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Review of nanocomposites in aerospace industry

P. Kozioł [a], S. Labocha [b], T. Tański [c]

[a] Student of Silesian University of Technology, Mechanical Engineering Faculty
email: p.koziol14@gmail.com

[b] Student of Silesian University of Technology, Mechanical Engineering Faculty
email: sz.labocha@gmail.com

[c] Silesian University of Technology, Mechanical Engineering Faculty
email: tomasz.tanski@polsl.pl

Abstract: Composite materials are usually preferred materials for construction of aircrafts. Nanocomposites can bring improvement to mechanical, thermal and electrical properties of construction elements like cockpit, fuselage, airframe and fins. When compared to conventional materials, nanocomposites may provide improvement in fields of elastic modulus, thermal performance, oxidation resistance and other properties. Low volume additions (1-5%) of nanoparticles in polymer matrix provide enchantment of properties that can be compared with a lot larger loading amount (15-40%) of traditional fillers. Usage of different matrix materials and types of nanoparticles, like SWNT or MWNT can produce materials with desirable properties. This work reviews selection of materials and their properties in possible application in aerospace industry.

Keywords: nanocomposite, aeroplane, mechanical properties, polymer, epoxy

1. INTRODUCTION

To obtain a composite material it is necessary to physically combine two types materials. Metallic, ceramic or polymer materials can be enhanced by reinforcing them with fibres, particles, bars or even layers of other material. One of the most popular examples can be reinforced concrete with is enhanced by metal bars to improve its mechanical properties. Example of concrete points out the most important reason of creation composite material, properties of the composite matrix are improved by application of reinforcement.

One of the most dynamic industry that widely uses composites is aerospace. Technological development and desire to be able to transport more and more passengers led to the point where conventional materials were not good enough to be used in construction of airplanes. Main reason which terminates conventional materials from being used in aerospace industry is their weight to durability ratio. Achieving a good mechanical properties equals increasing mass of the material.

As a solution to this problem composites were invented, materials that can be characterized with light weight, using polymer matrix, with great mechanical properties, owing it to reinforcement made of metallic or ceramic material.

The next step in evolution of materials used in aerospace industry is to introduce nanomaterials in fabrication of composites. Nanocomposites can be characterized by better mechanical properties when keeping the same weight like traditional composites or can be lighter, because of lower addition of reinforcement, keeping at the same time properties of traditional material.

Main purpose of this article is to compare nanocomposites with traditional composites (

Table *1*) and properties of different nanocomposites that can be applied in aerospace industry (Table 2).

2. DATA COMPARISON AND ANALYSIS

Materials that undergo comparison in this work are different types of nanocomposites, they can differ in a way of reinforcement arrangement or what kind of material is used for it. As Ion Dinca and others showed in their article *Nanocomposites as Advanced Materials for Aerospace Industry* [1], material used for a matrix in compared composite was iglycidyl ether of bisphenol A (Ropoxid P 401), liquid epoxy resin, with a usage of curing agent in the form of Triethylenetetraminecompound TETA1(I 3301) both provided by SC Policolor SA Bucharest.

A multi-wall carbon nanotubes (MWCNT) were used as a reinforcement, and can be characterized with following properties [1]:

- Diameter: 2 nm
- Length: 5-15 µm
- Purity > 95%
- Specific surface: 40-300 m^2 / g
- Amorphous carbon content < 3%

Matrix and nano-reinforcement were combined together to achieve composite structure via dispersion method. Nanofillers with different concentration, controlled by ultra-sonication method to provide adequate arrangement, were placed in the epoxy resin matrix, and kept in there for 30 minutes, in the temperature that can not exceed 70 °C not to damage nano particles. Curing process took place over the course of 24 hours in room temperature and lead into maturation process lasting 7 days in room temperature. Curing process was accelerated by usage of microwave furnace.

Table 1 Thermal and mechanical properties of selected composite materials [1]

Structural composite	Tensile Strength (MPa)	Elasticity Modulus (GPa)	Shore Hardness	Thermal Stability (°C)	Friction coefficient
Neat epoxy resin P401	95	2.8	75	55	0.2
P401/CF	638	25.2	83	130	0.132
P401/GF	416	14.8	83	129	0.25
P401-MWCNT-COOH (2%)/CF	490.7	27.1	87	131	0.134
P401-MWCNT-COOH (2%)/GF	391.4	15.8	85	120	0.19
P401-MWCNT (2%)/CF	490	26.49	87	136	0.134
P401-30B (2%)/CF	440	-	87	130	0.134
P401-30B (2%)/GF	366	-	86	120	0.22

Application of any type of reinforcement improves properties of the epoxy resin significantly, while composites without nanoparticles characterizes with higher tensile strength, all of the other parameters shows advantage of the nanocomposites or their value is almost identical. Values of the tensile strength nanocomposites can be characterized with are lower from the values of the composites which had been reinforced only with carbon or glass fibre. The differences in the values are 30% for the carbon fibre and 6% for the glass fibre. The elasticity modulus for the composite reinforced with carbon fibre and MWCNT compared to the one with only carbon fibre exhibits a 7% improvement of the value, for the composite with glass fibre the difference is 6.5% in favour of the nanocomposite. Value of Shore hardness in the nano-particle reinforced composites increased by 4.5% and 2,5% for carbon fibre and glass fibre respectively. Thermal stability and friction coefficient values for carbon fibre composite and nanocomposite are very similar and displays no significant improvement of using MWCNT-COOH as an additional reinforcement. Usage of the other type of the carbon nanotubes improves thermal stability of the composite by 4.5%, while still not affecting the friction coefficient by a large number. On the other hand, value of the thermal stability for the glass fibre composite after usage of the MWCNT-COOH decreases by 7.5%, while friction coefficient also being decreased by 31% compared to the value of the composite with only glass fibre reinforcement.

James Njuguna and Krzysztof Pielichowski in their paper *Polymer Nanocomposites for Aerospace Applications: Properties* [2] presented a table with comparison of different composite materials with nano additives. Those materials present wide spectrum of properties and can be used in many of applications, that needs specific material characteristic.

Table 2 Properties comparison of different nanomaterials composites [2]

	Tensile Strength (MPa)	Elasticity Modulus (GPa)	Elongation (%)	Nanomaterials
Poly (ether ether ketone) [2]	101	5.6±0.2	-	15 %VGCF
Poly (tetramethylene glycol)/Clay [3]	6.09	0.0278	517.6	Clay
Poly (butylene adipate) diol/Clay [3]	9.74	0.0401	419.9	Clay
VGCF/Epoxy composite [4]	0.749	6.05	-	18.2% VGCF
Laser ablation SWNT/TOR-NC [5]	120	3.2	4.9	SWNT (0.2 vol. %)
Laser ablation SWNT/TOR-NC [5]	94	3.2	3.5	SWNT (0.1 vol. %)
HiPCO SWNT/TOR-NC [5]	99	2.6	4.0	SWNT (0.2 vol. %)
HiPCO SWNT/TOR-NC [5]	101	2.7	4.2	SWNT (0.1 vol. %)
Polycarbonate 600TM [6]	88	0.002751	24	3-5% wt. CNT
MWNT/polyestrene [6]	120	~2.2	-	0.05 vol. % MWNT
LaRC^{TM}CP2/SWNT [6]	~22	3.72	-	0.05 vol. % SWNT

Comparison between tables 1 and 2 shows a wide range of different properties values, it indicates the fact how universal and innovative nanomaterials can be. A slight change of matrix material or nano-filling percentage share can lead to the utterly different values of the properties. Thanks to that ability it is possible to obtain a composite that will be perfect for one the aerospace applications. Composites in table 2 have lower values of the properties in comparison to the composites showed in table 1, although this mean that they can be used in other parts of the aircraft, not for the exterior like composites in table 1.

Interesting comparisons that can be spotted in table 2 are the difference in values of the properties between laser ablation SWNT/TOR-NC and HiPCO SWNT/TOR-NC. This are composites that were made using different methods with same nanomaterials, although altering the percentage share of nanophase. LA SWNT/TOR-NC with 0.2% of the nanotubes characterizes itself with higher value of the tensile strength (~20% improvement) while being compared to the composite with 0.1% of the nanotubes. HiPCO composites while being made with the same nanoparticles as previous one, do not share same change of properties with the alteration of SWNT percentage share. With higher number of SWNT in the composite values of tensile strength, elastic modulus and elongation are lower than in the composite with 0.1% of the SWNT, showing that in order to achieve a composite that characterizes itself with better mechanical properties thanks to the increased amount of the SWNT phase it is better to use laser ablation method than HiPCO.

The volume of nano additives have big factor in properties of material. If the volume is too small, then properties won’t be enhanced in a level that we expect and addition of nano additives will be pointless from that point of view. On the other hand, adding too much of nano additives may have negative impact on some properties and can be very costly. One of the causes is that nano particles has tendency to agglomerate and it is very hard to obtain equally dispersed structure. The points with agglomerations can become a weak points of material, and therefore worsen the properties, mainly tensile. That is why it is very important to determine optimal volume of nano additives. This dependence can be seen in the experiments that are described in the article *Effect of Nanoparticles on Mechanical and Wear Properties of Ceramic-Polymer Composites Used in Dentistry* [7].

3. CONCLUSIONS

Nanoparticles used as fillers can bring definitive improvements in thermo-mechanical properties of composites materials, but they can not be used as replacement of reinforcement, which can be clearly seen in Table 1. Epoxy resin with traditional carbon fibres has the best tensile strength among all tested composites, but small addition of MWCNT can bring improvements to values of elasticity modulus, hardness and thermal stability but with cost of reducing its tensile strength. Situation with composites reinforced with glass fibres is similar, but negative effect on tensile strength is significantly lower.

Nanocomposite properties can be tailored to the specific application. But amount and type of filler must be properly chosen to the manufacturing method and application, because too high addition of filler can have negative effect of composite mechanical properties, which can be observed in change of values from Table 2.

REFERENCES

1. I. Dinca, C. Ban, A. Stefan and G. Pelin, “Nanocomposites as Advanced Materials for Aerospace Industry,” INCAS BULLETIN, Volume 4, Issue 4/ 2012, Bucharest.
2. J. Njuguna, K. Pielichowski, “Polymer Nanocomposites for Aerospace Applications: Properties,” Advanced Engineering Materials 5(11), 2003.
3. B. K. Kim, J. W. Seo, H. M. Jeong, “Eur. Polym”, J. 2003.
4. R. D. Patton, C. U. Pittman Jr., L. Wang, J. R. Hill, “Composites Part A”, 1999.
5. J. G. Smith Jr, K. A. Watson, C. M. Thompson, J. W. Connell, 34th Inter. SAMPE Technical Conference, Maryland, November 4-7, 2002.
6. J. Sandler, P. Werner, M. S. P. Shaffer, V. Demchuk, V. Altstädt, A. H. Windle, “Composites Part A”, 2002.
7. M. Szafran, E. Bobrzyk, B. Szczęsna, M. Jałbrzykowski, "Effect of Nanoparticles on Mechanical and Wear Properties of Ceramic-Polymer Composites Used in Dentistry", 2006.