УДК 629.735.017.83

IMPROVING AIRCRAFT PARTS DUE TO USING NANO-COMPOSITE AND MICRO-COMPOSITE MATERIAL

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In this paper it is investigated how to make composite carbon nanofiber/ epoxy resin and carbon micro-fiber / epoxy resin. Also, these materials' features are compared and it is shown how effective and benefitial are the received products containing carbon nano- and micro-fibers.

In this study, epoxy composites were prepared in order to improve their mechanical and electrical properties. Ergo, carbon nanofibers and carbon microfibers were used as fillers. On the one hand, purchased microfibers were incorporated into the epoxy resin to produce epoxy/carbon microfiber composites via mechanical mixing at 1800 rpm in different concentrations (0.0125, 0.0225, 0.05, and 0.1).

On the other hand, carbon nanofibers were prepared via electrospining method at room temperature, then epoxy/carbon nanofiber nanocomposites were prepared at mixing temperature of 60 °C at 1200 rpm at different concentrations (0.0125, 0.05, and 0.1).

Morphology of samples was investigated via Field Emission Scanning Electron Microscopy (FESEM). Mechanical properties of samples were investigated via tensile and bending tests. Tensile test results revealed that incorporation of 0.0125 wt% carbon naofibers increased the epoxy resins modulus about 200%. Bending strength of sample containing 0.1 wt% carbon microfibers had the most increment (from 20 to 100 MPa).

Key words: nanofibers, ultrasonic irradiation, mechanical mixing method, a vacuum oven (200 mm Hg), the elastic nature of nanofibres, electron microscope, modulus, tensile strength.

INTRODUCTION

There is a growing interest in using nanofibers as reinforcement for composites. The high surface area of nanofibers coupled with good fiber-matrix bonding offers exceptional properties due to the high fiber-matrix interface area. One of the common techniques to produce nanofibers is electrospinning. This process is recognized as an efficient technique to produce nanofibers from polymer solutions or melts and it dates back то the early 1930s. In this technique, an electric field is used to produce an electrically charged jet of polymer solution or polymer melt flowing out of pendant or sessile droplet . Electrical forces stretch and thin the jet as it flows away from the droplet producing nanofibers in the range of 500 nm or less. Many applications have been reported for electrospun fibers, such as drug delivery, filtration, energy generation, and other applications. The focus of this study is on the use of nanofibers in the reinforcement of composites. Several studies have been conducted on utilizing nanofibers in the reinforcement of composites. Strong adhesion was reported between the nanofibers and the matrix, and consequently the mechanical performance was significantly improved. Compared to neat resin, flexural strength, flexural modulus and work of fracture improved by 18.7%, 14.1% and 64.8% respectively, after adding 0.1 wt% PAN-PMMA nanofibers [1, 3, 6, 7].

The superior performance of the short nanofiber was attributed to the improved dispersability of the short nanofibers in the matrix polymer.

In this study, the use of short electrospun PMMA nanofibers in reinforcing epoxy resin has been assessed. flexural and tensile properties were determined for epoxy samples with various nanofiber weight fractions. furthermore, scanning electron microscopy (SEM) was utilized to examine fracture surface of the nanocomposite samples.

TWO-STAGE METHOD TO PRODUCE A COMPOSITE OF MICRON-SIZE CARBON FIBER / EPOXY RESIN

At the beginning of our process, we should disperse microcarbon fibers (25% resin by weight, the fibers are obtained by ER) in acetone for one hour. After this is done, we produce a suspension from this solution.

Next, the suspension must be subjected to ultrasonic radiation (2 hours). Then, we mix the suspension mechanically with carbon fiber (in stages 0.0125%, 0.225%, 0.05% and 0.1%) and epoxy resin at speed of 1800 rpm. This stage is finished after the suspension is irradiated with ultrasound (US) for about two hours. After irradiation, degasation is performed.

The degasation process consists of three phases:

1) for one hour at 50 °C vacuum oven (200 mm Hg),

2) one hour at 70 °C in a vacuum oven (200 mm Hg),

3) to 16 hours at 100 °C in a vacuum oven (200 mmHg). After completion of the degasation process, it is necessary to add a curing agent which is introduced by mechanical mixing at speed of 300 revolutions per minute for 5 minutes. Then we prepare a sample of a certain size, place it in a vacuum oven, and bake the sample. This step also consists of two phases:

1) the sample is baked at 75 °C for 2 hours,

2) the sample is baked at 140 °C for 1 hour.

TWO-STAGE METHOD TO PRODUCE A COMPOSITE OF NANO-SIZE CARBON FIBER / EPOXY RESIN

Thus, in the beginning of our test process, we have to disperse nanocarbon fibers (20% mass faction of resin, the fibers are obtained by ER) in acetone for one hour. Thereafter, we obtain a suspension out of this material. It is necessary to put the suspension under ultrasonic radiation for about two hours. Now, we mechanically mix the nanocarbonfiber suspension with epoxy resin.

The mixing is done at 1200 revolutions per minute (with the nanocarbon fiber fraction of 0.0125%, 0.05%, and 0.1%). We finish this step after ultrasound (US) irradiation for about two hours. After that degasation is performed. Degasation process comprises three phases:

1) one hour at 70 °C in a vacuum oven (200 mm Hg),

2) one hour at 70 °C in a vacuum oven (200 mm Hg).

3) 16 hours at 100 °C in a vacuum oven (200 mm Hg).

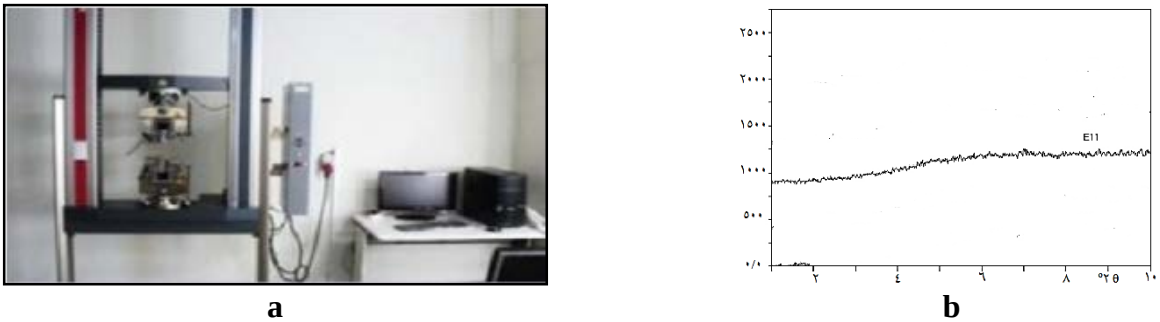
After the degasation is complete, we add a hardener by mechanical mixing at 300 revolutions per minute for 5 minutes. Then, we prepare a sample of a certain size, put it into a vacuum oven, and bake it. This step also consists of 2 phases:

1) at 75 °C for about 2 h,

2) at 140 °C for 1 hour.

Performing a tensile and bending test. Our tensile test is performed according to "ASTMD638" standard on the "Santam SMT-200" machine (Fig. 1). We set tensile speed at 5 min/mm and force at 2000 kg [9].

The distance and the angle of deviation between the layers is checked by means of X3 and nickel-filtered Philips PW 1840 (λ = 0/154 nm) device that produces Cu- Kα radiation at 40 kV voltage, 25 A current, and 5 °/min scanning speed (Fig. 2). We analyzed the data by means of a FESDEM HitachiS4160 device at 15 V voltage. To improve image quality, we broke open the sample and placed it into liquid nitrogen; then the broken sample was coated with gold.



a **b**

Fig. 1. SMT machine (a) and a sample for tensile elastic testing (b)

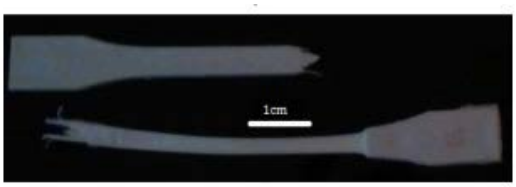


Fig. 2. Angle of deviation of X3 regent vs angle θ and the regent strength

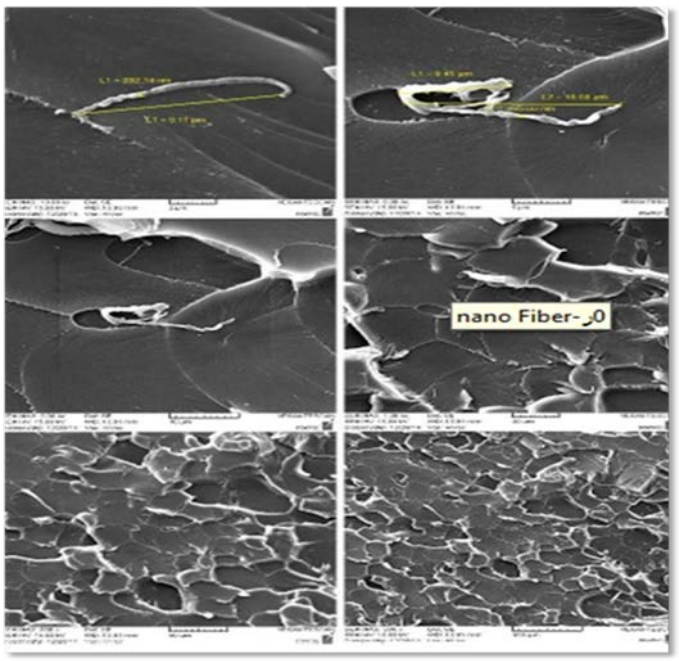


Fig. 3. Image from FESEM electronic microscope for a sample containing 0.1 wt% nanofibers

Bending test is conducted according to ASTMD790 standard by means of a "Santam SMT-200" machine [8–9, 11–12]. A more detailed image of nanocomposite samples is presented on Figure 3. This figure shows a sample containing 0.1 wt% nanofibers. In this figure it can be seen that the ratio of length to diameter is 30, which is beyond the sensitivity limit of an optical microscope.

The plots depicting the Modulus of elasticity vs CMF and CNF Content are shown on Figure 4. Our samples were made from nanofibers and microfibers, as well as without the nanoparticles. As can be seen, all the nanofiber elasticity moduli are greater than the microfibers elasticity moduli; this fact indicates that the nanofibers increase the modulus greater than microfibers do. In samples containing 0.0125 wt% nanofibers and microfibers, we observed maximum value of the modulus of elasticity. This value indicates the optimal concentration of the nanofibers to maximize elasticity modulus. In this case, the sample containing 0.0125 wt% of nanofibers has its modulus increased twice as much as the sample containing the same fraction of microfibers.

This may be due to greater effective surface of nanofibers compared to that of microfibers. Further, after adding fibers to the samples, it is observed that the modulus decreases. The modulus of the sample containing microfibers decreses faster as compared to the modulus of the sample containing nanofibers. Further reduction of the modulus of the samples with high percentage of the composites can be attributed to agglomeration of fibers. As nanofiber fraction goes over 0.1 wt%, the modulus increases again.

Figure 5 shows how elongation modulus increases at the break point for our samples containing our nanofibers and microfiber. As can be seen, in the samples containing nanofibers with addition of 0.0125%wt, the increase of elongation modulus at the break point abruptly decreases (from 5% to 2%). Further increase of 0.05 wt% of the nanofiber causes the increase of elongation at the break point to increase again (3, 5%). As the weight fraction of the nanofiber increases even further up to 0.1%, the increase of elongation starts decreasing again. This "sawtooth" behavior is also observed in our samples containing microfibers. Figure 5 shows that the "sawtooth" behavior of the modulus of elongation at break point. As it is well known, the modulus of elasticity behaves in the opposite way to the elongation modulus.

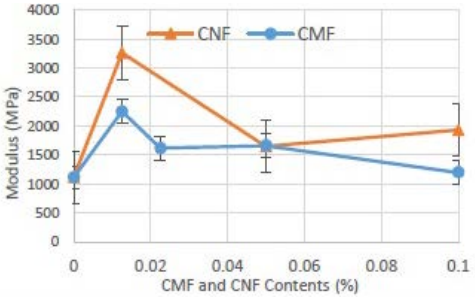


Fig. 4. Ultimate tensile strength and elongation of nano and microfibers

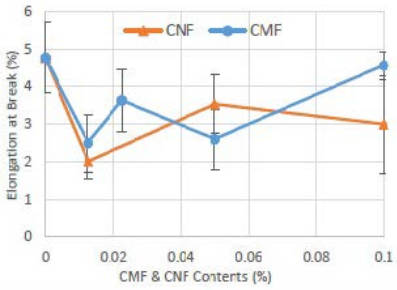


Fig. 5. Elongation at the break point vs CMF and CNF Content

Figure 6 shows the elastic modulus for our samples of carbon nanofibers and microfibers. As it can be seen, as the carbon fiber of micro and nano-size is added, the elastic modulus increases. In our samples with low (less than 0.05% by weight) content of the carbon fibers, the micro-fibers have more impact on the modulus then the nanofibers. However, as the content of the carbon fiber increases, the behavior changes. On the one hand, for the samples containing 0.1 wt% of nanofiber, the modulus increases. Yet for the samples containing 0.1% by weight of microfibers, the modulus decreases.

The ultimate tensile strength of our samples containing carbon fibers is shown in Figure 7. It is obvious that the ultimate tensile strength behaves almost identically to the modulus of elasticity. Only the sample with 0.1% of microfiber weight shows greatly reduced ultimate tensile strength.

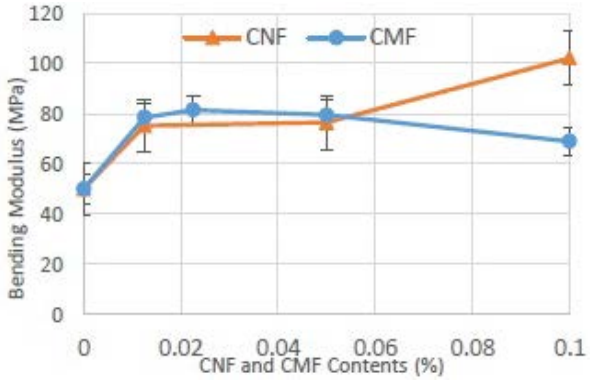


Fig. 6. Elastic modulus

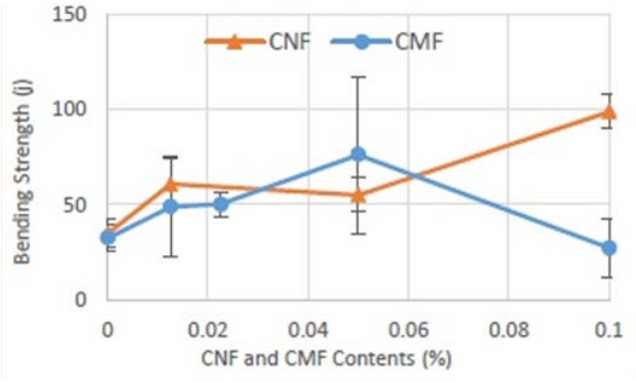


Fig. 7. Ultimate bending strength

Table 1

Physical and mechanical properties of carbon and nanocarbon composites and micro-carbon composites

Material	Ultimate tensile strength, GPa	Elasticity modulus, GPa	Density, g/cm^3
CNF	3,2	110	1,9
CMF	2,5	75	1,3

CONCLUSIONS

Our FESEM images demonstrated that the ratio of length to diameter of our nanofibers is much greater than the sensitivity limit of an optical microscope, so it is impossible to accurately see nanofibers using this kind of microscope. We investigated the mechanical strength of our samples by means of ultimate tensile strength tests and impact tests.. As a result of the tensile tests, it was found that if we add 0.0125 wt% nanofiber epoxy, the sample's Young's modulus increases by 200%, but the strength and elongation at the break point decreases. The highest value of our samples' ultimate tensile strength is obtained for the sample containing 0.1% by weight of microfibers (from 20 MPa to 100 MPa).

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ВОССТАНОВЛЕНИЕ ЭЛЕМЕНТОВ ВОЗДУШИХ СУДОВ С ПРИМЕНЕНИЕМ НАНО-КОМПОЗИЦИННОГО И МИКРО-КОМПОЗИЦИОННОГО МАТЕРИАЛА

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Разработан метод двухэтапного процесса получения композита из наноуглеродволокна размером до 500 нанометров и эпоксидной смолы. Для сравнения качества композитов при использовании их в авиационных конструкциях и влияния размера волокон тем же методом получен композит из углеродволокна размером до 100 микрон и эпоксидной смолы.

В этом исследовании эпоксидные композиты были приготовлены с целью улучшения их механических и электрических свойств. Углеродные нановолокна и углеродные микроволокна использовались в качестве наполнителей. С одной стороны, приобретенные микроволокна были включены в состав эпоксидной смолы для производства композитов с помощью механического перемешивания при скорости 1800 об/мин в различных концентрациях (0,0125, 0,0225, 0,05, и 0,1). С другой стороны, углеродные нановолокна были приготовлены с помощью метода электроформования. Нанокомпозиты на основе эпоксидной смолы и углеродного волокна получили при механическом смешивании со скоростью 1200 об/мин, при температуре 60 °C, в различных концентрациях (0,0125, 0,05 и 0,1). Морфологию образцов исследовали с помощью полевой эмиссии, сканирующей электронную микроскопию (FESEM). Механические свойства образцов были исследованы на растяжение и на изгиб. Результаты испытаний показали, что введение в состав 0,0125% наноуглерода увеличило модуль упругости эпоксидных смол примерно на 200 %. Предел прочности при изгибе образца, содержащего 0,1 мас% углерода микроволокна, имел наибольший прирост (от 20 до 100 МПа).

Ключевые слова: нановолокна, ультразвуковое облучение, механический метод смешивания, вакуумная печь (200 mm Hg), эластический характер нановолокон, электронный микроскоп, модуль упругости, предел прочности.

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Поступила в редакцию	19.01.2017	Received	19.01.2017
Принята в печать	27.04.2017	Accepted for publication	27.04.2017