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COMPRESSION AFTER IMPACT TESTING OF CARBON-EPOXY RESIN COMPOSITES SAMPLES WITH GRAPHENE

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Abstract

The article presents compression after impact test of composite samples with graphene. In the presented research, graphene (in the form of a planes of (dimensions) 90×100 mm on adhesive film as a media agent were applied. Fabricated composite structures made of unidirectional prepreg MTM46/HTS(12K)-150-35%RW with dimensions of 150×100 mm with adhesive films and composite panels with graphene on adhesive films were presented. For samples with and without grapheme, the results of a Compression After Impact (CAI) test with compression speed of 0.005 mm/s were shown. The relationship of force versus displacement for samples with an adhesive film and graphene on an adhesive film were investigated. Studies on residual compressive strength show large differences in compressive strength for samples with graphene and without graphene. It was determined that the obtained differences are due to various locations of destruction. The destruction of the sample was not concentrated at the place of impact, but in the place where the border of the adhesive film flashed. It was found that at the upper edge of the sample partial propagation of destruction caused by the impactor occurred.
Keywords: composite, graphene, composite with graphene, CAI test.

1. INTRODUCTION

Due to the advantageous properties of composites, including polymer composites, ie. low weight, high stiffness and resistance to fatigue loading conditions, compared to metal alloys, composites are increasingly applied mainly in the automotive industry (cars), aviation and space (satellites), sporting goods (skis), as well as in items of common use (household goods) [1÷4].

The polymer composite has small hardness, as a result of which the impact of such composite can cause delamination and cracks. In order to improve mechanical and electrical properties of polymer matrix composites the reinforcement in the form of nanofillers such as carbon nanotubes, nanofibers, carbon black, and recently graphene were added [5].

The addition of graphene to carbon fiber-epoxy resin composites improves the properties of such a material, ie.: compressive strength of the composite, residual strength after impact, resistance to cracking and delamination, and shear coefficient [5, 6].

Suitable addition of graphene also has the beneficial influence on the tensile and flexural strength of the material [7], and increases thermal conductivity [8, 9].

This article presents the influence of graphene on carbon fiber-epoxy resin composites residual compressive strength. Graphene planes of 90×100 mm on adhesive film were used. Compression after impact test were done according to ASTM D7137/7137M-12 procedure. The samples applied was after impact test. The aim was to compare the residual strength of graphene reinforced and unreinforced composite material.

1. COMPOSITE SAMPLES USED IN CAI TEST

For testing the behavior of material after impact composite samples were prepared (Fig. 1). The samples were cut from composite plates (Fig. 2) and were made from layers of unidirectional prepreg MTM46/HTS(12K)-150-35%RW type which were cured in an oven. Composite panel consisted also of 6 layers of adhesive film and adhesives film with graphene (Fig. 1).

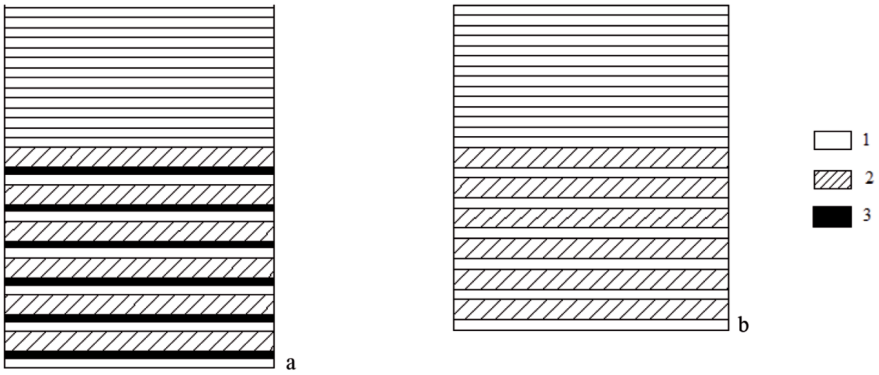

Fig. 1. Vertical cross-section scheme of the arrangement of prepreg, adhesives films layer and graphene plane in composite samples: a – sample with graphene and b – without graphene, 1 – prepreg layer, 2 – adhesive film, 3 – graphene sheet [own work]

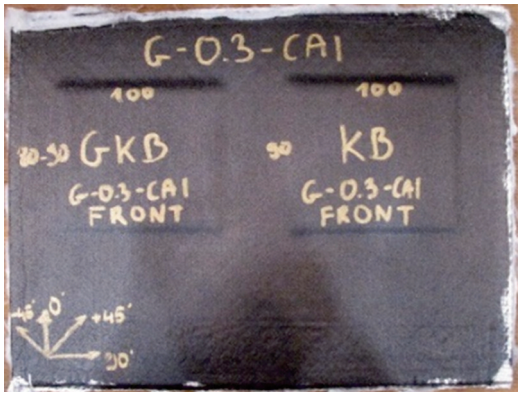

Fig. 2. Composite panel with layers of adhesive film (KB) and adhesive film with graphene (GKB) [own work]

Fabricated composite samples measuring 100×150 mm (Fig. 2) 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 adhsive 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 (Fig. 2).

2. COMPRESSION AFTER IMPACT TEST OF COMPOSITE SAMPLES

Compression after impact test were conducted according to ASTM D 7137 procedure with the use of MTS322 Test Frame devices (Fig. 3).

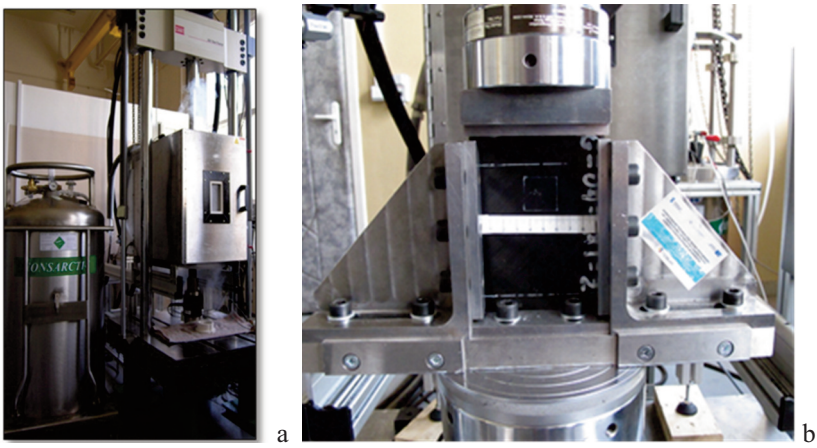

Fig. 3. CAI test fixture: a – machine for material strength determination MTS 322, b – fixture for CAI test with mounted sample [own pictures]

Firstly, CAI tests were carried out with samples without graphene from G-04 G-CAI and CAI-05 composites panel. Figure 4 shows the results of CAI test.

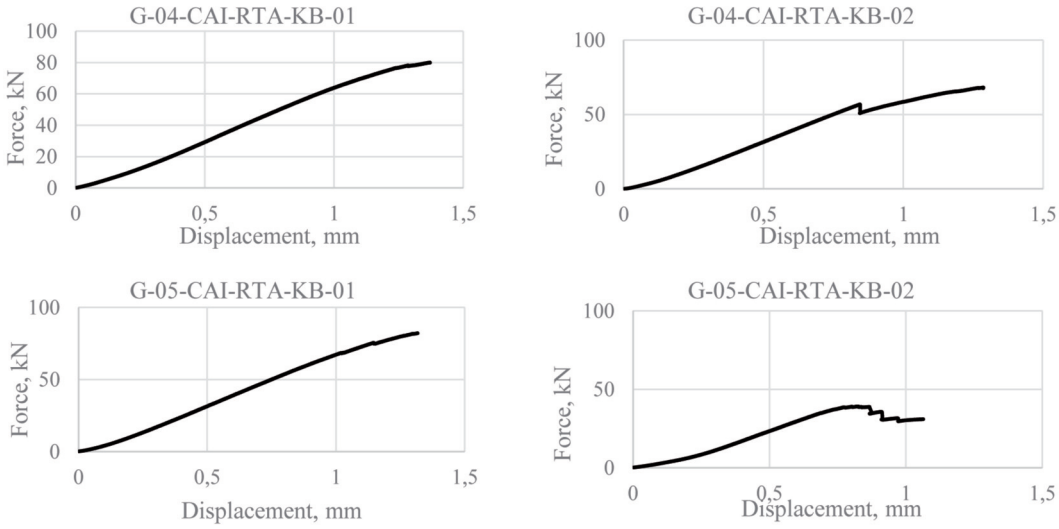

Fig. 4. Compressive force vs displacement in CAI test for composite panels with adhesive film [own work]

Destructive force during the test was not targeted at the place of damage caused by drop-weight impact test and hence not resulting in the crack propagation of impact destruction. Samples were destroyed in areas where the adhesive film layers ended. In addition, non-uniform thickness of the samples (due to the fact that the part of the sample contains more layers) caused difficulties in the proper placement of the samples in the test fixture, and generated destruction round at the edge of the samples. Hence, the obtained results are characterized by huge value variations of the maximum failure force in the range of 40÷80 kN (Fig. 4).

Before carrying out other tests on graphene reinforced samples (from panels G-02 G-CAI and CAI-03) the thickness of the samples was equalized. Samples were immersed in epoxy resin and then polished to original dimensions 100×150 mm (Fig. 5). This operation aimed at increasing the stability of the sample in the test fixture, thereby reducing the probability of sample failure at an undesirable location.

Fig. 5. Sample during immersion in epoxy resin and grinding to origin dimensions 100×150 mm

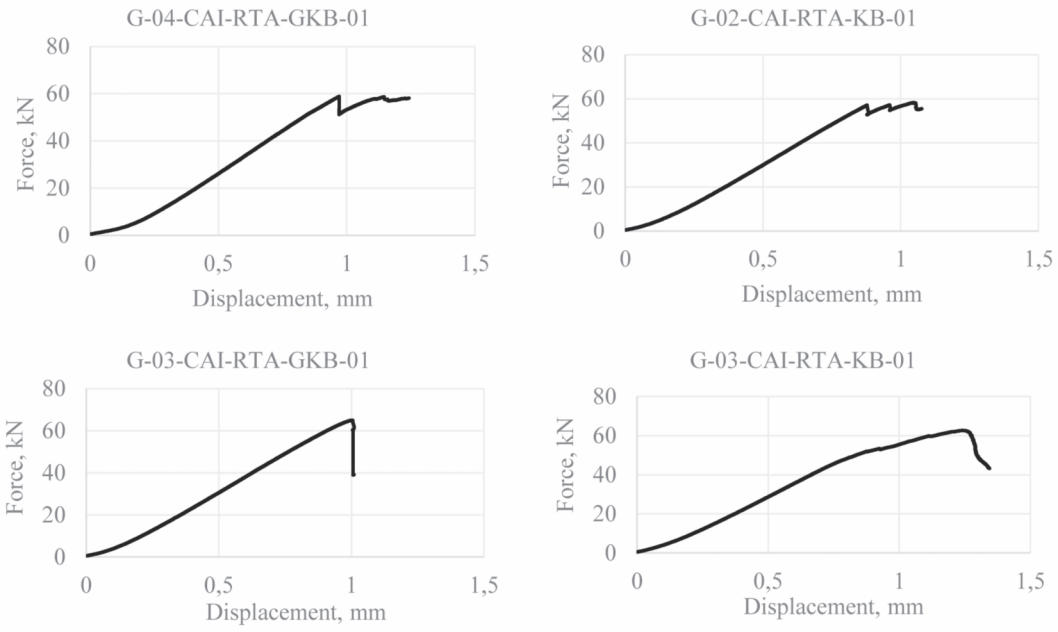

Fig. 6. Results of CAI test for samples from G-02-CAI and G-03-CAI panels [own work]

Samples with adhesive film (KB) and the adhesive film and graphene (GKB) from panels G-02-CAI and G-03-CAI, prepared in such a way, were subjected to the CAI test. The results were presented as force versus displacement relationship on graphs shown in Figure 6.

Table 1 summarizes the results of the residual strength and maximum force of the samples in CAI test. All samples were destroyed at the location where the adhesive film edges occurred: in the location of the upper edge or in the center of the sample. Only in one case propagation of delamination caused by the impact in Drop Tower test was observed.

Table 1. Summary of the results of CAI test for all samples

Sample designation	Force prior to failure, P_{max}, kN	Residual strength, F, MPa	Region of failure
G-02-CAI-RTA-GKB-01	59,24	125,42	central part of the sample – boundary of adhesive film
G-02-CAI-RTA-KB-01	58,32	123,59	central – boundary of adhesive film
G-03-CAI-RTA-GKB-01	64,98	137,51	central – boundary of adhesive film
G-03-CAI-RTA-KB-01	62,65	132,83	upper edges of sample
G-04-CAI-RTA-KB-01	80,08	168,13	upper edges of sample
G-04-CAI-RTA-KB-02	68,14	144,30	central – boundary of adhesive film
G-05-CAI-RTA-KB-01	82,20	173,71	upper edges of sample, partial propagation of impact delamination
G-05-CAI-RTA-KB-02	39,16	82,62	central – boundary of adhesive film

Figure 7 shows the sample after CAI test. Arrows marked on the white rectangles in the drawings indicate the place of destruction in impact test on Instron 9350 Drop Tower, and the arrows on top of the sample the damage caused in the sample after CAI test.

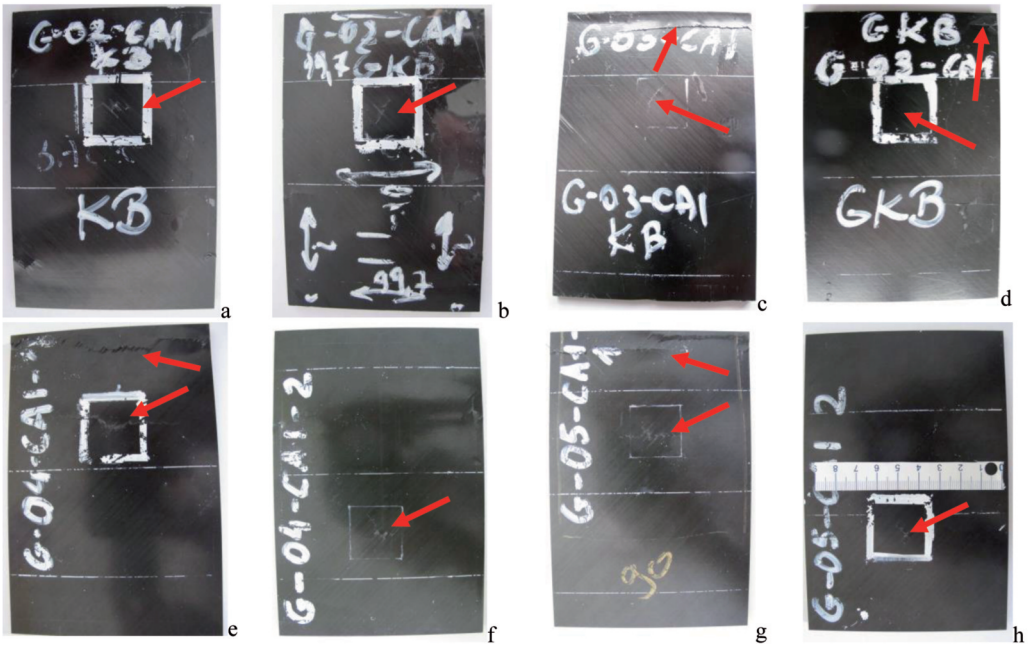

Fig. 7. Photos of G-(02÷05)-CAI samples: a, c, e÷h with adhesive film (KB), b and d with adhesive film and graphene (GKB) after CAI test (arrows indicate the place of sample destruction) [own work]

4. CONCLUSIONS

The study leads to the following conclusions:

1. Results of CAI test shows large divergences. For samples with graphene a residual strength was 125.4 MPa and 137.5 MPa. Comparative samples – but without the graphene, shows strength of 82.6÷168.1 MPa. The differences in results are due to the place of destruction of the samples. Destruction not concentrated at the impact point of the sample, but in region of adhesive film boundary. Only G-05-CAI-RTA-KB-01sample was partially destroyed in the preferred point of impact, resulting in a propagation of delamination caused by impact. Due to the different location of destruction the obtained results are not comparable.
2. The tests performed reveal the need to consider changes in the design of the sample by use an adhesive film layer over the entire surface of the sample, which will make the thickness of the sample more uniform and eliminate the problem of the destruction of the samples on an adhesive film boundary.

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BADANIA WYTRZYMAŁOŚCI RESZTKOWEJ PO UDERZENIU WĘGLOWO-EPOKSYDOWYCH PRÓBEK KOMPOZYTOWYCH Z GRAFENEM

Streszczenie

W artykule przedstawiono badania wytrzymałości resztkowej kompozytów węglowo-epoksydowych z grafenem. W pracy zastosowano płaszczyzny grafenu o wymiarach 90x100 mm na kleju błonkowym jako na nośniku. 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. Dla próbek z grafenem i bez grafenu pokazano wyniki badań statycznych wytrzymałości resztkowej próbek po uderzeniu CAI (Compression After Impact) o prędkości ściskania próbki 0,005 mm/s. Przedstawiono wykresy zależności siły od przemieszczenia dla próbek z klejem błonkowym i z grafenem na nośniku z kleju błonkowego. Badania resztkowej wytrzymałości na ściskanie wykazały duże rozbieżności wytrzymałości na ściskanie dla próbek z grafenem i bez grafenu. Określono, że otrzymane rozbieżności wynikają z miejsca zniszczenia próbek, a zniszczenie koncentrowało się nie w miejscu uderzenia próbki, ale w miejscu, gdzie przebiegała granica kleju błonkowego. Stwierdzono, że przy górnej krawędzi próbki wystąpiła częściowa propagacja zniszczenia powstałego po uderzeniu bijaka.
Słowa kluczowe: kompozyt, grafen, kompozyt z grafenem, CAI test.