

Overview of production of pre-preg, prototype and testing

S Rusnáková¹, M Kalová² and Z Jonšta²

¹Department of Production Engineering, Faculty of Technology, Tomas Bata University in Zlín, Vavrečkova 275, 760 01 Zlín, Czech Republic

²Faculty of Metallurgy and Materials Engineering, VŠB – Technical University of Ostrava, 17. listopadu 15/2172, 708 33 Ostrava, Czech Republic
rusnakova@utb.cz

Abstract. The content of the scientific work is to evaluate the properties of matrix pre-preg systems of composite materials suitable for the production of high performance composite parts, for example for automotive or aerospace industry. The research work introduces composite materials, types, properties and fields of use of matrices and fibres. The main part deals with the description of the pre-preg production, the description of the state of the material conversion with a focus on the B-state of the resin, including the technologies for the production of composite materials from pre-preg systems. The practical part is focused on the testing of matrices intended for the manufacture of pre-preg systems of composite materials, it compares different types of epoxy matrix and glass fiber in several layers. The aim of the work is to evaluate the tested composite systems suitable for pre-preg applications, to compare the properties and parameters of the given application with the focus on the recommended production methods. The result of the work can then be used as the most suitable production application according to the customer's requirements for the product.

1.Introduction

Pre-pregs are often used to produce of composites. Pre-preg systems are called semi-finished products to produce fibre composites, the main component of which is pre-impregnated reinforcement with partially cured resins. Pre-preg is the abbreviated form of the English word preimpregnated fibres, which means "pre-impregnated fibres". Prepregs are semi-finished flats with specially developed resin matrices that are reinforced with artificial fibres such as carbon, glass and aramid [1].

These systems are stacked to the desired thickness and then molded into molds and subsequently pressurized with heat and pressure. Pre-pregs are most commonly used with unsaturated polyester resins, vinyl and epoxy systems. The resulting composite material is highly rigid, heat resistant, extremely stiff and extremely lightweight. One of the advantages of pre-preg technology is also a simpler manufacturing process where machine fabrics are pre-impregnated to produce a high-quality product with very low bulk density and excellent mechanical properties [2].

2.Pre-preg overview

Pre-preg technology is a technology based on the principle of using a semifinished product consisting of a saturated reinforcement by resin. During pre-preg production we distinguish three basic phases or states of resin - called. "A-state", which is an uncured resin, "B-state", in which the polymerization of resin (pre-preg) "C-state", which is the final polymerized matrix (composite) [3]. The B-state is a transition degree of polymerization between the uncured resin and the final polymerized matrix. The resin of the semifinished product in the so- B-condition means, that the material has been partially but



very sparingly crosslinked. The resulting pre-preg material, however, has a limited workability, especially at room temperature, because it is usually stored in a freezer box. The workability at room temperature is only a few days depending on the type of material. In Tab. 1 is a brief description of the advantages and disadvantages of individual manufacturing processes in the B-state of pre-preg production.

Table 1. Advantages and disadvantages of pre-preg manufacturing technique.

Process type	Advantages	Disadvantages
Solvent based	Easy impregnation Low viscosity Storage stability	Solvent vapour formation Residual solvent content Risk of sedimentation
Hot-melt based	Resin handling Stickiness Solvent-free	High viscosity Difficult impregnation
Chemical B-stage	Resin handling Adjustable reactivity Solvent-free	Exothermic risk Stickiness reproducibility

The production of pre-pregs in the so- B-state can be divided into three ways:

- Physical B-state: solvent based systems
- Physical B-state: hot-melt based systems
- Chemical B-state

3. Experimental part

Two systems were choosing for pre-preg prototype production. The polymer matrix I/ System I is available from company Huntsman and are designed for high performance composite materials and pre-preg systems. The resin has an extremely long processability time and the resulting composite has a chemical resistance to acids at temperatures up to 176°C. Pre-preg processing is the chemical B-state method, and production methods of winding, pultrusion and die casting are recommended for the resulting composite material. The resin hardens only above 80°C to 160°C, which determines the heat resistance of the final system (it is not cured at room temperature).

Second polymer matrix II/System II, the Eporezit Epovil A / T-111 epoxy system has been chosen to for prototype pre-preg prototypes. An important factor of choice was its availability and features.

As composite sample reinforcement, we chose Aeroglass 200 (198g/m²). It is a high-quality glass fabric used for most resins and is suitable as a universal fabric thanks to its construction, does not shrink and does not look like loose fibers, is resistant to defects in handling and molding.

3.1. Experimental testing according EN ISO 527-4

The tensile test was performed on the ZWICK test machine. Tensile test was done according to EN ISO 527-4: 1997, Plastics - Determination of tensile properties - Part 4: Test conditions for isotropic and orthotropic fiber reinforced plastic composites. Evaluation of test was done by using Test Expert II.

Samples were prepared by pressure molding technology (PCM). Pressure molding technology is popular manufacturing technique for composite parts. Pressure molding technology offer a high degree of automation, short cycle times, good reproducibility and excellent dimensional stability thermosets which is the reason for diverse applications in various industrial sectors including the automotive industry.

Table 1 and table 2 describes proposed pre-preg systems for prototype production and mechanical testing. Systems re with different processing times, different curing temperature and different number of layers.

Table 2. Proposal and processing conditions for pre-preg system I.

Pre-preg System I				
Components		System 1	System 2	System 3
		Weight ratio of components		
Araldite LY1556		100	100	100
Aradur 1571		23	23	23
Accelerator 1573		3	5	7
Hardener XB 3471		14	14	14

Processing by ratio of components		System I/1		
Curing temperature	Curing time	Sample - description		
		Number of layers of fabric		
		2 layers	4 layers	6 layers
110°C	18-22 min.	CH1-2-I.	CH1-4-I.	CH1-6-I.
120°C	8-12 min.	CH1-2-II.	CH1-4-II.	CH1-6-II.
130°C	4-6 min.	CH1-2-III.	CH1-4-III.	CH1-6-III.

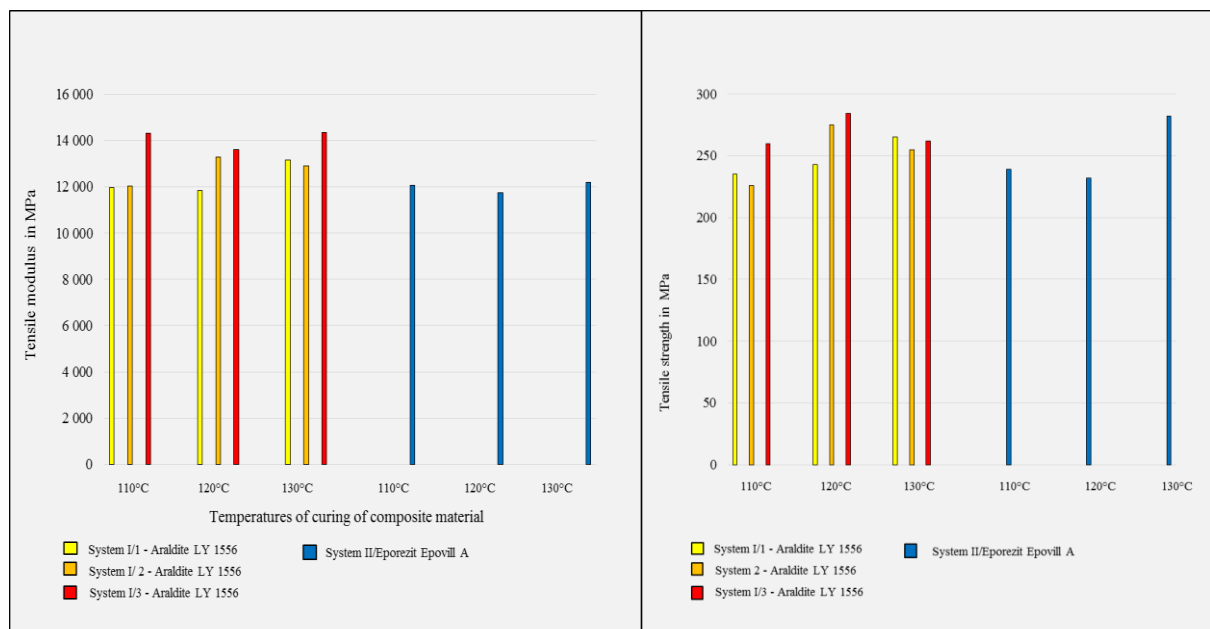
Processing by ratio of components		System I/2		
Curing temperature	Curing time	Sample - description		
		Number of layers of fabric		
		2 layers	4 layers	6 layers
110°C	18-22 min.	CH2-2-I.	CH2-4-I.	CH2-6-I.
120°C	8-12 min.	CH2-2-II.	CH2-4-II.	CH2-6-II.
130°C	4-6 min.	CH2-2-III.	CH2-4-III.	CH2-6-III.

Processing by ratio of components		System I/3		
Curing temperature	Curing time	Sample - description		
		Number of layers of fabric		
		2 layers	4 layers	6 layers
110°C	18-22 min.	CH3-2-I.	CH3-4-I.	CH3-6-I.
120°C	8-12 min.	CH3-2-II.	CH3-4-II.	CH3-6-II.
130°C	4-6 min.	CH3-2-III.	CH3-4-III.	CH3-6-III.

Table 3. Proposal and processing conditions for pre-preg system II.

Pre-preg system II				
Components		Weight ratio of components		
EPOREZIT EPOVILL-A		1000		
EPOREZIT T-111		735		
Processing by ratio of components		EPOREZIT		
Curing temperature	Curing time	Sample - description		
		Number of layers of fabric		
		2 layers	4 layers	6 layers
100°C	18-22 min.	CH1-2-I.	CH1-4-I.	CH1-6-I.
130°C	8-12 min.	CH1-2-II.	CH1-4-II.	CH1-6-II.
160°C	4-6 min.	CH1-2-III.	CH1-4-III.	CH1-6-III.

Comparison of modulus of elasticity E in composite with 2 layers of glass reinforcement - assessment of temperature influence and ratio of composite components is depict on figure 1 (on the left) and comparison of the tensile strength σ in the composite with 2 layers of the glass reinforcement - assessment of the influence of temperature and the ratio of composite components on figure 1 (on the right).

**Figure 1.** Comparison of modulus of elasticity and tensile strength in the composite with 2 layers.

Comparison of modulus of elasticity E in composite with 4 layers of glass reinforcement - assessment of temperature influence and ratio of composite components is depicting on figure 2 (on the left) and comparison of the tensile strength σ in the composite with 2 layers of the glass reinforcement -

assessment of the influence of temperature and the ratio of composite components on figure 2 (on the right).

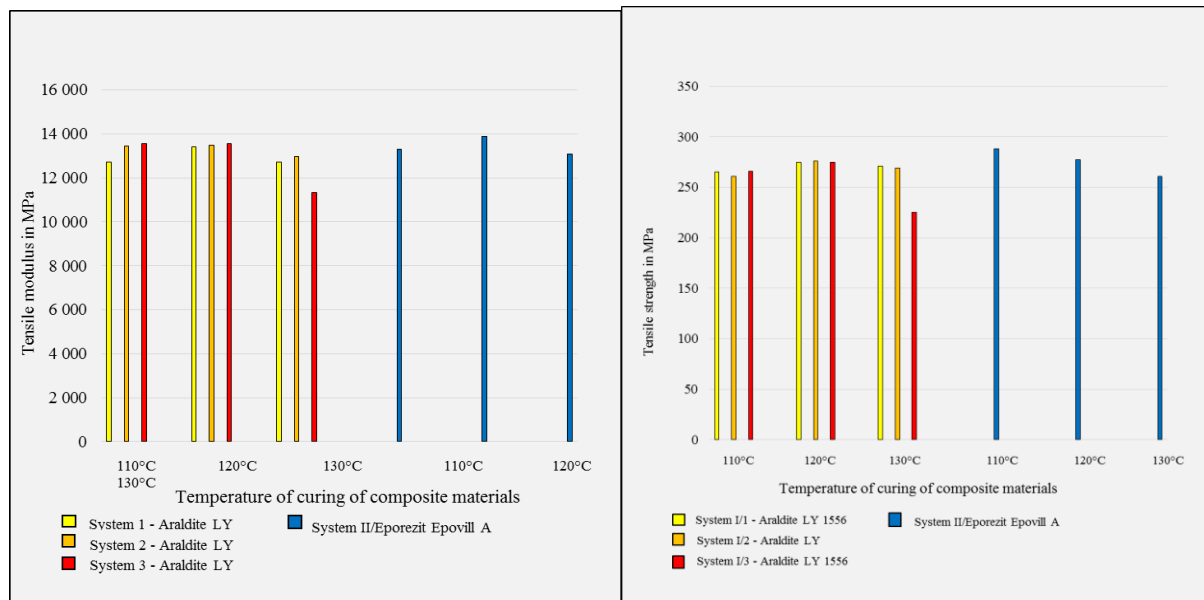


Figure 2. Comparison of modulus of elasticity and tensile strength in the composite with 4 layers.

Comparison of modulus of elasticity E in composite with 6 layers of glass reinforcement - assessment of temperature influence and ratio of composite components is depicting on figure 3 (on the left) and comparison of the tensile strength σ in the composite with 2 layers of the glass reinforcement - assessment of the influence of temperature and the ratio of composite components on figure 3 (on the right).

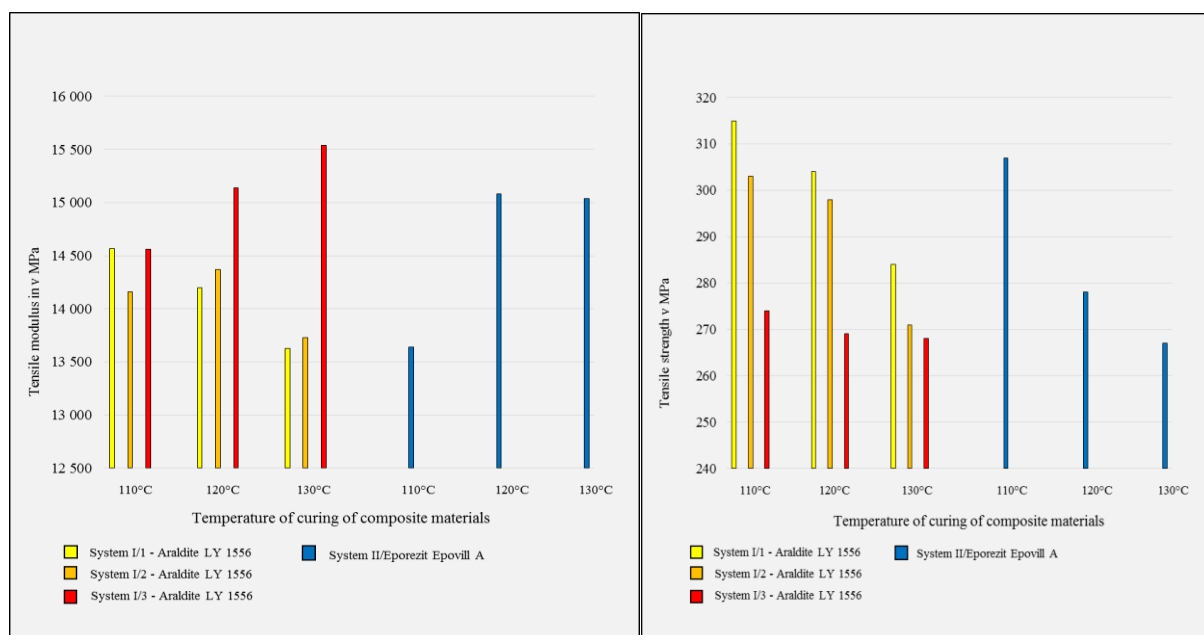


Figure 3. Comparison of modulus of elasticity and tensile strength in the composite with 6 layers.

4. Results

The main advantage of pre-preg production systems is the high fiber ratio with the optimum amount of matrix. During experimental prototype production of pre-preg systems with various number of laminas we used manual production. Commercial production line used machine production process, where is achieved perfect impregnation of reinforcement (unidirectional, woven) [4].

With multiple layers of glass reinforcement increase the modulus of elasticity, but the tensile strength decreases. This decrease of tensile strength is due to experimental production of pre-preg system [5].

The saturation of fabric is an important factor of mechanical properties of composites. If the impregnation is ideal, the appearance of delamination, formation of cavities is minimalized.

References

- [1] MORGAN, P. (2005). Carbon fibers and their composites, 1153 p. Taylor & Francis Group, Boca Raton, Florida. ISBN-10 0-8247-0983-9.
- [2] KRETSIS, G. (1981). A review of the tensile, compressive, flexural and shear properties of hybrid fibre-reinforced plastics. Composites, Vol. 18, No. 1, pp. 13–23.
- [3] HULL, D., CLYNE, T. W. (1996). An Introduction to Composite Materials, 326 p. Cambridge University Press, Cambridge. ISBN 0-521-38855-4.
- [4] Banks, R., Mouritz, A. P., John, S., Coman, F., Paton, R. (2004) Development of a new structural prepreg: characterisation of handling, drape and tack properties. Composite Structures, Volume 66, Issues 1–4, pp 169-174.
- [5] Nobuyuki Odagiri, Hajime Kishi, Masaki Yamashita (2012) Development of TORAYCA prepreg P2302 carbon fiber reinforced plastic for aircraft primary structural materials, Advanced Composite Materials, 5:3, 249-254.

Acknowledgement

This paper was created with the financial support of the internal grant of TBU in Zlín No. IGA/FT/2018/004 funded from the resources of specific university research.