant on line coating

A-PA6 use cases

The versatility of CQFD Composites' A-PA6 reactive thermoplastic pultrusion, based on caprolactam, is demonstrated through the following product examples dedicated to 4 different markets: solar, building, electrical and aeronautic.

EcoFrame® (Figure 4) is a patented low-carbon and 100% recyclable composite solar frame for PV modules. A protection layer is applied online solving many issues related to painting. The profile is 100%

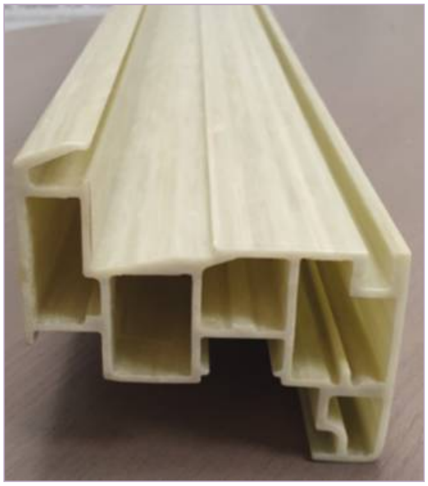

Fig. 5: A-PA6 composite profile for window application

Fig. 7: Curved pultruded thermoplastic profile based on a multi-axial carbon fibre structure combined with a high T° matrix

recyclable, earthing is no longer required, thermal dilatation is reduced and galvanic corrosion is no longer an issue. Injection moulded corner can be obtained from recycled pultruded frame.

The novel composite window profile system was developed under the lead of the Rehau Group with CQFD Composites and the company Anybrid. It was awarded the AVK innovation award in 2024. This window profile uses CQFD Composites' A-PA6 reactive thermoplastic pultrusion with an online thermoplastic surface coating. Figure 5 illustrates the achievable complexity of A-PA6 pultruded profiles. The thermoplastic matrix offers advantages in recycling and simplifies downstream processes. The profiles are joined using the mobile injection moulding technology from Anybrid.

CableBox® (Figure 6) is a patented thermoplastic composite concept that reduces CO_2 emissions compared to traditional metal cable trays. Its patented flat-pack design optimises transport and storage while its minimalist structure, combining A-PA6 pultrusion and injection moulding, cuts weight by 50% and eliminates the need for earthing.

Pultrusion work is part of the Descartes project (Figure 7), led by the Jules Verne French Institute in collaboration with a consortium of key industrial partners (Airbus, Airbus Atlantic, Latécoère, Duqueine, Arkema, CQFD Composites, Cero and Cousin Composites). Based on a patented innovative curved thermoplastic pultrusion process engineered by CQFD Composites, this project is leading to a disruptive technologie to produce fuselage frames in C/PAEK material at low cost and high production rates.

Composites for the future

As more companies take meaningful steps towards environmental protection – limiting CO_2 emissions, integrating full life cycle analysis early in product development and seeking alternatives to high-emission steel or aluminium profiles – the next logical step is the widespread adoption of low-carbon, recyclable thermoplastic composite profiles. With this vision in mind, CQFD Composites is set to expand its presence across multiple markets and plans to launch a fundraising campaign in 2025. □

Fig. 6: CableBox® in its flat space saving configuration

Focus

Various recycling approaches

With the support of Canoe (read p.87), CQFD Composites has carried out recycling work based on the A-PA6/glass pultruded profiles. The process proceeds in 3 basic steps: shredding down the profiles into medium size pieces, grinding down these pieces into smaller sizes (about 10 mm) and using that as a raw material on an extrusion granulation line.

More information:
www.cqfd-composites.com