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Influence of the content of a glass-polyester recycled additive on the properties of layered composites in dynamic tests

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Abstract

Polyester-glass composites are widely used in many industries, in various types of constructions, including dynamically loaded ones. This article examines the influence of the content of a glass-polyester recycled additive on the strength properties of layered composites. The recyclate was polyester-glass waste, which was pre-crushed and then milled into the appropriate fractions. Manual laminating technology was used to make the materials. The composite materials were made with a waste content of 0%, 10%, 20% and granulations of ≥ 1.2 mm and ≥ 3 mm. Samples for testing were prepared in accordance with the PN-EN ISO 179-1: 2010E standard (Plastics – Charpy Impact Assessment – Part 1: Non-instrumental impact test). Impact tests of the samples were performed using the Charpy method with the Zwick Roell RKP450 swinging hammer. The test results showed that the addition of polyester-glass recyclate, its content %, and its granulation size, have an impact on the composite resistance to loads in dynamic tests.

Introduction

Polyester-glass composites are often used in structures exposed to dynamic loads. These loads are characterized by a wide range of energy and impact velocities. The use of composite material in the design of light aircraft, gliders, cars, wind turbine blades (Królikowski, 2012) gives them high specific strength and modulus of elasticity values (Hyla, 1989). These constructions are exposed to impacts such as hail, stones, sea waves or gusts of air. Knowledge of the properties of resistance to dynamic loads (such as impact strength) is a very important issue in their widespread use in industry (Barcikowski & Królikowski, 2013).

Polyester-glass composites as a separate group of materials are not without flaws, including high sensitivity to impact loads. These loads, even if they do not lead to the formation of scrap, can result in the formation of post-stranded micro-voids in the material, which leads to a decrease in the strength of the composite. As a result of dynamic loads, the values characterizing the static strength and the kinetics of the destruction process can change in the material. It is therefore of major importance, in the design and operation of responsible engineering structures, to know the influence of laminate construction elements on behavior in a situation of impact load (Hylla & Lizurek, 2002).

The development of technologies related to polymer composites (Gucma et al., 2015; Gawdzińska et al., 2017) reinforced with fibers includes the possibility of applying waste materials (Rutecka, Śleziona & Myalski, 2004; Rutecka et al., 2005). The condition for the re-use of composite raw materials is how they were processed previously and the form of the processed materials determines their final use (Habaj, 2008). There are many methods for recovering ceramic fibers from waste, which can then be used as full-value components (Asokan, Osmani & Price, 2009), replacing part of the reinforcement phase in new composites with waste material

(Kowalska, Wielgosz & Bartczak, 2002; Pickering, 2016). Continuous progress in the recycling of composite materials (Bignozzi, Saccani & Sandrolini, 2000), which in the past were considered unsuitable for re-use, encourages the search for new, more complete methods of waste management (Jastrzębska, 2011; Jastrzębska & Jurczak, 2011; Błędzki, Gorący & Urbaniak, 2012).

This article examines how the content of the glass-polyester recyclate additive effects the properties of layered composites. The recyclate was a polyester-glass waste, which was pre-crushed and then milled into the appropriate fractions. A manual laminating technology was used to make the materials. Composite materials were made with a waste content of 0%, 10%, 20% at granulations of ≥ 1.2 mm and ≥ 3 mm. Samples for testing were prepared in accordance with the standard PN-EN ISO 179-1: 2010E (Plastics – Charpy Impact Assessment – Part 1: Non-instrumental impact test). Impact tests of the samples were performed using the Charpy method with the Zwick Roell RKP450 swinging hammer. The test results showed that the addition of polyester-glass recyclate, its content %, and its granulation size, has an impact on the composite resistance to loads in dynamic tests. An increase in the content % of polyester-glass decay results in a decrease in the impact properties of the samples. This article is a continuation of research on the strength of laminated composites with polyester and glass recyclates (Panasiuk & Hajdukiewicz, 2017; Kyzioł, Panasiuk & Hajdukiewicz, 2018; Panasiuk, 2018).

Methodology of preparation of test samples

A fragment of polyester-glass scrap was obtained from original composite material from a marine hull manufactured in Poland in the 1980s. The scrap was pre-crushed with a hammer and then crumbled on a specially prepared station for processing plastic waste (the "crusher"). After crushing, the waste was sieved through sieves with eye diameters of 1.2 mm and 3 mm to obtain a recyclate, which was added as a filler to the matrix of the composite (Panasiuk & Hajdukiewicz, 2017).

In order to make composite panels with the addition of polyester and glass recyclate content of 10% and 20% and granulations of ≥ 1.2 mm and ≥ 3 mm using the manual laminating method, a mat with an accidental fiber direction was used as the reinforcement. The advantage of using this type of reinforcement is the comparable strength properties in all directions of the mat's surface. The basis was Polimal 1094-AWTP resin (Kyzioł, Panasiuk & Hajdukiewicz, 2018).

Samples for testing (Figure 1) were prepared in accordance with the PN-EN ISO 179-1: 2010E standard (Plastics – Charpy Impact Assessment – Part 1: Non-instrumental impact test), using the water-cutting method.

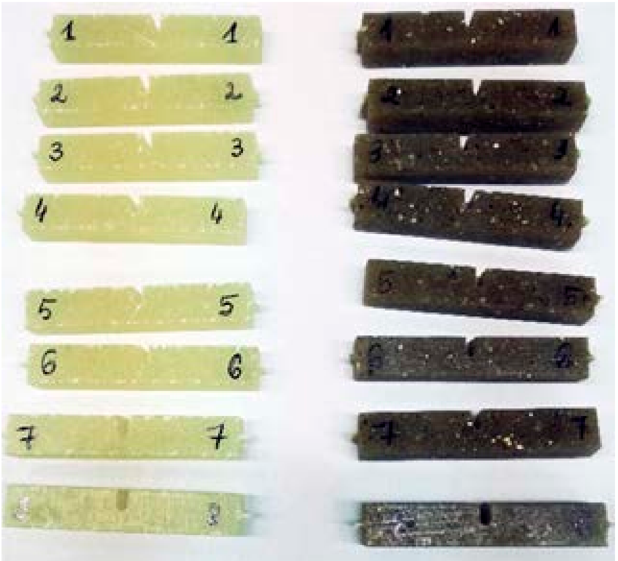

Figure 1. Charpy impact test specimens

Methodology of research

The tests used dynamic three-point bending of notched specimens. For this purpose, a Charpy-type swinging hammer, RKP 450 by Zwick Roell (Figure 2), was used. Thanks to the additional instrumentation, this allowed us not only to determine impact

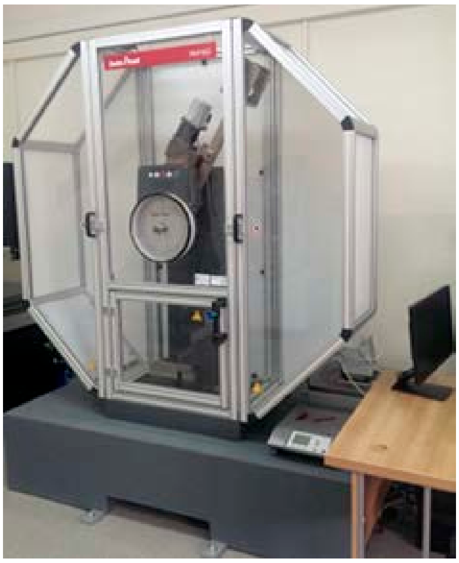

Figure 2. Swinging hammer, model RKP450 from Zwick Roell

strength but also changes in bending force and its accompanying deformations, in very short time intervals (Hylla & Lizurek, 2002). Figure 2 shows the sample placed in the holder before testing. Figure 3 shows part of the samples after dynamic three-point bending tests.

Figure 3. Samples after Charpy impact test

Results of research

Figure 4 shows the impact of the content of the recycled additive and its fractions on (averaged) impact resistance (resistance to dynamic loads of the tested materials).

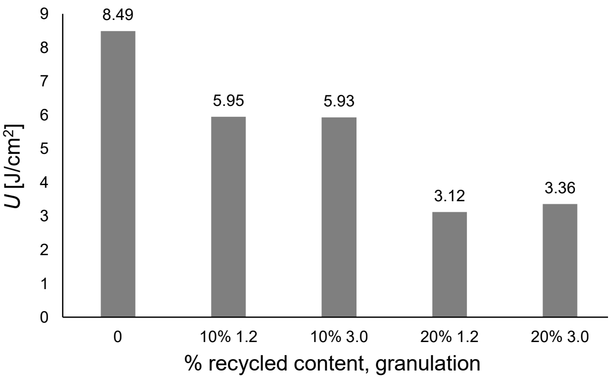

Figure 4. Impact of recyclate content % and granulation on impact resistance [J/cm^2]

Based on the histograms in Figure 4, it can be seen that using 10% recycled content in the composite reduces the impact resistance by $\Delta U \sim 30\%$. The applied waste granulation (≥ 1.2 mm, ≥ 3.0 mm) has little effect on the impact strength of the material with a 10% recyclate addition.

In the case of composite materials with a 20% content of waste, there is a noticeable impact resistance of $\Delta U \sim 63\%$ in relation to the material without its addition. Different recyclate granulations (≥ 1.2 mm, ≥ 3.0 mm) for composites with 20% wastage content show a greater difference than in materials with 10% additives.

Figure 5 shows the effect of the recycled additive content % and the granulations on the (averaged) energy [J] necessary for the destruction of the notched specimens.

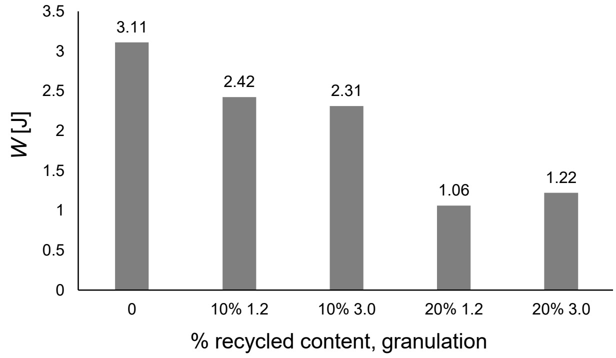

Figure 5. The effect of recyclate content % and granulation on energy (*W*)

By analyzing the impact of recycled content % and granulation on work (*W*), it can be concluded that the work necessary to destroy samples with 10% recyclate content, as opposed to samples without recyclate, decreases by about $\Delta W \sim 22\%$. The granulation of the waste (≥ 1.2 mm, ≥ 3.0 mm) alone has little effect on changing the work needed to destroy the samples. In the case of composite materials with 20% recyclate content, the work necessary to destroy the sample with $\Delta W \sim 66\%$ in relation to the material without its addition is noticeable. In this case, the granulation of waste is more important than for samples with 10% recyclate content.

From the plot of how the recycled additive % and granulation influences force (F_{max}), corresponding to the material reaching the largest possible load, it can be concluded that the maximum strength for a composite with 10% recyclate content, as opposed to samples without recyclate, decreases by $\Delta F \sim 14\%$. The granulation of waste (≥ 1.2 mm, ≥ 3.0 mm) alone has little effect on changing the maximum destructive force. In the case of composite materials with 20% recyclate content, it is noticeable to reduce the maximum force necessary to destroy the sample by $\Delta F \sim 47\%$ in relation to the maximum destructive force of the material without added waste. The recycling of recyclate is important in this case, as illustrated in Figure 6.

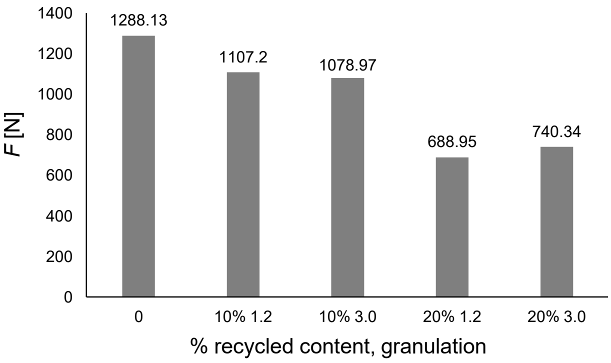

Figure 6. The effect of recyclate % and sieve on force (F_{max})

Table 1 presents a summary of the impact test results, including the recycled content and sieve thickness.

Table 1. Obtained results from impact test of composite materials with different recyclate content %

Recycled content	Thickness of sieve	F_{max}	W	U
[%]	[mm]	[N]	[J]	[J/cm^2]
0	–	1288.13	3.11	8.49
10	≥1.2	1107.2	2.42	5.95
10	≥3.0	1078.97	2.31	5.93
20	≥1.2	688.95	1.06	3.12
20	≥3.0	740.34	1.22	3.36

F_{max} – maximum strength, W – work necessary to destroy the sample, U – toughness.

Conclusions

1. Adding polyester-glass recyclate to the composite effects the resistance of this material to dynamic loads.
2. The results show that using 10% recycled additive in a polyester-glass composite reduces:
   a. the impact strength with $\Delta U \sim 30\%$,
   b. the work necessary for destruction by $\Delta W \sim 22\%$,
   c. the maximum force for destruction by $\Delta F \sim 14\%$,

   in comparison to the material without added waste (pure composite).
3. The results show that using the 20% recycled additive in the polyester-glass composite reduces:
   a. the impact strength with $\Delta U \sim 63\%$,
   b. the work necessary for destruction by $\Delta W \sim 66\%$,
   c. the maximum force for destruction by $\Delta F \sim 47\%$,

   in comparison to the material without added waste (pure composite).
4. The effect of granulation of the used waste, i.e. ≥ 1.2 mm and ≥ 3.0 mm added to the composite, has little effect on the resistance of such materials to dynamic loads in the impact test.

References

1. Asokan P., Osmani, M. & Price, A.D.F. (2009) Assessing the recycling potential of glass fibre reinforced plastic waste in concrete and cement composites. *Journal of Cleaner Production* 17 (9), pp. 821–829.
2. Barcikowski, M. & Królikowski, W. (2013) Effect of resin modification on the impact strength of glass-polyester composites. *Polimery* 58(6), pp. 450–460.
3. Bignozzi, M.C., Saccani, A. & Sandrolini, F. (2000) New polymer mortars containing polymeric wastes. Part 1. Microstructure and mechanical properties. *Composites Part A: Applied Science and Manufacturing* 31, 2, pp. 97–106.
4. Błędzki, A.K., Gorący, K. & Urbaniak, M. (2012) Possibilities of recycling and utylisation of the polymeric materials and composite products. *Polimery* 57, 9, pp. 620–626 (in Polish).
5. Gawdzińska, K., Szymański, P., Bryll, K., Pawłowska, P. & Pijanowski, M. (2017) Flexural strength of hybrid epoxy composites with carbon fiber. *Composites Theory and Practice* 1, pp. 47–50.
6. Gucma, M., Bryll, K., Gawdzińska, K., Przetakiewicz, W. & Piesowic, E. (2015) Technology of single polymer polyester composites and proposals for their recycling. *Scientific Journals of the Maritime University of Szczecin, Zeszyty Naukowe Akademii Morskiej w Szczecinie* 44 (116), pp. 14–18.
7. Habaj, W. (2008) The technological work over the production of polymer composites reinforced by short aramide fibres. *Problemy Techniki Uzbrojenia* 37, 105, pp. 61–73 (in Polish).
8. Hyla, I. (1989) Beitrag zum Schädigungs – und Bruchverhalten von faserverstärkten Verbndwerkstoffen. *Hutnictwo* 33.
9. Hylla, I. & Lizurek, A. (2002) Zastosowanie badań dynamicznych do analizy mechanizmu pękania udarowego kompozytów warstwowych. *Kompozyty* (*Composites*) 5, pp. 374–377.
10. Jastrzębska, M. & Jurczak, W. (2011) Modification of composites containing glass reinforced polyester waste. *Przetwórstwo Tworzyw* 17, 6, pp. 460–463 (in Polish).
11. Jastrzębska, M. (2011) Effect of nanofiller NanoBent® ZW1 on mechanical properties of composites containing glass reinforced polyester waste. *Kompozyty* (*Composites*) 2, pp. 111–113.
12. Kowalska, E., Wielgosz, Z. & Bartczak, T. (2002) Utilization of glass fiber-reinforced polyester laminate wastes. *Polimery* 47, 2, pp. 110–116 (in Polish).
13. Królikowski, W. (2012) *Polimerowe kompozyty konstrukcyjne*. Warszawa: PWN.
14. Kyzioł, L., Panasiuk, K. & Hajdukiewicz, G. (2018) The influence of granulation and content of polyester-glass waste on properties of composites. *Journal of KONES* 4.
15. Panasiuk, K. & Hajdukiewicz, G. (2017) Production of composites with added waste polyester-glass with their initial mechanical properties. *Scientific Journals of the Maritime University of Szczecin, Zeszyty Naukowe Akademii Morskiej w Szczecinie* 52 (124), pp. 30–36.

16. Panasiuk, K. (2018) Analysis of technologies for producing composites with polyester-glass recyclate. *Scientific Journal of Polish Naval Academy* 214(3), pp. 63–73.
17. Pickering, S.J. (2016) Recycling technologies for thermoset composite materials – current status. *Composites Part A: Applied Science and Manufacturing* 37, 8, pp. 1206–1215.
18. Rutecka, M., Kozioł, M., Myalski, J. & Śleziona, J. (2005) Utilization of composite wastes as a filler of polymer matrix in composites. *Kompozyty* (*Composites*) 2, pp. 68–73 (in Polish).
19. Rutecka, M., Śleziona, J. & Myalski, J. (2004) Estimation of possibility of using polyester-glass fiber recyclate in laminates production. *Kompozyty* (*Composites*) 9, pp. 56–60 (in Polish).