Lightweight reinforcements for window frames

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Introduction

Fibre reinforced polymer matrix composites have long established themselves as lightweight and durable materials for structural reinforcement. While most materials are based on thermoset matrix material, thermoplastic matrix polymers are becoming increasingly popular. These materials allow for different processing methods, primarily related to how the matrix and reinforcement material are pre-mixed before forming the composite. In the case of long fibre reinforcements the matrix material can be introduced in form of long fibres as well.

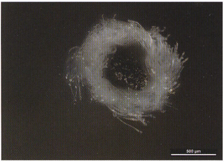

Figure 1: basalt / polymer roving, cross section

By different techniques continuous rovings of reinforcement and matrix yarns can be produced that can be further processed into fabrics by e.g. knitting, weaving or braiding. For this reason these materials are also of interest to the textile industry.

The processed fabrics but also the rovings on their own can be processed into composite structures by thermoforming, i.e. application of sufficiently high temperature and pressure. Since no wet chemicals are involved, these materials are easy to handle.

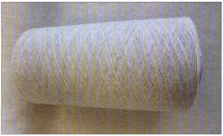

Figure 2: basalt / polymer roving

For the choice of matrix and reinforcement material varieties of combinations are possible, taking into account that (1) the strength of the reinforcement material is not compromised by the thermoforming process and (2) the matrix material wets the reinforcement fibres well. The strength and toughness of the final composite material depend on different factors, including the ratio of reinforcement to matrix material, the adhesion between reinforcement and matrix and the final porosity of the composite.

In the following we will discuss the results of a project where the suitability of polyester/basalt thermoformed composite strips for replacing the steel reinforcements currently used in PVC window frames was investigated. The interest in using basalt/polyester reinforcements was the reduction in weight these would make possible.

Reinforcements in window frames

PVC is a very weather resistant and easy care material for window frame applications and has several advantages over aluminium or wood windows. Unlike these other two materials it is too soft, especially when exposed to elevated temperatures (e.g. sun exposure) and needs internal reinforcements to maintain its shape. The traditional way for doing this is using steel strips or rods. Since these have a much higher specific weight, replacing them by a lighter weight composite will reduce the total weight of the window frame. Additionally, steel has a high thermal conductivity. Glass fibre reinforced polyester is a suitable material for replacing the steel rods, as the polyester has an intrinsically good compatibility with PVC. Basalt fibres, being produced from the natural mineral, have potentially better reinforcement properties, which is why they were chosen for the study reported here. As reinforcement material different low melting polyester types were chosen.

The reinforced parts of the window frame are produced using a so-called pultrusion process, which allows for a continuous production. Here one starts with producing of a uniaxially reinforced composite tape made of a set of mixed basalt/polyester rovings. The tape is pulled through an extruder, forming a continuous strip of reinforced PVC already in the shape of the window frame part. The final part is formed by cutting the strip into the correct length.

For study purposes the two steps can also be performed separately. This allows for e.g. studying the composite tape forming process.

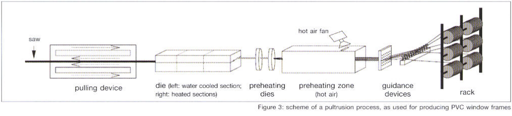

Figure 3: scheme of a pultrusion process, as used for producing PVC window frames

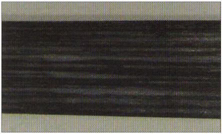

Figure 4: basalt/polyester composite tape

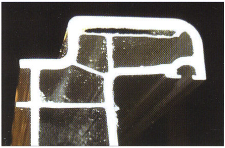

Figure 5: part of reinforced window frame.
The reinforcement can be seen as dark strip on top.

Important parameters for the production of the tape are (1) the impregnation of the basalt fibres with the polyester during processing, (2) the compatibility of the polyester with the production process, (3) the bonding of the polyester with the PVC, (4) the strength, toughness and temperature stability of the reinforcing tape. Since the sizing (coating on the basalt fibres) plays an important role for wetting and adhesion, basalt yarns with different types of sizing were tested. Before testing the rovings in an actual production run, small scale composite plates were produced by uniaxial compaction in a lab scale press.

Evaluation of the composite properties

The composites (both plates and tapes) were evaluated using different analysis techniques, including optical microscopy, three-point bending tests and DMA (dynamic mechanical analysis) and HDT (heat deflection temperature).

The results were related to the final properties of the obtained window profiles. A comparison was also drawn with the commercially available Twintex® glass/polyester material (formerly Owens Corning, now FGI).

Composite structure

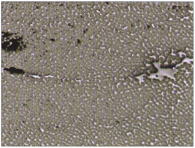

Figure 6: basalt / polyester composite structure

Figure 6 shows the polished cross section of a basalt/ polyester composite tape. The distribution of the basalt fibres is quite regular, but the outline of the original roving is still visible (bent line in the centre of the image). Some porosity is also present (black feature to the left). White areas indicate pure matrix material.

As expected the mechanical properties of the composites decreased with porosity. At a level of <5% this effect levelled off, indicating that there is some tolerance allowed with respect to porosity.

Effect of sizing

The adhesion between fibre and matrix was evaluated by three-point bending in 0° direction. Testing in 90° direction was not possible due to the uniaxial fibre arrangement.

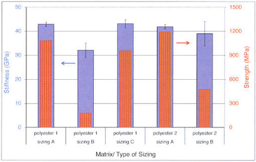

Figure 7: results from testing composite plates by three-point bending

The results (Figure 7) show clearly that sizing type A results in the best mechanical properties, for both types of polyester. Therefore this sizing was used for the further steps in the project.

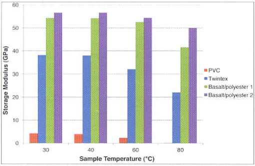

Figure 8: temperature dependence of the storage modulus of composite plates (DMA)

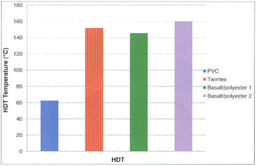

Figure 9: heat deflection temperature (HDT) of the composite plates

Temperature dependence of mechanical properties

As already mentioned the window frames need to resist exposure to temperatures up to 70° C without showing deformation.

To evaluate the thermal stability of the composites, the evolution of stiffness (E-modulus) with temperature and the heat deflection temperature (softening point of the composite) where determined.

DMA measurements on composite tapes (Figure 8) showed that both types of basalt/polyester composites perform better than the commercial Twintex material (glass/polyester), with the basalt/polyester 2 showing the best properties.

The HDT results (Figure 9) show that the three materials Twintex, basalt/polyester 1 and basalt/polyester 2 perform very similar, with basalt/polyester 2 performing best.

The HDT and DMA measurements also clearly indicate the properties of the basalt/polyester 1 and basalt/polyester 2 composites are stable enough for temperatures up to the required 70° C.

Conclusions

The results from this study showed that basalt/polyester rovings can be used to produce composite tapes that can be used as light weight reinforcement materials in PVC window frames.

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