INNOVATIVE EQUIPMENT CONCEPTS FOR COATING OF COMPOSITE PRODUCTS WITH DUROPLASTIC AND THERMOPLASTIC ADHESIVES

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ABSTRACT

Today the use of coated products for prepregs is growing rapidly. This increasing demand has resulted in the development of new and highly innovative impregnation and coating machinery concepts for prepregs at machinery producers.

1 INTRODUCTION

Composites based on fibre reinforced polymers using prepregs are used in a wide range of industries and applications. The Airbus A 380 (figure 1) contains more than 23 mass-% and the new Airbus A350 more than 53 mass-% of fibre reinforced polymers in the structure. Also the use in windmills (figure 2), in trains and in the automotive sector (e. g. BMW i3) increases. New polymer and fabric developments in these growing industries demand in the development of new and highly innovative impregnation and coating machinery concepts for prepreg machinery producers.

Figure 1. Airbus A380. Photograph: Christian Dreyer.

Figure 2. Windmills in Rhineland-Palatine. Photograph: Christian Dreyer.

2 PREPREGS AND THE COMPOSITE MARKET

The European composites industry represents ~25% [1] of the global composite market and provides materials to numerous end-user sectors, and is valued at >€17.5 billion p.a., with >10,000 companies (>80% SMEs) employing >150,000 people [2]. An amount of 1.04 million tons of glass fibre reinforced polymers (GFRP) was produced 2014 in Europe, according to the AVK Industrievereinigung Verstärkte Kunststoffe e.V. [1]. This was a slight increase of about 2% compared to 2013.

For the emerging market of carbon composites an annual growth of 10.6% is expected (Figure 3). In 2013 72.000 t of Carbon composites were produced, which correspond a turnover of 14.7 Billion US$.

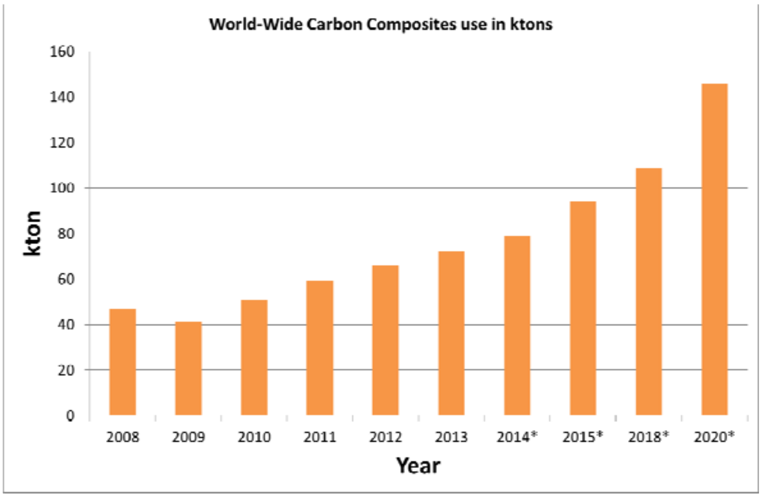

Figure 3. Global demand for carbon composites. Values for years 2014 – 2020 are estimated. Data from [1].

Carbon fibre reinforced polymers have an annual turnover of 9.4 Billion US$ (2013) [1]. The relevance of prepregs for fiber reinforced polymers and lightweight construction is shown in Figure 4. This chart gives an overview of the technologies for production of carbon fibre reinforced polymers (CFRP). Carbon fibers are mainly used for high performance applications. The share of prepregs in these application fields is especially high, because the highest fiber volume contents for FRPs can only be reached with prepreg technology. Prepreg processes are with 37% the second biggest process technology after the pultrusion- and filament winding technologies. This is a slight percental decrease compared to the 2013 value of 40%, but still an absolute increase from 28,8 ktons to 29,3 ktons.

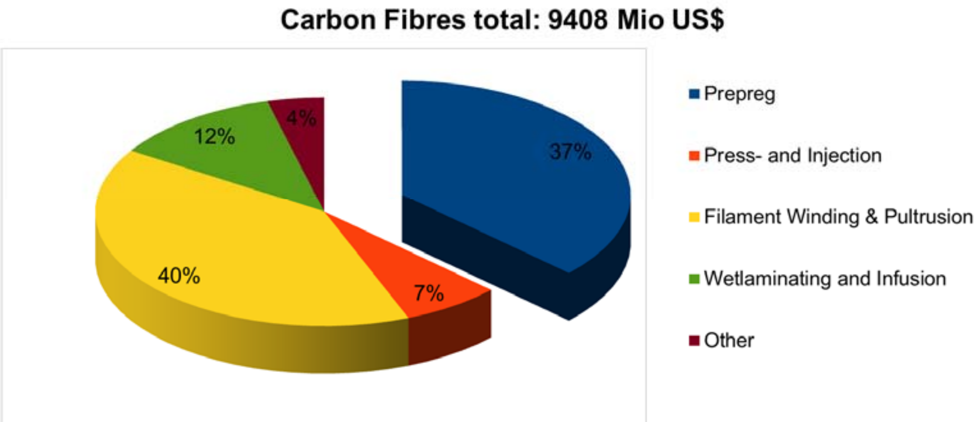

Figure 4. Shares of process-technologies for CFRP. Data from [1].

Aviation accounts for 2% of global man-made CO_2 emissions and with industry figures reporting that a an aircraft saves 34,000 liters of fuel per year for each kg less in weight per seat, this can be a major benefit for operators' in reducing costs to be more competitive or increasing margins. The European Union has included aviation in its Emissions Trading Scheme from 2012, capping emissions at 97% of the average annual 2004-2006 emissions in 2012 and 95% from 2013. If airlines emit more they will have to purchase allowances from other industries that have been more successful in reducing emissions.

Weight saving is of vital importance in cabin interior design to aid in the overarching requirement to reduce fuel burn and help to meet emission targets, and by far, the largest composite applications are sandwich panels made with low density honeycomb cores and thermoset resins/glass fiber skins to increase the panel's stiffness. A typical interior sandwich panel is made up of Nomex® honeycomb core (made from aramid fiber paper supplied by DuPont®) faced with one or two skin plies of glass/phenolic prepreg for most ceilings and walls, and glass/epoxy or carbon/epoxy for floor panels, which require higher tensile strength. The annual prepreg usage for aircraft interiors is estimated at 6,000 tons.

A classical example for use of prepregs in the aircraft interior is the sidewall-panel depicted in figure 5.

Figure 5. Sidewall-panel of an Airbus A320 from the backside. Photo: Fraunhofer PYCO.

3 TYPICAL PROCESS AND LINE LAYOUT

The design of efficient coating technologies and the effective treatment of the fibre materials for Prepreg products present a number of mechanical engineering challenges. Generally Prepregs are temperature activated intermediate products with tailor made properties. Application advantages for the use of Prepregs are superior stiffness, high tensile strength, low density, corrosion resistance, high vibration resistance, low heat elongation, low weight, extraordinary fatigue resistance, easy installation in use, low maintenance costs in use.

For the thermosetting machinery solution in general it is necessary to apply epoxy resin or phenol resin chemistry on a variety of substrates made of different material type. Difficulties in handling various products must be evaluated for winding, material guiding, coating and drying processes. Depending on the substrate, the coating chemistry and the end product it is necessary to perform a detailed evaluation of each piece of equipment proposed for coating and impregnating lines.

An additional requirement for special handling of products for Prepreg materials is influenced by the use of chemical solutions. Resins (matrix) as coating materials can include solvent or water based epoxy resins, phenol systems polyester/vinyl ester/acrylic resin systems.

The coating technology is for thermosetting systems followed by drying, a very important feature of a Prepreg coating line. In general precise adjustments of the drying or curing processes must be realized for a high quality end product.

Important parameters for coating plants for Prepreg handling result in specialized plant layout:

- Various winding technology with perfect tension control
- Various coating technologies depending on the coating weight and the coating chemistry, viscosity and delivery
- Drying technology depending on the coating chemistry (water or solvent based) and appropriate exhaust technology, like drying/curing via IR, drying via hot air

Figure 6. Typical coating technologies: Foulard, 3 Roller, Powder Scattering, Slot die. Photo: Coatema.

Figure 7. **Lab Line: 0,1–20 m/min - Roller width 1.000 mm - Working width 800 mm**
✓Bobbin creel - Fibre spreading module - Web un-winder
✓Partial Click and Coat design - Multiple coating applicators - Inline calender
✓Hot air and hot plate curing - Eex design

Figure 8. **Production line: 1–10 m/min - Roller width 2.200 mm - Working width 2.000 mm**
✓4 x 120 Creel - Fiber spreading module - Turret winder
✓Hot air dryer - Infrared field - Heating table
✓Inline calendar - Lamination/De-lamination

4 EXAMPLE FOR A PREPREG DEVELOPMENT BASED ON RESIN WITH RENEWABLE COMPONENTS

Within the project NAKAB, founded by the German Ministery for Economics and Energy BMWi (FKZ: 20K1105A) a new prepreg-system was developed at Fraunhofer PYCO.

Goal of the project was the development of components for the aircraft cabin using renewable resources. Up to now materials from renewable sources are not qualified for aircraft applications, due to their low mechanical performance and their high flammability, meeting not the requirements for the aircraft cabin.

To reach a property profile, which allows the use of the new materials in the cabin, within this project new resin formulations and composites on the base of renewable sources were developed. Due to the high mechanical and FST (fire, smoke, toxicity)-requirements new innovative solutions were necessary. It was demanded, that the new resins can be processed reliable with established process technologies, especially with prepreg-technology. Hence, the pilot impregnation plants at Fraunhofer PYCO were used within this development.

A number of different approaches were followed. The final resin (Pycophen 2087314) for prepreg-production with a property-profile in accordance with aircraft requirements is a biomodified phenolic resin with a content of 17 wt% of modifier based on renewable resources. For the prepreg a glass-fibre fabric, ISOLA VR 781, 8H satin (300 g/m²; finish: C) was used. A resin content of 37 - 40 wt% corresponding to a prepreg area weight of 475 – 500 g/m² was obtained. The curing of the prepregs can be done for one hour at 140°C under a pressure of 5 bar, resulting in a residual VOC of 5 ± 3 wt%.

The material was tested in a sandwich-construction to determine the peel strength of the prepreg on honeycomb core, resulting in 81 N peel strength (Table 1). Laminates were manufactured from the prepreg to determine the mechanical values of the composite and the Fire-Smoke-Toxicity (FST)-values.

Peel strength[a] [N]	Stiffness[b] [MPa]	Young's Modulus[b] [GPa]
81	610 (warp) 580 (weft)	17,3 (warp) 18,0 (weft)

Table 1: Mechnical properties of composites from the biomodfied phenolic resin. [a] Honeycomb sandwich panel, with one top and one bottom layer. [b] 8-layer laminate, 4-point-bending test.

A Stiffness of 610 MPa in warp-direction and of 580 MPa in weft-direction was obtained (Table 1). The Young's modulus was determined to 17.3 GPa in warp-direction and 18.0 GPa in weft-direction.

FST-values can be found in Table 2.

TTI [s]	HRR [kW/m²]	THR [MJ/m²]	TSR [m²/m²]	CR [wt-%]
111	198	16,8	556	78

Table 2: Fire-Smoke-Toxicity values of composites from the biomodfied phenolic resin. Determined via cone calorimetry (Heat flux 50 kW/m²).

The new developed resin will be – when produced commercially – approximately 20%

cheaper than a comparable aircraft prepreg resin, due to lower cost of the raw materials.

9 CONCLUSIONS

End users choose composite materials due to the characteristics of weight, strength and economy of use. As a result of the extreme differences in individual products, expectations from production machines are very high. With decades of experience Coatema Coating Machinery GmbH is in a position to offer highly innovative and economical prepreg machine solutions. These concepts need to be tailored to each customer’s specific needs.

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