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EFFECT OF THE RECYCLATE ON A DEFLECTION OF COMPOSITES IN BENDING

Katarzyna Panasiuk, Lesław Kyzioł, Grzegorz Hajdukiewicz

Maritime University of Gdynia
Department of Mechanical Engineering
Morska Street 81-87, 81-225 Gdynia, Poland
tel.: +48 58 5586484, +48 58 5586480, +48 58 5586399
e-mail: k.panasiuk@wm.umg.edu.pl, l.kyziol@wm.umg.edu.pl
g.hajdukiewicz@wm.umg.edu.pl

Abstract

The aim of the research was to determine the effect of polyester-glass recyclate on the deflection of composite samples subjected to three-point bending. The polyester-glass recyclate was obtained from the part of the ship's hull made of polyester-glass composite, constituting scrap metal. The pieces of scrap were pre-fragmented and then processed into a prepared stand for this purpose. Such a fragmented recycling will be used to make composites with different scrap / recycled content. For this purpose, research materials were made using the vacuum bag method with the percentage of 0%, 10% and 20% recyclate) as well as various granulation (i.e. 1.2 mm and 3.0 mm). The research material consisted of rectangular plates with a thickness corresponding to the thickness of the samples. The samples for testing were made by water cutting. The tests were carried out on a suitably prepared stand, which was made of a universal Zwick Roell testing machine and three-point bending handles and a dial indicator. The spacing of the supports has been determined in accordance with the binding standard for three-point bending. Obtained results from tests, i.e. strain, stress, deflection, deformation allowed analysing the impact of recyclate on bending strength and defining the deflection arrow. Based on the results obtained from three-point bending, it can be concluded that the polyester-glass recycling has an influence on the decrease of strength, stress and deflections of the tested composites.

Keywords: *recycling, three-point bending, composites, new materials, force-strain curves*

1. Introduction

Composite materials are a competitive alternative to traditional metallic materials due to their lower density, higher stiffness, higher strength and better resistance to fatigue compared to steel or aluminum. Such properties allow composites to be used in the aerospace and automotive industries [2, 3]. The quasi-static and dynamic load of the composite causes complex damage mechanisms, including many delamination than other composite materials [15]. Bending is one of the basic methods of determining the bending strength and modulus of elasticity in bending, the yield stress and deformation in bending. From the distribution of normal stresses when bending it follows that in the middle plane of the beam is equal to zero, therefore the modulus of elasticity in tension, compression and bending are equal. In the case of composites whose modulus of tension and compression are different, this means that the normal stresses are not equal in the centre plane of the beam. Bending tests use three-point bending or four-point cubic beams. Flexural strength is a parameter describing the greatest stress that arises in the material at the time of fracture. The important parameters of the measurement system are load, loading speed, type of loading ram, sample geometry and the range of maximum deflection applied [10].

The use of a three-point support bending test to predict the stiffness of anisotropic composite bending plates tested by Nunes et al. and the results obtained show that the behaviour of composites in bending depends on several factors, such as fibre orientation, layering, waviness of the surface and forming temperature [9]. Several methods have been proposed for determining the mechanical properties of laminated composite materials. These methods include several sample configurations with different static-weight laminate designs. In the case of laminating composites with unidirectional fibre arrangement, mechanical properties can be divided into two main categories: normal and shear properties. When it comes to shear or interlayer properties, there are many different shear test methods depending on the geometry of the sample, the type of load used and the laminate configuration [6]. A lot of research has been carried out on the bending properties of the composite laminate, taking into account several factors such as fibre orientation, laminate laying and production conditions [1, 4-6].

The article analyses the impact of polyester and glass recyclate on the mechanical properties of composites subjected to three-point bending. In principle, bending tests are not recommended to determine the parameters necessary for designing, because the bending beam has a complex state of stress and stress concentration on the supports and under the attacking mandrel in bending three-point beam [16]. Therefore, bending tests were treated as tests complementing the strength properties of the tested composites [7, 8, 11-13].

2. Research methodology

The polyester-glass recyclable added to the new composite was made from the part of the ship's hull made of polyester-glass composite. The research materials were made using the vacuum bag method with different percentage of recyclate successively: 0%, 10%, 20%), as well as different granulation (i.e. 1.2 mm and 3.0 mm), with reinforcement with an accidental fibre direction. Composite samples for nominal size measurements of 80x15x6 mm were prepared from composite materials by water cutting method (Fig. 1) in accordance with the PN-EN ISO 14125: 2001P standard [14]. The tests were carried out on a universal Zwick Roell testing machine, using three-point bending handles as well as a dial indicator. The spacing of supports was 60 mm. Fig. 2 shows a picture of bending test specimens.

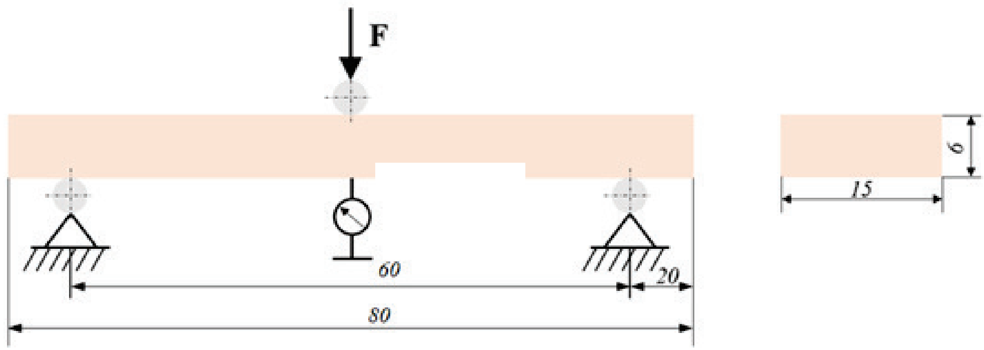

Fig. 1. Support and load diagram of the composite sample

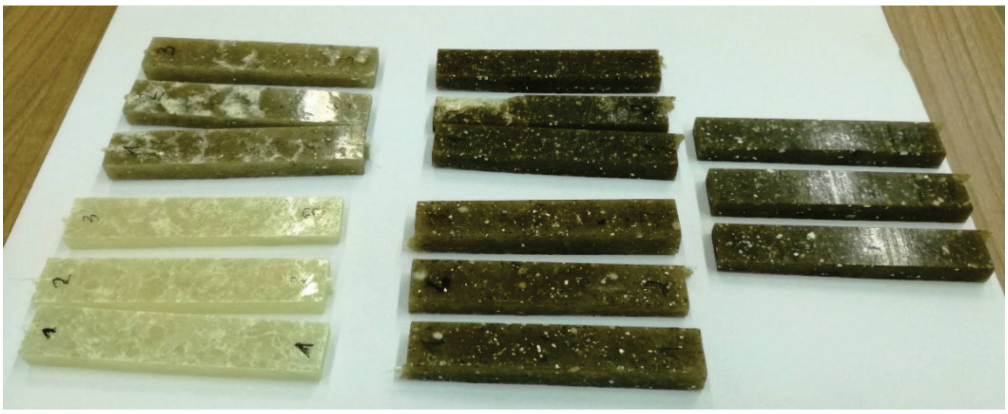

Fig. 2. Samples prepared for three-point bending tests

Figure 3 shows the tooling together with a three-point bending sample

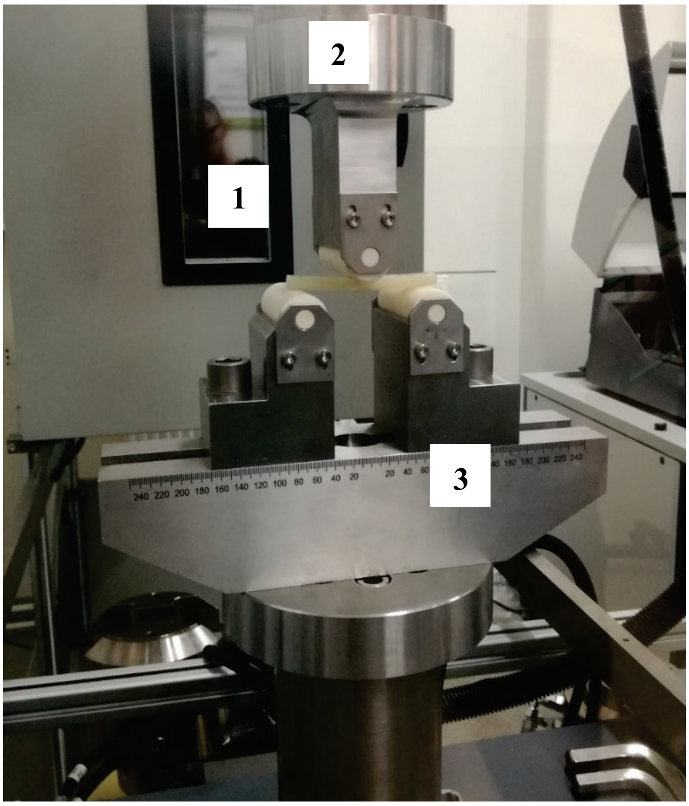

Fig. 3. Zwick Roell testing machine with three-point bending equipment and a fixed sample
1 – sample, 2 – thrust, 3 – support

Figure 4 shows an example of a sample image after the three-point bending process, the places of the applied load are visible.

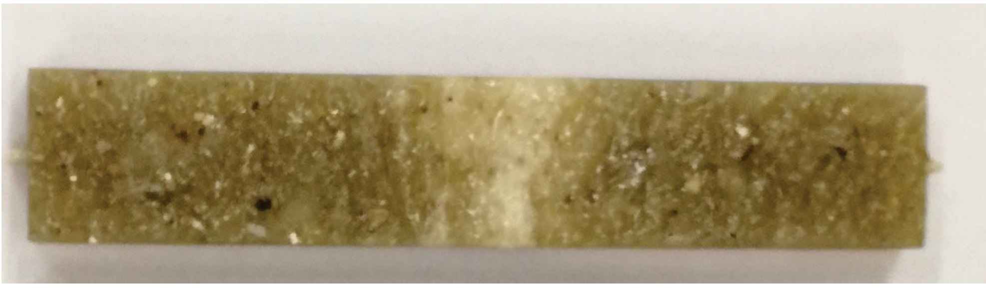

Fig. 4. The sample after the three-point bending test

3. Research results

Five composites characterized by different recyclate content, glass mat and resin were tested.

Table 1 shows the averaged results from 5 samples obtained from three-point bending tests with standard deviation. At the same time, the designations of materials have been introduced in such a way that:

- WP0 – composite without recyclate,
- WP10.1.2 – 10% recyclate with a grain size of 1.2 mm,
- WP10.3.0 – 10% recyclate with a grain size of 3.0 mm,
- WP20.1.2 – 20% recyclate with a grain size of 1.2 mm,
- WP20.3.0 – 20% recyclate with a grain size of 3.0 mm.

Tab. 1. Bending results of composite samples made using the vacuum bag method

	R_{mg}	f	F
	MPa	mm	N
WP0			
Average value	189	3.79	1457
Standard deviation	2	0.33	48
WP10.1.2			
Average value	150	3.67	1341
Standard deviation	16	0.24	69
WP10.30			
Average value	147	3.8	1180
Standard deviation	17	0.25	82
WP20.1.2			
Average value	66	2.88	615
Standard deviation	1	0.92	101
WP20.3.0			
Average value	58	2.46	479
Standard deviation	8	0.58	98

Figure 5 shows the force-deflection diagram for three-point bending of samples made with the vacuum bag method from a composite without recyclate.

Figure 6 shows the force-deflection diagram obtained from the three-point bending test on samples made with the vacuum bag method, material with 10% recyclate content, granulation ≤ 1.2 mm and ≤ 3.0 mm.

Figure 7 presents stress-deflection chart obtained from three-point bending tests on samples made with the vacuum bag method, material with 20% recyclate content with granulation ≤ 1.2 mm and ≤ 3.0 mm.

Figure 8 shows the effect of recycled content on bending strength.

Figure 9 shows the effect of the recycled content on sample deflection in a three-point bending test. Values in points are averaged values from 5 samples.

On the basis of the results presented in Figs. 5-9 in the form of graphs and in Tab. 1, the previous results [7, 8, 11-13] of the impact of recycled content on the change of mechanical properties of the material are confirmed.

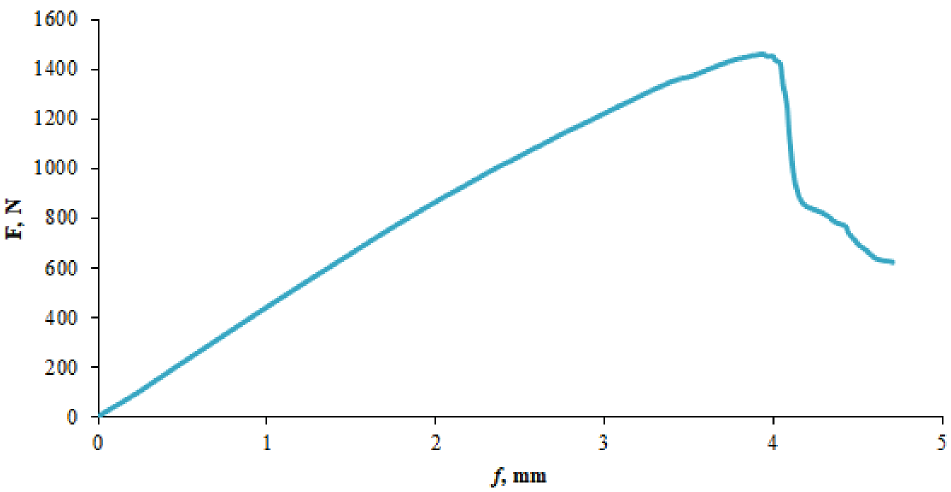

Fig. 5. Force-deflection graph obtained based on three-point bending composite without recyclate – WP0

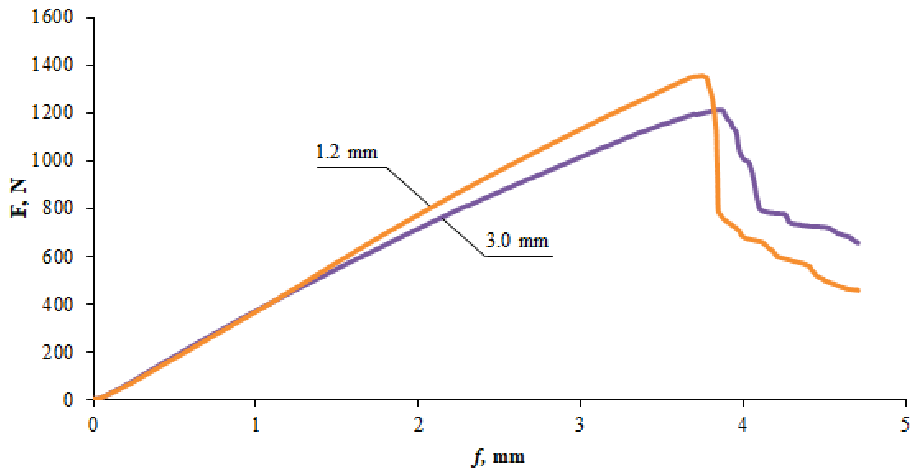

Fig. 6. Strength-deflection plot, obtained on the basis of three-point bending composite with 10% recyclate content and granulation ≤ 1.2 mm and ≤ 3.0 mm (WP10.1.2; WP10.3)

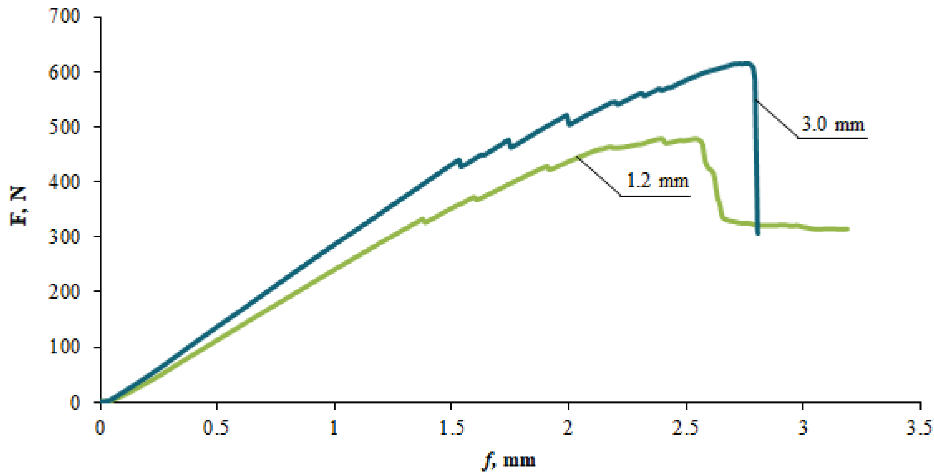

Fig. 7. Strength-deflection curve, obtained based on three-point composite bending with 20% recycled content and granulation ≤ 1.2 mm and ≤ 3.0 mm

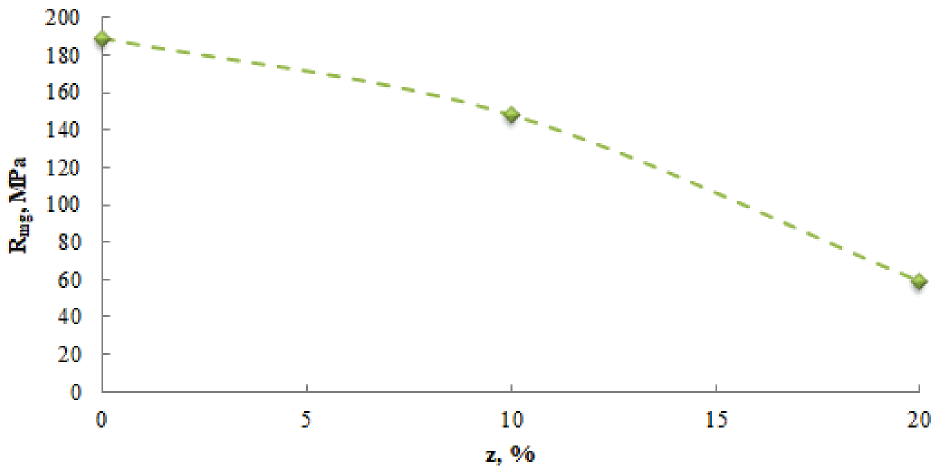

Fig. 8. The effect of recycled content on bending strength

4. Analysis of results and conclusions

Composite samples characterized by different recyclate content, subjected to a three-point bending test showed a decrease in flexural strength with increasing recyclate content in relation to

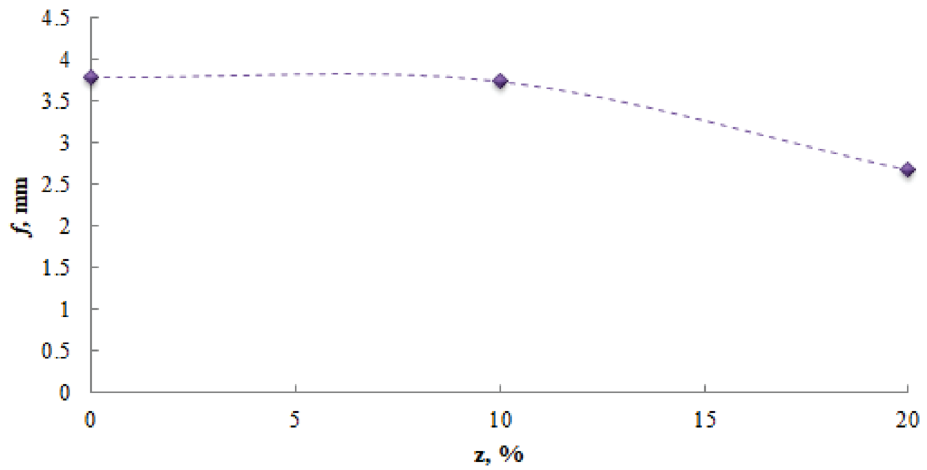

Fig. 9. Effect of recycled content on beam deflection in the three-point bending test

the composite without recyclate. In particular, the composite with a content of 10% recyclate and granulation ≤ 1.2 mm and ≤ 3.0 mm, shows a decrease in ΔRmg by 20% and 25% respectively in relation to the composite without recyclate. The increase of the granulate size of the slightly reduces the bending strength. Composite with a content of 20% recyclate and granulate size ≤ 1.2 mm and ≤ 3.0 mm, shows a decrease in bending strength of ΔRmg 60% and 70%, respectively.

Like the bending strength, the maximum bending forces decrease with the increase of the granulate content. In particular, for a composite with a content of 10% recyclate and a granulate size of 1.2 mm and 3.0 mm, the bending force was reduced by ΔF 8% and 19% respectively in relation to the composite without recyclate. In the case of materials with 20% recyclate content and a granule size of 1.2 mm and 3.0 mm, the bending force was reduced by 58 and 67% in relation to the composite without the addition of recyclate.

The results of the three-point deflection showed that the increase of the recycled content causes a decrease in the deflection while the bending force decreases. This indicates low stiffness of the material.

The conducted three-point bending tests, earlier tests of static gaps and the analysis of composites with the use of polyester-glass recyclate showed that the recyclate contained in the composite above 10% causes a significant reduction in its mechanical and plastic properties. The higher recycled content means that the elastic deflection is low for low values of loading forces. In addition, it has been found that the granulate size affects the properties of the composite. With more recycled granules, the structure becomes loose, slightly compact, large inclusions / grains cause the material to become brittle, has elasticity only in the low load range. In any case, for a composite with the same recycled content but different granulation, a composite with a fine and compact structure always has higher properties.

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