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Properties of laminates containing polymer glass fiber recyclates

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Properties

ABSTRACT

Purpose: In this paper the possibilities of application of polyester-glass fiber recyclates in composite's materials were estimated. Different materials with addition of recyclates were made: laminates stratified laminates and polymer concrete.
Design/methodology/approach: Recyclate obtained after grinding was a mixture of cured polyester resin particles and glass fibers. Two different groups of recyclates have been obtaining after separation. Recyclate with grain size of 0,063-2,0 mm was used to prepare of stratified laminates. Recyclate size below <0,063 mm was used as filler of polymer matrix in laminates. In first group of composites recyclate was used as core in lamitates reinforced wowen or mat fabric. The value of using recyclates obtained 25, 35, 45 and 55% wt.
Findings: The results of the investigation have shown that using of polymer composites wastes as a filler, leads to decreasing of the tensile, bending and impact strength. However obtained material had bending strength comparable with standard material. The best properties were achieved for the laminates with two layers of glass mat as a surface layer. It has been shown that the content of the recyclate has small influence on the studied mechanical properties. The values of bending strength, impact strength for the laminates were evaluated and compared with analogical properties appointed for standard sample. The results of the investigation have shown that using of polymer composites wastes as a filler materials (core), leads to decreasing of the measured properties in bending and impact tests. It has been shown that content of the recyclate has significant influence on studied mechanical properties. In the case of second group of recyclate (size below 0,063 mm) was used as a filler in polymer matrix. In case the stratified laminates with addition of 4wt., 10%wt., and 20%wt. of recyclate were made.
Practical implications: The results of the investigation have shown that using of polymer composites wastes as a filler, leads to decreasing of the measured properties in bending and impact tests. It has been shown that content of the recyclate has significant influence on studied mechanical properties.
Originality/value: The results of the investigations allow to affirm, that the polymer composites waste of small granulation can be used as a filler polymer matrix in production of new composites, being also one of the way utilization of composite with thermosetting matrix.
Keywords: Material recycling; Polyester-glass fiber recyclate; Fiber reinforced polymer laminates, Sandwich core structure

1. Introduction

Glass polyester laminates are nowadays one of the basic construction materials used for the production of many industrial facilities. Their working conditions to be met, beside their naturally high corrosion resistance, is resistance to shock load, dynamic load and to high static loads. These materials can fulfil a variety of construction related requirements due to the possibility

of designing their laminar structure [1,2,4,6]. Laminates are most frequently made as symmetric, mostly sandwich-like, laminar structures [3].

In the research conducted, particular focus was placed on sandwich structures with infilling of coremate and glass fibres coming from composite material wastes with a polymer matrix reinforced with glass fibre. The use of composite wastes in material recycling, beside the ecological aspect, makes it possible to use the recycle glass fibre as reinforcement in production of new composite materials.

2. Materials used for investigation

The tests carried out under the research project aimed at determining the possibilities of using composite material recycles as infilling in sandwich laminates. Recycle was obtained by breaking up fibre composites - polyester resin reinforced with glass fibre. The breaking up was carried out in a knife/beater mill, which allowed preserving the reinforced fibre structure [7,9]. Next, the recycle was divided into fractions of sizes below 0.063 mm, 0.063 mm, 0.31 mm, 1.0 mm, 1.6 mm and above 2 mm. Fractions larger than 0.63 mm were inserted into the laminate to replace traditional sandwich materials (infilling material), such as coremate. The mass fraction of the recycle used as infilling was 25, 35, 45, 55 %. The fraction below 0.063 mm with very short fibres well-connected with the matrix, was used as resin filler during the fabrication of laminates reinforced with glass cloth. The share of the filler introduced into the polyester resin was 4, 10 and 20% of the resin weight.

Tests to determine the influence of recycle on mechanical properties were carried out on samples taken from sandwich laminates with a polyester resin matrix of the following structures:

- laminate with two layers of glass wool of basis weight of 450 g/m^2 and a core made of recycle,
- laminate with two layers of glass cloth of basis weight of 450 g/m^2 and a core made of recycles,
- laminate with twelve layers of glass cloth of basis weight of 450 g/m^2 and a polyester resin filled with recycle.

The structure of laminates is shown in Figure 1 in the form of a diagram.

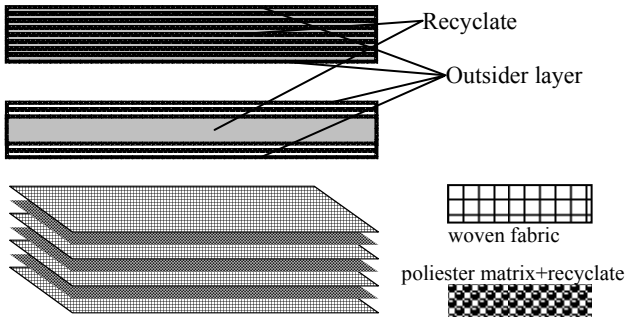

Fig. 1. Structure of laminates using in investigation: a- recycle using as a reinforced component, b- recycle using as a filler in polyester matrix.

Therefore, the recycling process of thermosetting polymers or composites on their matrix should be based, first of all, on raw materials recycling. This will also allow to preserve good properties of the reinforcing fibres contained in composites with a matrix made of hardening plastics and replace at least part of the reinforcing fibres deliberately introduced with fibres contained in the recycle material. The amount of the recycle material added must be precisely defined, otherwise it may result in a change of the final product properties or in changes of the processing properties.

3. Results of investigation

An assessment of the influence of the fraction volume and size on the mechanical properties of laminates was made based on the results of static strength (tension, bending) and dynamic strength tests. The results of these tests are shown in Figures 2-4.

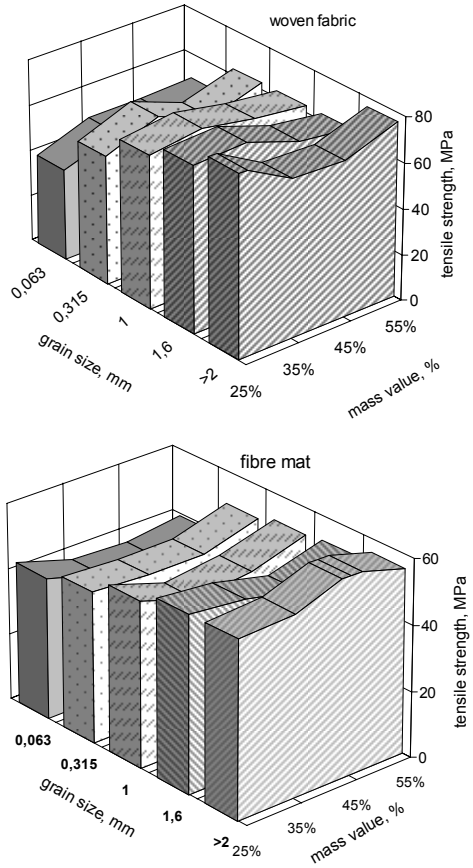

Fig. 2. Influence of grain size of recycles on tensile strength

The results of tensile and bending tests show that composite's resistance grows with an increasing size of recycle particles. A significant increase of strength as a function of particles' sizes occurs in the case of a recycle of the size above 1 mm. Similar tendency can be observed in the results of impact resistance tests.

Mechanical properties of recyclate are enhanced with an increasing recyclate portion. The increase of bending strength and impact resistance is of a linear nature. Only the results of tensile strength tests indicate that after the recyclate portion in the core layer has exceeded 45%, the strength slightly decreases, which is a consequence of structural defects (pores, voids) appearing during the production of laminate. In the case of bending strength and impact resistance, where other types of load are present, the portion and size of recyclate have a greater influence on the strength and resistance than any defects formed in composite fabrication process.

It was found that in composites with very small recyclates (<0.063 mm) used as a matrix filler, the use of about 10% of the filler contributes to an increase in laminate strength (Fig. 5).

The results of the investigation have shown that using of polymer composites wastes as a filler, leads to decreasing of the tensile strength and impact. However obtained material had bending strength comparable with standard material. The best properties were achieved for the laminates with two layers of glass mat as a facing. It has been shown that the content of the recyclate has small influence on studied mechanical properties [10-11].

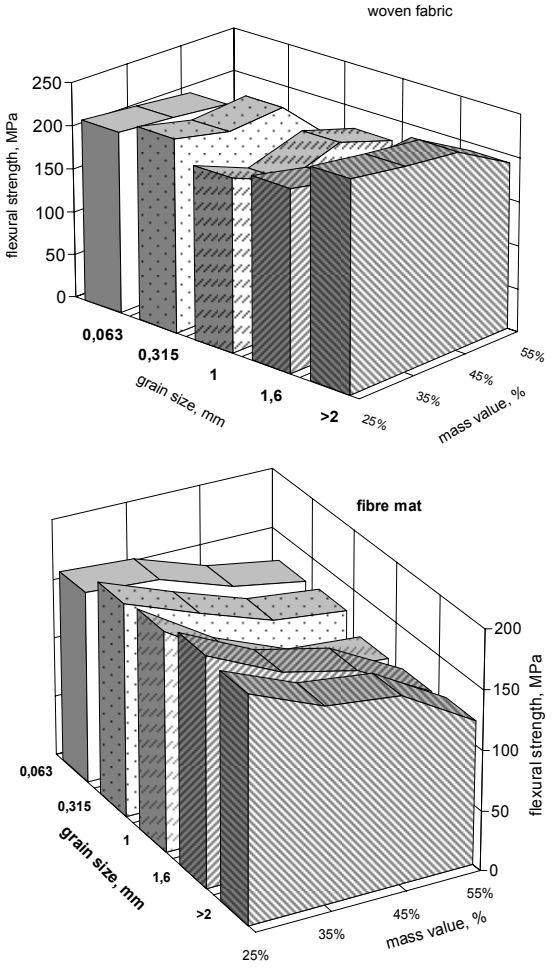

Fig. 3. Influence of grain size of recyclates on flexural strength

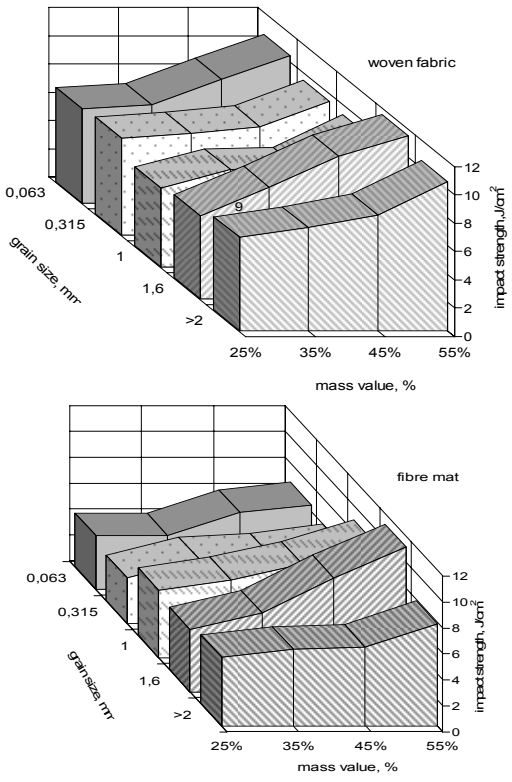

Fig. 4. Influence of grain size of recyclates on impact strength

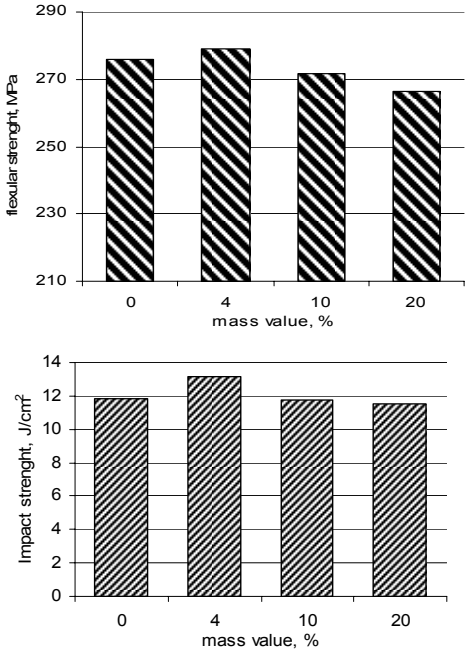

Fig.5. Flexural strength (a) and impact strength (b) composites containing recyclate using as fillers component

4. The structure of composites containing recyclates

The way in which composites containing fillers are destroyed is mostly determined by the granulation and phase composition of individual recyclate grains. The examined recyclate grains had a diverse content of composite reinforcing fibres and different forms of fibres (clusters or strands, individual fibres). In the recyclate, also only resin particles occurred. The examples of grain forms in the recyclate are shown in Figures 6 and 7. This determines the quality of connections between recyclate particles and the matrix [6,8]. The same type of resin was used both for the laminate composite matrix and for the recyclate matrix. In spite of this, the recyclate particles have a weak connection with the matrix, which contributes considerably to the occurrence of cracks on the resin - recyclate boundary (Fig. 7).

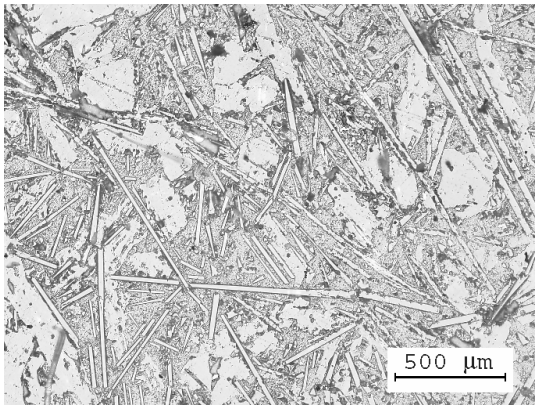

Fig. 6. Fine resin particles and individual fibres

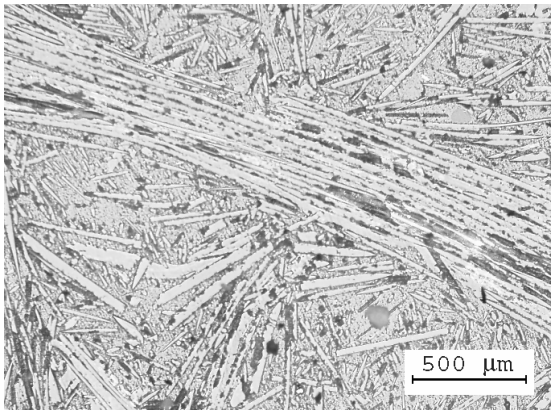

Fig. 7. Fibre clusters in the form of strands.

The pores visible in pictures (Fig. 8 and 9, which are the result of the laminate production technology, additionally contribute to the weakening of material properties, especially in the case of a high recyclate content. The technology of composite formation does not ensure a uniform distribution of the recyclate in the laminate, as a result of which cracks and delamination frequently appear on the boundaries of recyclate clusters. Partial elimination of the unfavourable phenomena in the material, aimed at improving the quality of recyclate filling, will allow enhancing the strength related properties.

Fig. 8. Surface on the recyclate particle - matrix boundary fracture

Fig. 9. Destruction on the recyclate - matrix boundary as a result of fracture and fibres pulling out

5. Conclusions

The research carried out made it possible to conclude that composite wastes can be used as core materials in laminate structures. The properties of such laminates are first of all determined by the size of the broken-up recyclate. It is beneficial to use sizes above 1mm with a large weight fraction exceeding 50%. Enhancement of the strength of laminates that contain recyclates can be obtained through a proper preparation of recyclate particles, owing to which, the strength of the recyclate /matrix connection will improve and the number of technological defects, such as bubbles, particle clusters or recyclate particles

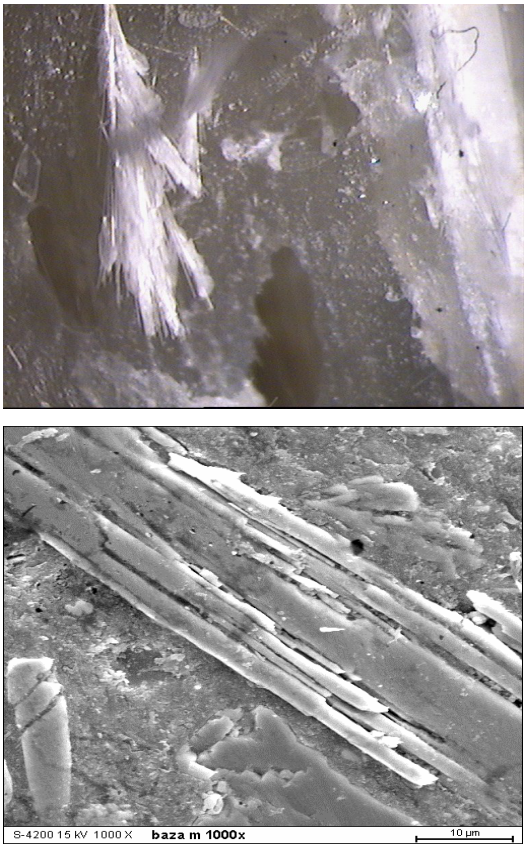

Fig. 10. No infiltrated concentration of recyclate fibres strands

poorly wetted by resin, will be reduced. Smaller recyclate particles can be used in small amounts as a filling material for the polymer matrix. The polymer composites waste can be used as a filler in laminates production, with properties comparable to typical stratified laminates, being also one of the way of thermosetting polymers utilization.

Acknowledgements

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