

IMPACT TESTING OF CARBON FIBER-EPOXY RESIN COMPOSITE WITH GRAPHENE

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Abstract

The article presents the state of knowledge in the field of dynamic tests with the use of Drop Tower devices of the impact energy of a spherical pivot 18 J. Developed structures of composite samples were presented, with dimensions of 150×100 mm, consist of unidirectional prepreg MTM46/HTS (12K)-150-35% RW and adhesive film with and without addition of graphene plane. The impact strength of these composites panels were investigated according to ASTM D7136/7136M-15 method. Relationship between impact force versus time during impact test was presented. Relationship between deformation and impact energy in the time of the test was also consulted. The type and degree of samples destruction were observed by the microscope. The effect of graphene addition on the properties of carbon fiber-epoxy resin composites were determined.

Keywords: composite, graphene, composite with graphene, drop tower impact test.

1. INTRODUCTION

Polymer composites, including carbon fiber-epoxy resin composites, are broad scale used as structural components in the automotive, aviation, aerospace industry [1÷4]. Due to well-known limitations in application of such materials numerous solutions to eliminate or reduce the disadvantages of their features were proposed. One such solution is to make the composite material even more complex by the inclusion in its composition nanofillers. Nanofillers not eliminate the positive features of polymer composites, such as low weight, high stiffness, high fatigue resistance, and at the same time introduce new advantageous properties. The example can be a reduction in brittleness of the composite material, which has a further influence on increasing the resistance of delamination and cracks, and that kind of destructions are undesirable in aircraft structures [5 ÷ 7].

Nowadays, one of the most interesting and advanced nanofiller is graphene. The addition of graphene to polymer composites has complex effects on the properties of the composite material. The tensile strength of composites with graphene is shaped twofold. A small addition of graphene (less than 1 wt.%) results in an increase in tensile strength up to 25%. On the other hand, when the graphene content in the composite is more than 1 wt.%, graphene composites have worse properties than material without graphene reinforcement. Similar situation occurs in bending tests [8]. The bending strength properties decrease with increasing graphene percentage in the composite, due to the difficulty of uniform dispersion of graphene in the resin with the increasing mass fraction of the

nanofiller. In addition, the high content of graphene increases the viscosity of the resin, resulting in the formation of voids in the structure, which negatively affects the composite properties.

Apart from the influence on the mechanical properties of composites graphene contributes to a better thermal resistance of the material, therefore, the graphene coating can be used as an element lowering the ignition of the composite parts [9, 10].

Quoted works on strengthening the carbon fiber-epoxy resin composites concern using reduced graphene oxide in forms of flakes with dimensions not exceeding a few hundred nanometers. There is no data on the production and properties of composites reinforced with larger graphene structures. This paper presents methods for producing composites reinforced with graphene in a form of planes with dimensions of 90×100 mm and shows the effect of the addition of such graphene on an impact resistance of composites.

The aim of this study was to determine the impact resistance of composite panels with graphene of dimensions of 90×100 mm and for comparison composites without graphene. The impact strength was determined according to ASTM D 7136 / 7136M-15 method with the use of Drop Tower devices.

2. COMPOSITE SAMPLES USED IN IMPACT TEST

For testing the behavior of material after impact composite samples were prepared (Fig. 1). The samples were cut from composite plates and were made from layers of unidirectional prepreg MTM46 /HTS (12K)-150-35% RW type which was cured in an oven. Composite panel consisted also of 6 layers of adhesive film and adhesives film with graphene (Fig. 1).

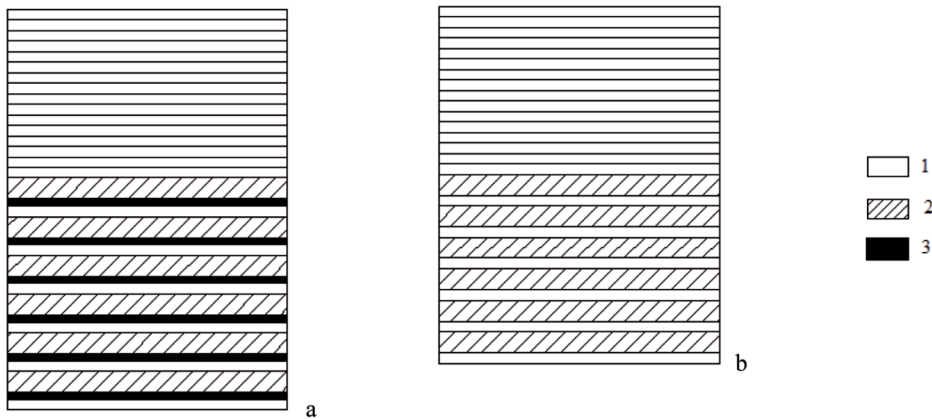


Fig. 1. Vertical cross-section scheme of the arrangement of prepreg, adhesives films layer and graphene plane in composite samples: a – sample with graphene and b – without graphene.

1 – prepreg layer, 2 - adhesive film, 3 – graphene sheet [Salacinska, 2016]

Fabricated composite samples measuring 100×150 mm consisted of 20 layers of prepreg, 6 layers of adhesive film with 6 graphene plane or without graphene.

For impact testing the following composites sample were prepared: samples with layers of adhesive film without graphene – (KB) and adhesive film with graphene (GKB). The orientation of unidirectional prepregs was as follows:

1. Sample with adhesive film only [45/KB/0/KB/-45/KB/90/KB/90/KB/-45/KB/0/ 45/45/0/-45/-45/0/45],
2. Sample with adhesive film and graphene: [45/KBG/0/KBG/-45/KBG/90/KBG/45/KBG/0/KBG/-45/90/45/0/-45/90/45/0].

The taken samples consisted of graphene layers with dimensions of 90×100 mm, so the graphene planes size was smaller than the composite samples.

3. DYNAMIC TEST OF GRAPHENE COMPOSITE SAMPLES

3.1. Impact test of samples

The impact tests were performed on Instron Drop Tower 9350 (Fig. 2). The samples and test procedure were made in accordance with ASTM D7136 method. From each composite panel two samples were cut. On one side of each sample, between the outer layers of the prepreg the adhesive film were incorporated (Fig. 1). Impact tests were performed from the opposite side, in the central part of the adhesive film.

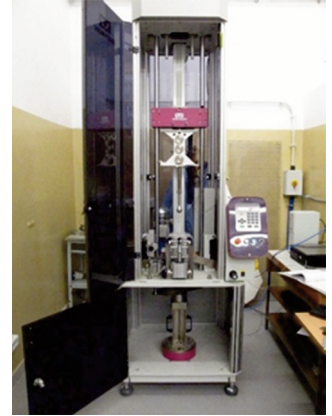


Fig. 2. Instron Drop Tower 9350 test machine [Wisniewski, 2016]

The samples were placed on an anvil of the test machine and pressed by a pneumatic presser. Views of the sample before and after pressing are presented in Figure 3.

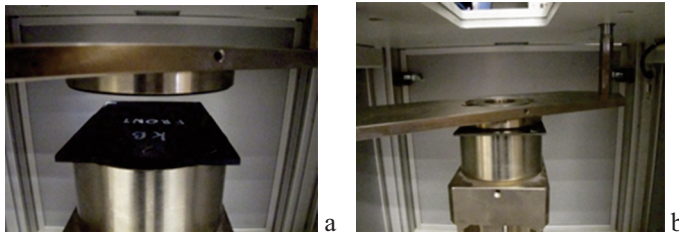


Fig. 3. The sample on anvil of test machine: a – before pressing, b – after pressing [Wisniewski, 2016]

After the impact test measuring the depth of dent was made. The measuring stand is shown in Figure 4.

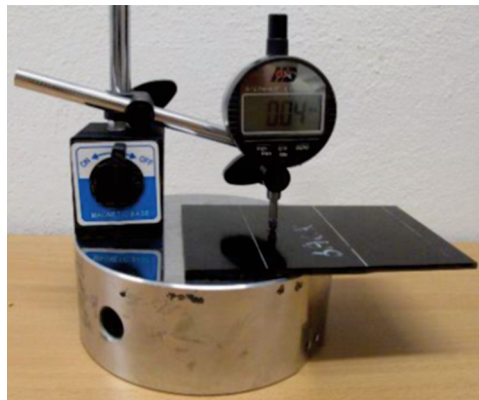


Fig. 4. Measuring stand for identification of the dent depth [Wisniewski, 2016]

Parameters of an impact test condition, which are identical for all samples, are shown in table 1.

Table 1. Impact test parameters

Impact energy	18 J
Impactor weight	5088 g
Impactor diameter	1.5''
Drop height	360 mm
Internal diameter of anvil	74 mm
Downforce to the anvil	1000 N

During the impact test fixture a few parameters were recorded such as: the force of penetration of impactor into the sample, the sample deformation, energy and speed of impactor versus time. Figure 5 shows the recorded force as a function of time during the impact test of the samples from panels G-0.2÷0.5 with or without the graphene plates, where KB1, KB2 (sample with adhesive film) and GKB1 (samples with graphene).

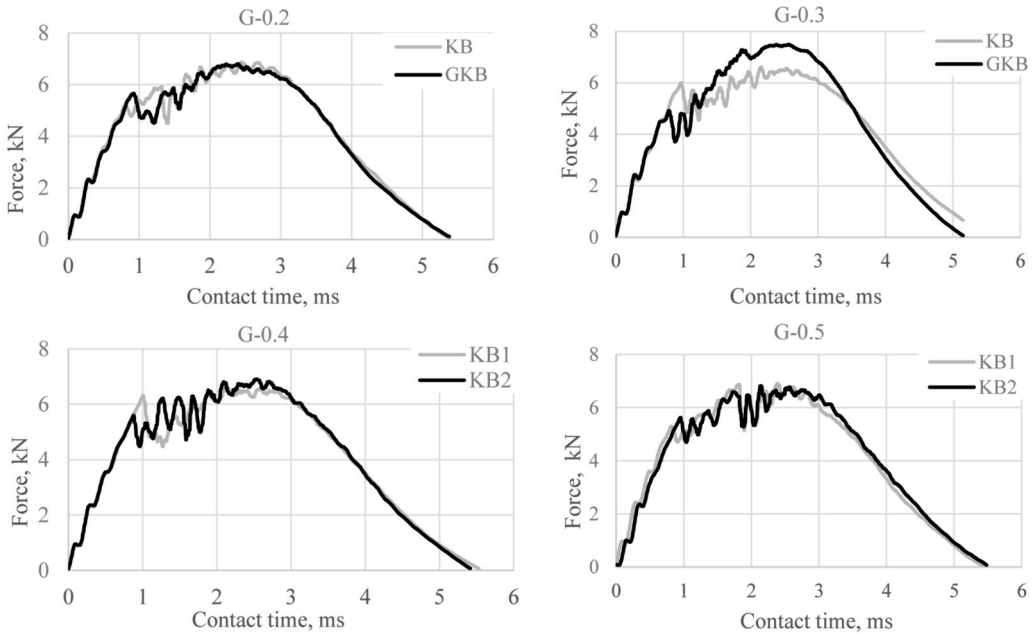


Fig. 5. Force vs time relationship in impact test for samples from panels: G-0.2÷G-0.5 (KB, KB1, KB2 – samples with adhesives film; GKB and GKB1 – samples with adhesives film and graphene) [Wilk, 2016]

Figure 6 shows the depth of deformation in the impact test.

The next examined parameter was the energy of impact, which was shown in Figure 7.

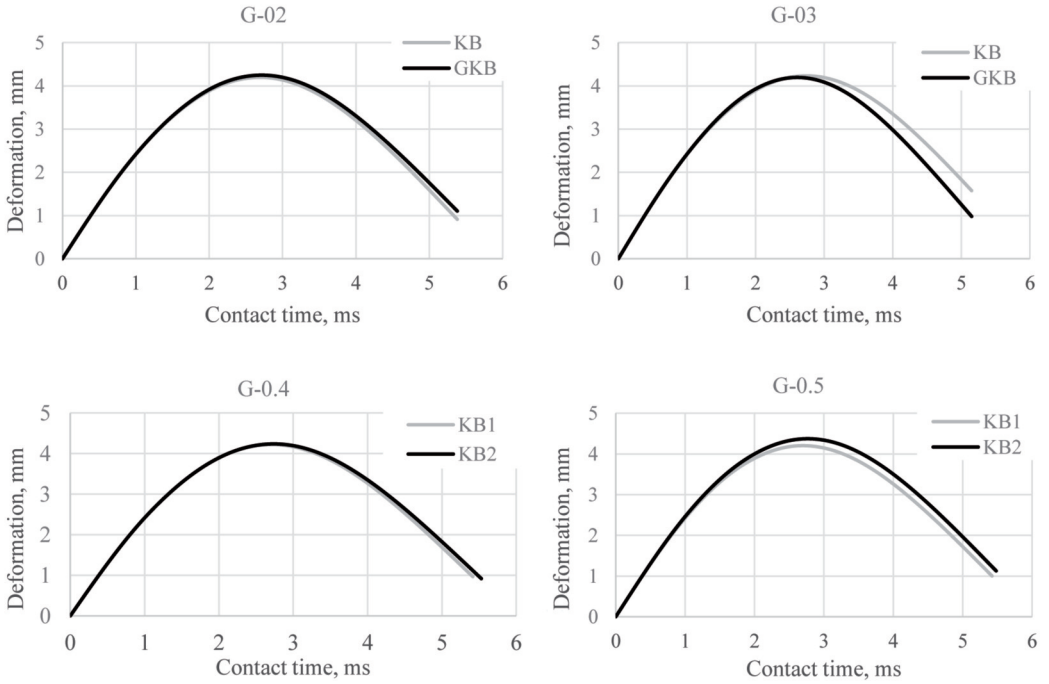


Fig. 6. Deformation vs time relations in the impact test for samples from panels: G-0.2÷G-0.5 (KB, KB1, KB2 – samples with adhesives film; GKB and GKB1 – samples with adhesives film and graphene) [Wilk, 2016]

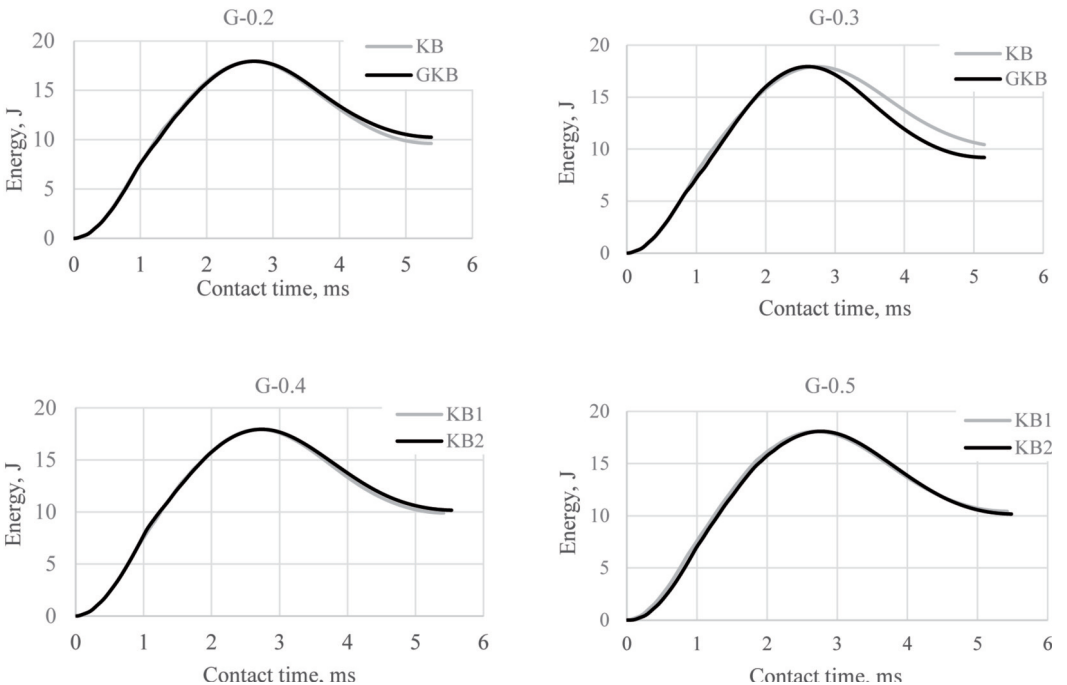


Fig. 7. Energy vs time relations in impact test for samples from panels: G-0.2÷G-0.5 (KB, KB1, KB2 – samples with adhesives film; GKB and GKB1 – samples with adhesives film and graphene) [Wilk, 2016]

Figure 8 shows the velocity of impactor during impact test.

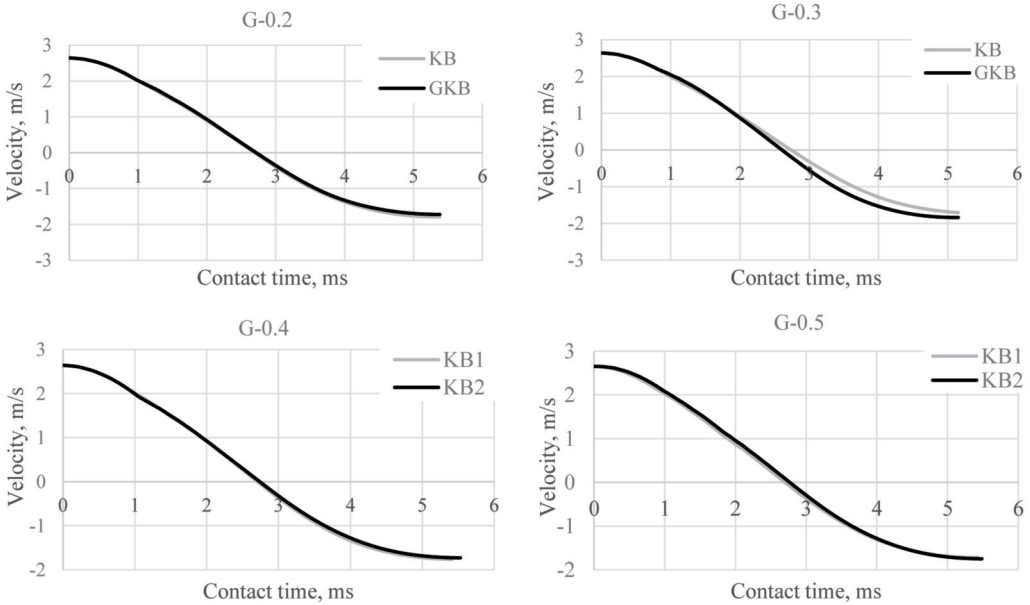


Fig. 8. Impactor velocity vs time relations in impact test for samples from panels: G-0.2÷G-0.5 (KB, KB1, KB2 – samples with adhesives film; GKB and GKB1 – samples with adhesives film and graphene) [Wilk, 2016]

Presented on graphs relationships indicate that the produced materials - sample composites with graphene and without graphene, react in the same way on the destruction caused by the impact. Incorporation of graphene to composite structure has no effect on the properties of the material. It can be due to a small mass share of graphene in the sample. Nevertheless, received relationships allow to be sure that the introduction of graphene does not weaken the properties of the material, and thus developed method of manufacturing such materials is a well-promising one.

3.2. Microscope observation of sample after impact test

All samples cut from the panels G-0.2÷G-0.5 were subjected to microscope observation after the impact test with the use of Leica Microscope. For each sample 3 area was observed: the edge of the area with adhesive film (OZKB), transition area (OP) and the area without adhesive films (OBKB). Pictures were taken from both sides of the samples (a – left side and b – right side), ie. 6 images per each sample. In addition, the surface of samples in the place of impact (POW) were shown. Figures 9÷14 presenting all samples come from panels G-0.2÷G-0.5 after the impact test.

Microscope observations show a very similar way of destroying the samples after impact. The extent and the shape of the damage were the same. The exception is a sample of graphene-G 0.3-CAI-GKB-RTA-01, where on the surface any traces of destruction were observed. To deduce further conclusions about the effect of graphene on the surface condition it is necessary to examine more samples.

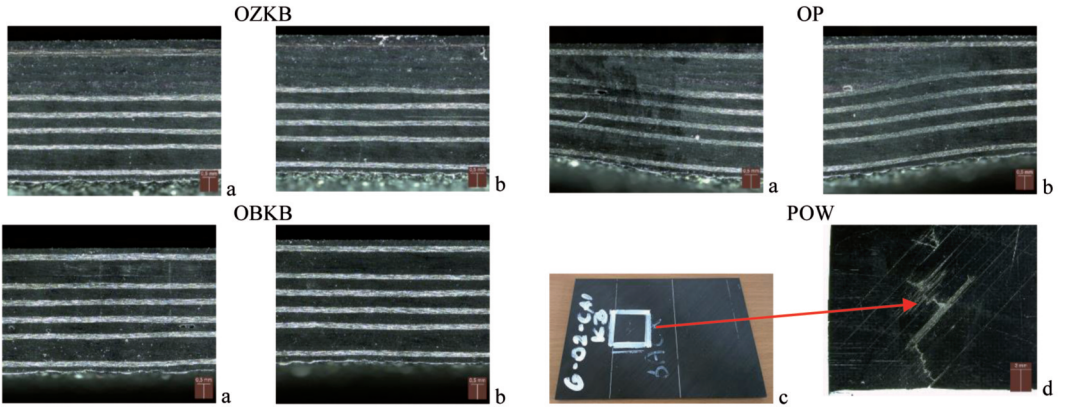


Fig. 9. The view of edges and surface of sample G-0.2-CAI-KB-RTA-01 with adhesive film only after the impact test: a, b – left and right side of edges; c – surface of the whole sample, d – sample surface in impact area [Salacinska, 2016]

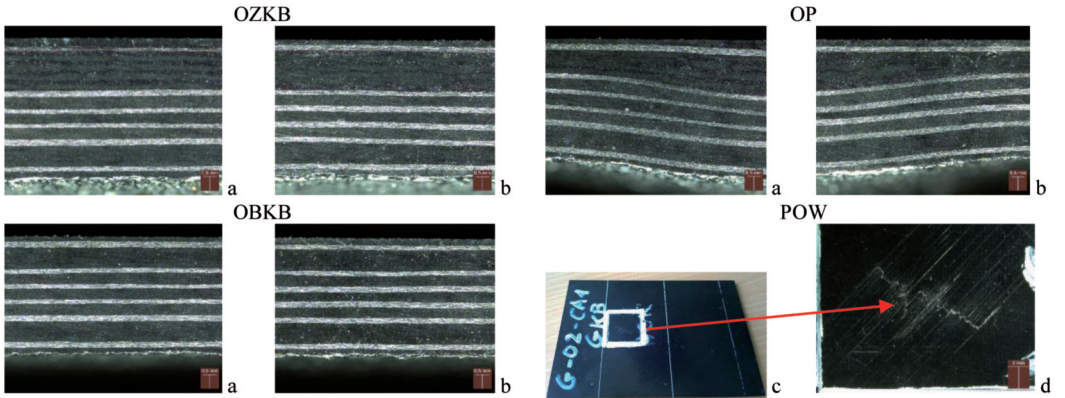


Fig. 10. The view of edges and surface of sample G-0.2-CAI-GKB-RTA-01 with adhesive film and graphene after the impact test: a, b – left and right side of edges, c – surface of the whole sample, d – sample surface in impact area [Salacinska, 2016]

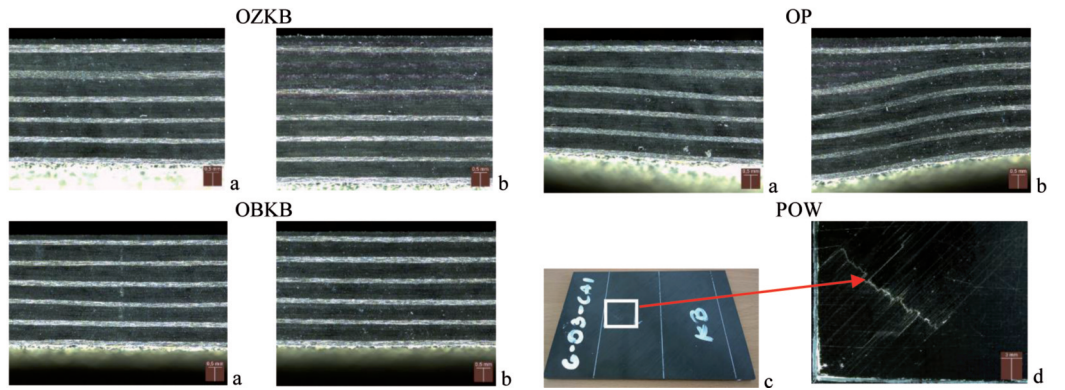


Fig. 11. The view of edges and surface of sample G-0.3-CAI-KB-RTA-01 with adhesive film only after impact test: a, b – left and right side of edges; c – surface of the whole sample, d – sample surface in impact area [Salacinska, 2016]

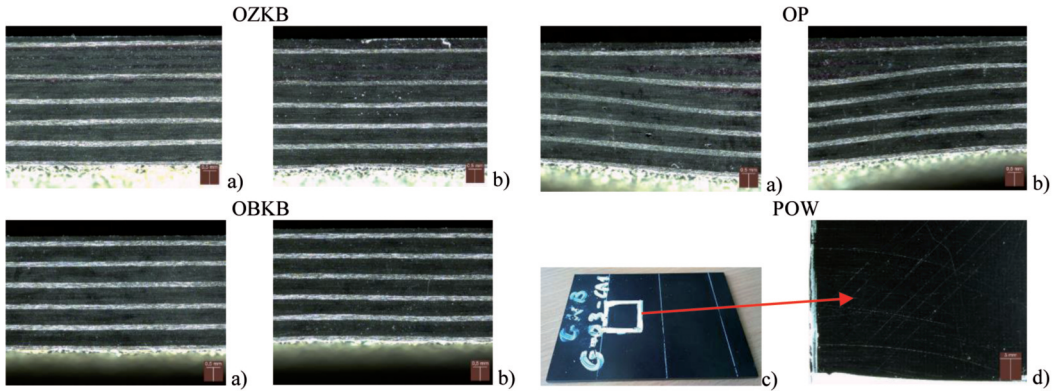


Fig. 12. The view of edges and surface of sample G-0.3-CAI-GKB-RTA-01 with adhesive film and graphene sheets after impact test: a, b – left and right side of edges, c – surface of the whole sample, d – sample surface in impact area [Salacinska, 2016]

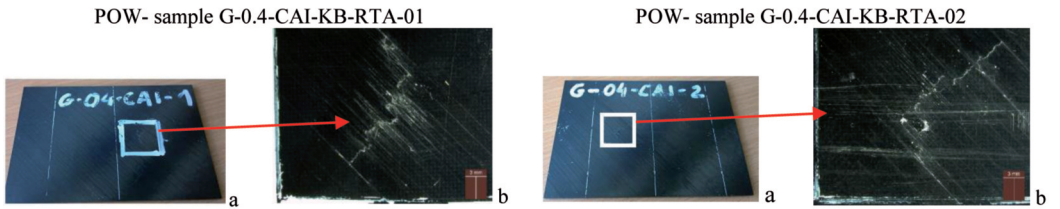


Fig. 13. The view of surface of samples G-0.4-CAI-KB-RTA-01 and G-0.4-CAI-KB-RTA-02 with adhesive film without graphene after impact test: a – surface of the whole sample, b – sample surface in impact area [Salacinska, 2016]

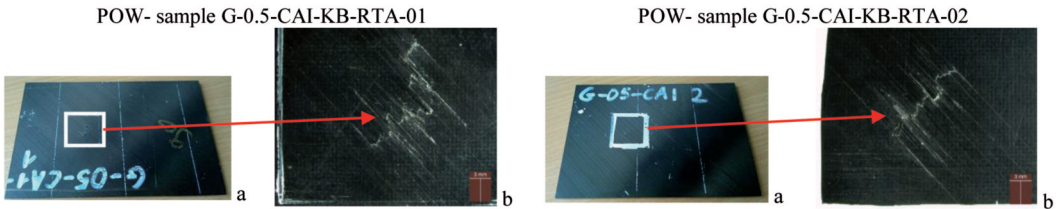


Fig. 14. The view of surface of samples G-0.5-CAI-KB-RTA-01 i G-0.5-CAI-KB-RTA-02 with adhesive film without graphene after impact test: a – surface of the whole sample, b – sample surface in impact area [Salacinska, 2016]

4. CONCLUSIONS

Based on the presented tests the following conclusions were drawn:

1. The impact test carried out on samples with and without graphene showed no change in the response of the material to impact. Gathered relationship for samples with and without graphene were identical. No differences in the process of destruction of the sample caused by impact or in the size of damage were observed.
2. The developed method of graphene reinforced composite panel fabrication does not influence impact properties of the material, and what is important does not weaken the composite.
3. The lack of positive influence of graphene on material impact properties may be due to its small mass and volume percentage in the sample.

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TESTY UDERZENIOWE KOMPOZYTÓW WĘGLOWO-EPOKSYDOWYCH Z GRAFENEM

Streszczenie

W artykule przedstawiono stan wiedzy w zakresie badań dynamicznych z zastosowaniem urządzenia Drop Tower o energii uderzenia trzpienia kulistego 18 J. Przedstawiono opracowane konstrukcje wykonanych płyt kompozytowych z użyciem preimpregnatu jednokierunkowego MTM46/HTS(12K)-150-35%RW o wymiarach 150×100 mm z klejem błonkowym i płyt kompozytowych z grafenem na nośniku z kleju błonkowego. Wykonano badania wytrzymałości tych płyt na uderzenie według normy ASTM D7136/7136M-15. Przedstawiono wykresy zależności siły od czasu podczas uderzenia próbek oraz zależności głębokości deformacji i energii uderzenia od czasu w próbie uderzenia. Oceniono sposób i stopień zniszczenia próbek z zastosowaniem mikroskopu. Określono wpływ grafenu na właściwości kompozytu węglowo-epoksydowego.

Słowa kluczowe: kompozyt, grafen, kompozyty z grafenem, drop tower test.