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Biocompuestos para perfiles avanzados adaptados a la edificación

Biocomposites for Advanced Profiles Adapted to Building Envelope

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***Resumen*— Compuestos alternativos en el sector de la envolvente se obtienen por extrusión de estirado de secciones y perfiles de panel de enclavamiento estrechas. Estos elementos estructurales, resistentes al impacto, tienen la ventaja de una instalación más rápida y segura, y su diseño modular les hace idóneos para muchos edificios y otras aplicaciones. Un desarrollo adicional en esta área puede ser la obtención de una alternativa sostenible a los perfiles compuestos actuales. Estudios anteriores han demostrado que los compuestos fabricados a partir de materiales naturales tales como fibras y polímeros bio-derivados, ofrecen una alternativa sostenible a los polímeros y materiales compuestos tradicionales. El objetivo de este desarrollo es reemplazar el típico perfil de acero ligero. Los perfiles de acabado también se pueden utilizar para terminar tabiques de mampostería existentes, revestimiento de ejes mecánicos y de extracción y revestimiento de la columna. Los perfiles se han diseñado utilizando bio-polímeros, reforzados con fibras naturales. Se han establecido los parámetros de procesamiento y las formulaciones apropiadas de bioresina y fibras naturales. También se ha evaluado la adaptación de las técnicas de procesamiento de pultrusión existentes a las características concretas de los nuevos biomateriales y fibras naturales. Como resultado, los perfiles de pultrusión adaptados a la construcción se han desarrollado con la incorporación de nuevos materiales y biomateriales basados en resina.**

Palabras clave— Biocompuestos; fibras naturales; pultrusión; perfiles; envolvente del edificio.

***Abstract*— An alternative composites answer in the envelope sector is the fabrication by pultrusion of narrow interlocking panel sections and profiles. These impact-resistant structural elements have the advantage of quicker, safer installation and their modular design equally answers many identical building and other applications**¡Error! No se encuentra el origen de la referencia.**. An additional development in this area can be the obtaining of a sustainable alternative to current composite profiles. Previous studies have shown that biocomposites manufactured from natural materials such as fibres and bio-derived polymers; offer a sustainable alternative to traditional polymers and composites. The goal of this development is to replace the typical light gauge steel profile with a state of the art bio-composite integrated system. The finish profiles can also be used to finish existing masonry partition walls, cladding mechanical and extraction shafts and column cladding. The profiles have been designed using bio-polymers, reinforced with natural fibres where possible and necessary. Proper formulations of the bioresin, natural fibres and processing parameters have been established. The adaptation of the existing processing pultrusion techniques to the specific characteristics of the new biomaterials and natural fibres has been also assessed. As a result, demonstrators of pultrusion profiles adapted to building envelopes have been carried out incorporating novel materials and bio based resin.**

Index Terms—Biocomposites; natural fibres; pultrusion; profiles; building envelope.

I. Introduction

An alternative composites answer in the envelope sector is the fabrication by pultrusion of narrow interlocking panel sections and profiles. These impact-resistant structural elements have the advantage of quicker, safer installation and their modular design equally answers many identical building and other applications (Starr, 2000)**¡Error! No se encuentra el origen de la referencia.**.

An additional development in this area can be the obtaining of a sustainable alternative to current composite profiles. Previous studies (Faruk. Bledzki, Fink, & Sain, 2012), (Ho, Wang, Lee , Ho, Lau, Leng, & Hui, 2012), (Kandachar & Brouwer, 2002), (La Mantia & Morreale, 2012) (Raquez, Deleglise, Lacrampe, & Krawczak, 2010) have shown that biocomposites manufactured from natural materials such as fibres and bio-derived polymers; offer a sustainable alternative to traditional polymers and composites.

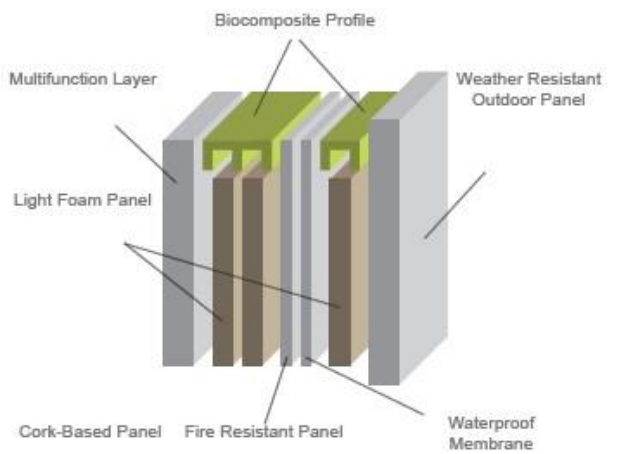

Fig. 1. Assembled modular multi-layer envelope based on biocomposites in which is integrated developed biocomposite profile

The goal of this development is to replace the typical light gauge steel profile with a state of the art bio-composite integrated system. The finish profiles can also be used to finish existing masonry partition walls, cladding mechanical and extraction shafts and column cladding. The profiles have been designed using bio-polymers, reinforced with natural fibres where possible and necessary (Fig. 1). Proper formulations of the bioresin, natural fibres and processing parameters have been established. The adaptation of the existing processing pultrusion techniques to the specific characteristics of the new biomaterials and natural fibres has been also assessed.

II. Methods

Processability of biocomposites is complex and has a low output. Because of this, there is a need of new technologies adapted to the behavior of the bio-based materials. Accordingly, thermoset biocomposite profiles have been developed in the Osirys project at pilot plant level. As reinforcement, continuous and low twist flax natural fibres have been employed for profile manufacturing.

A homogeneous curing, short residence times and low processing temperatures are required to improve formulations with bioepoxy and natural fibres. For this, specific characteristics of the new bioresins have been also assessed.

A. *Characterization*

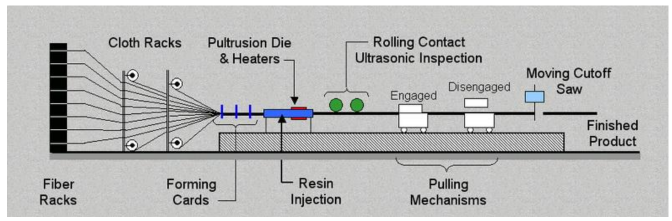

Fig. 2. General scheme of the pultrusion process

Evaluation of curing cycle of selected bioepoxy has been carried out taking into account requirements in terms of temperature due to natural fibers processing (160 ºC).

Assessments by Differential Scanning Calorimeter (DSC) and Dynamomechanical analyzer (DMA) have been performed about maximum temperatures to optimise glass transition temperature (Tg) results.

The prepared composites with different modifications were characterized by DMA to determine the effect of curing cycle in viscoelastic modulus, and subsequently in mechanical properties, and also in the glass transition temperature. This modulus gives information about the effect of material quality in thermal stability and mechanical properties. Tests were carried out in a DMA TA Instruments 2980 with a dual cantilever clamp by applying a sinusoidal deformation with 1 Hz of frequency and 20µm of deformation. A ramp temperature was programmed from 25ºC up to 200ºC in order to cover all possible thermal transitions of bioepoxy composite.

Differential scanning calorimetry (DSC) was used to obtain the glass transition temperature (Tg) of the bioepoxy resin at different curing conditions. A DIAMOND DSC equipment was used. DSC samples were heated from 20 to 250 ºC at 10 °C min-1.

B. *Production of biocomposite profiles*

Different techniques can be used for the production of biocomposites depending on raw materials, the required

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Fig. 3. Different phases of pultrusion process obtained by hybrid fibers (flax and glass).

product geometry, properties, processing time and cost. Pultrusion is a continuous manufacturing process for composite profiles. It uses continuous fibres as the major reinforcement. Different resin systems are used to gain the final desired properties. Flexibility in design and various material combinations are the main advantages with pultrusion technology. The structural possibilities are almost unlimited. In the pultrusion process the fibers are impregnated with a thermosetting resin and pulled through a heated die where curing takes place. Different laminate lay-ups are possible with reinforcements of roving, mats and fabrics. The finished profiles are cut to length by a saw at the end of the line. Fig. 2 shows a general scheme of the pultrusion process.

Adaptation of pultrusion process to biocomposites with

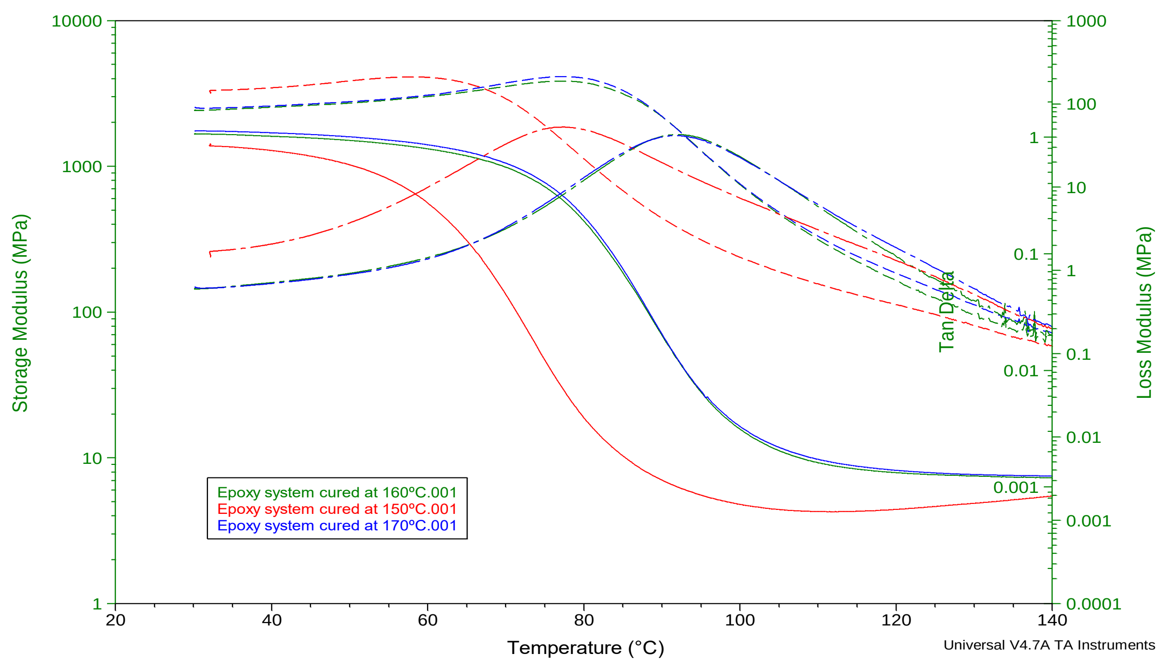

Fig. 4. DMA test for determining Tg values (at different curing cycles).

natural fibres yarns has been required to improve formulations and process parameters to avoid fibres break. A post curing area has been added in pultrusion equipment to adapt to requirements of bioepoxy resin in terms of post-curing.

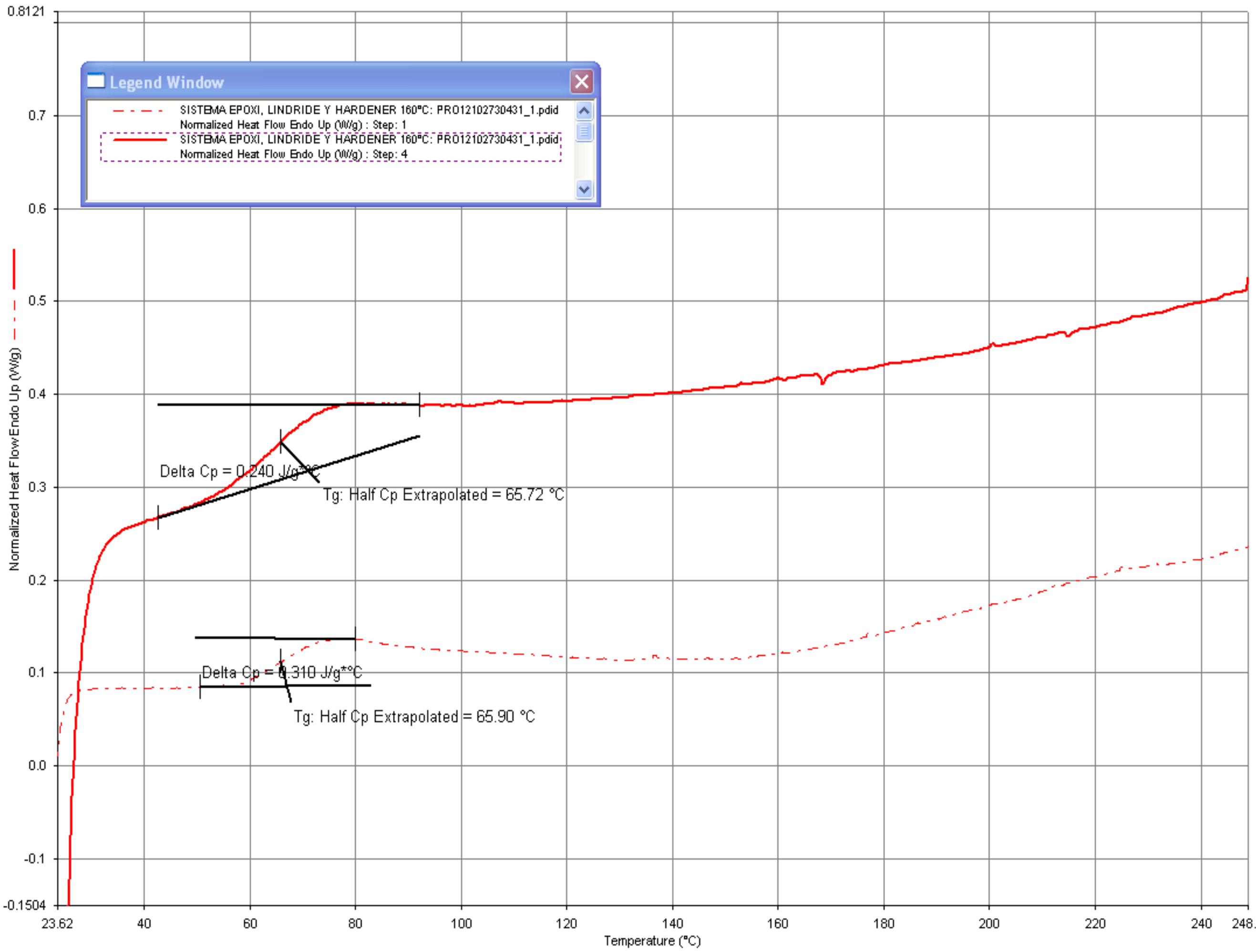

Fig. 5. DSC test at 160ºC curing cycle.

Different pultrusion trials with glass, flax and hybrid (glass and flax) fibers have been carried out with standard polyester resin and bioepoxy resin in order to optimize processability (Fig. 3**¡Error! No se encuentra el origen de la referencia.**). Yarns of glass fibers of 4800 tex and 100 % flax yarn of 2000 tex were used to perform them.

Pultrusion profiles were prepared for mechanical characterization according to ISO 10406-1:2008 standard. The length of bars was 300 mm. It was prepared an anchoring system adapted to the geometry of the test pieces (bars) and with the capacity to transmit only the tensile force along the longitudinal axis of the test pieces.

III. Results and Discussion

From DMA (fig. 4 & Table I) and DSC tests, it was shown that optimized results for bioepoxy systems were obtained with a curing cycle at 160 ºC. This curing cycle has been evaluated and optimized in the pultrusion process in order to adapt it to the requirements of natural fibers processing.

TABLE I
DMA results (at different curing cycles) of bioepoxy system

Sample	Tg onset E' (ºC)	Tg peak E'' (ºC)	Tg tan delta (ºC)
Curing cycle at 150ºC	60.49	60.82	77.35
Curing cycle at 160ºC	75.43	77.81	91.78
Curing cycle at 170ºC	75.82	77.93	91.74

From DSC results (fig. 5 & 6), the most suitable temperature profile (Table II) has been defined for the pultrusion process and a post curing area has been included to adapt to requirements of bioepoxy system.

TABLE II
Temperature pultrusion profile

Zone 1	Zone 2	Zone 3	Post curing

120 ºC	140 ºC	160 ºC	100 ºC

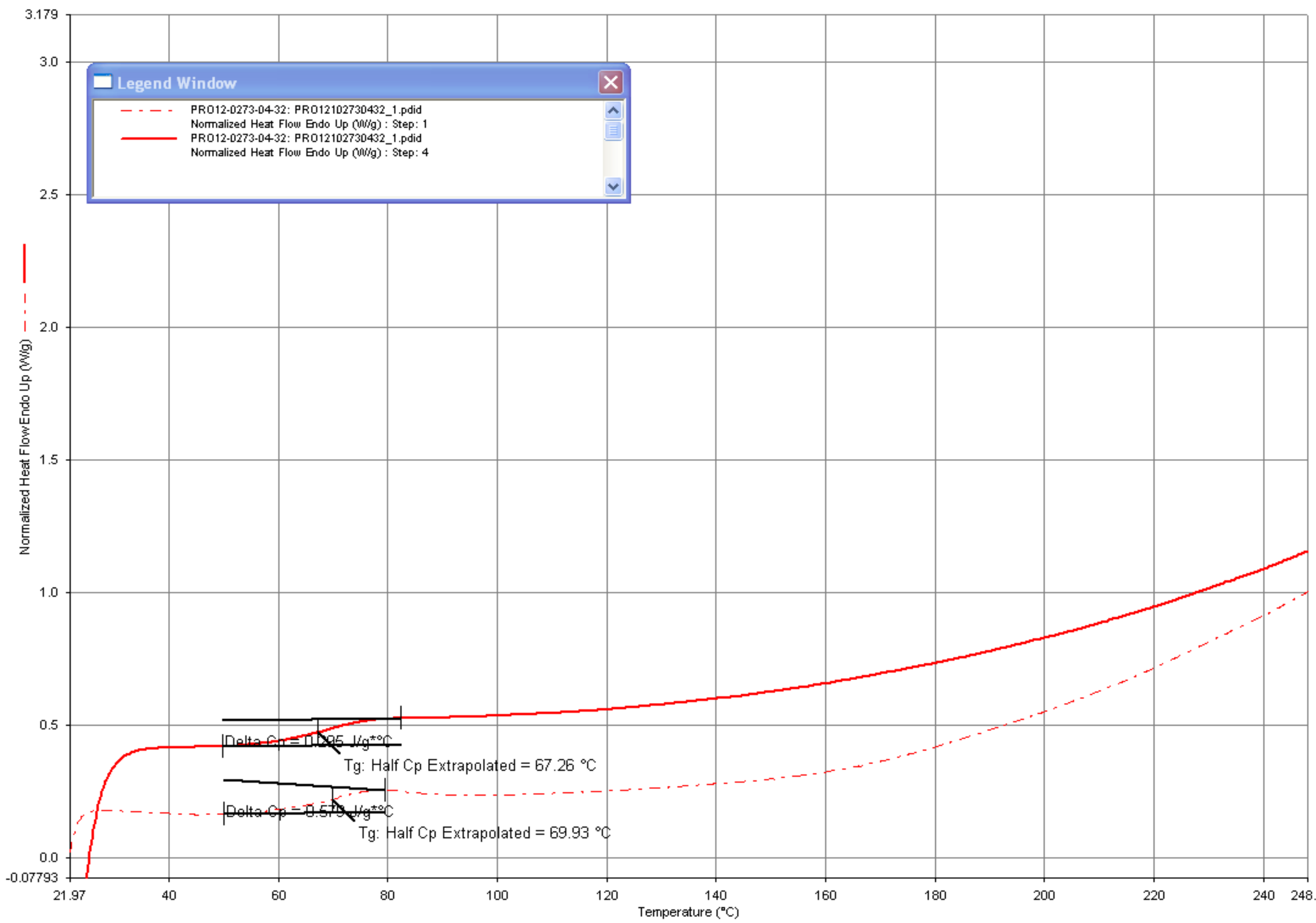

Fig. 6. DSC test at 170ºC curing cycle.

Specimens of pultrusion profiles were obtained by pultrusion process at pilot plant level (Fig. 3). Different compositions of the reinforced bars were evaluated by tensile tests according to ISO 10406-1:2008 (Table III).

TABLE III
Tensile results of rebars

Pultrusion profile composition	Young´s Modulus (MPa)	Tensile Strength (MPa)	Elongation at break (%)
Bioepoxy system + glass fiber	48400 s=2990	786 s=70	1,7 s=0,1
Polyester resin + glass fiber + natural fiber	46100 s=575	513 s=21	1,1 s=0,1
Polyester resin+ glass fiber	46400 s=1130	537 s=59	1,2 s=0,1
Polyester resin + glass fiber + alumina	33700 s=3840	346 s=49	1,1 s=0,3

IV. Conclusions

An optimised pultrusion process at pilot plant has been obtained to produce biocomposites profiles with bioepoxy resin. Better mechanical results in the pultrusion profiles have been achieved at pilot plant level using the bioepoxy system and glass roving. Nevertheless, flax fibers with low twist can be used to produce pultrusion profiles and no significant differences in the mechanical properties have been found between the profiles prepared with glass fibers and those obtained with hybrid fibres (glass and flax) with unsaturated polyester (UP) resin.

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