The 40th International Conference on
Mechanics of Solids, Acoustics and Vibrations &
The 6th International Conference on
"Advanced Composite Materials Engineering"
ICMSAV2016& COMAT2016
Brasov, ROMANIA, 24-25 November 2016

BENDING BEHAVIOUR OF NANO-FERRITES MODIFIED EPOXY RESINS

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Abstract: *Sustained efforts have been extensively devoted to prepare new composite materials based on nano-ferrite modified epoxy resins. Generally the modifying agents are used in order to change mechanical properties of final composite. In this study, composites were fabricated with two types of nano-ferrites and three types of epoxy resins. The aim of the analysis was to identify the effect of nano-ferrites on the bending behaviour of composites. From generated results it is noticed that, in the case of composite materials modified with ferrites, subjected to the bending test, breaking is influenced by the type and amount of modifying agents.*
Keywords*: bending, nano-ferrite, epoxy resin.*

1. INTRODUCTION

Composites are developed from two or more components often having very different properties [1]. Both constituents have to be present in reasonable proportions,say greater than 5% to obtain a material with required properties and performance [2]. Several studies reported significant changes in properties such as mechanical, optical, electrical, thermal by using clay, graphite, graphene and carbon nanotubes as filler in thermosetting polymer matrix [3], [4]. The progress of chemistry, associated with the industrial revolution, created a new scope for the preparation of new polymeric materials based on nano-ferrites. In a previous paper, the incorporation of small amounts of strontium ferrite and barium ferrite into polymers showed a significant improvement of electric conductivity than pure epoxy resin [5]. To get superior properties of polymers one usual way is to modify it by placing another phase, for instance a nano-sized one, into the polymer volume [6]. Such materials should provide unique mechanical and thermal properties combined with low specific weight and high wear resistance in order to ensure the safety and economic efficiency [7]. Among the most commonly used modifying agents are: carbon nanotubes, carbon black, nano-metals, talc, clays, starch and nano-ceramics [8]. Improving the overall properties of resulted materials by addition of filler to a polymer matrix is requesting using nano-particle due to its high contact surface but paying attention to the degree of dispersion of the filler in matrix system [9]. Ferrites remain the best magnetic material and cannot be replaced by any other magnetic elements because they are inexpensive, more stable and have a wide range of technological applications in transformer cores, high quality filters, radio wave circuits and operating devices [10]. The special properties of nano-sized ferrites had generated an increasing interest regarding the modification they can induce when they are dispersed into polymers. Other studies had shown that if the size of ferrites is at micro level they tend to aggregate inside the pre-polymer mixture. Morphology control of nano-particles is an extremely important issue because it has an effect on the mechanical properties of the composite [11]. The aim is to obtain uniform dispersion avoiding clusters formation as the clusters are constituting structural defects from the polymer network point of view [12]. The mechanical properties of polymers are of interest, in particular in all applications where polymers are used as structural materials. Mechanical behaviour involves the deformation of a material under the influence of applied forces [13].

2. EXPERIMENTAL METHOD

Three epoxy systems were chosen mostly because of their different bisphenol A content namely (E) Epiphen

RE4020-DE 4020 (Bostik), (C) Epoxy Resin C (R&G Gmbh Waldenbuch), and (HT) Epoxy Resin HT-2 (R&G Gmbh Waldenbuch). Ferrites used in this study are commercially available ferrite: Strontium ferrite ($SrFe_{12}O_{19}$) and barium ferrite ($BaFe_{12}O_{19}$). All these systems were modified by mixing the main component of the respective epoxy system (the resin) with 5g of ferrite and 10g of both ferrites [14]. The resins and the code designation for the test materials made from them are as follows: C1, E1, HT1 - epoxy resin with 5g barium ferrite; C2, E2, HT2 - epoxy resin with 5g strontium ferrite; C3, E3, HT3 - epoxy resin with 5g strontium and 5g barium ferrite; C, E and HT - unchanged resins, where C denotes *Epoxy resin C*, E denotes *Epiphen RE4020-DE4020*, and HT denotes *Epoxy resin HT* such as they were presented above. Ferrite composite materials were made by the following process: (1) mold preparation; (2) mixing ferrite particles with resin; (3) casting the mixture into the mold [2]. Cylindrical specimens (110x8 mm) as shown in Figure1 were used.

Three-point bending tests were performed according to EN ISO 14125 standard. The bending tests were performed at a speed of 5mm/s. Five specimens of each material were tested. The specimen tension state is scratchy, primarily due to the variation of the bending moment from one cross section to another and secondly due to the fact that, for a certain cross-section, tensions are linearly varying in elastic field. The aim of these tests was to identify the effect of nano-ferrites on the bending behaviour of composites.

Starting from what is known, namely that the modification of the epoxy matrix was made with different concentrations of modifying agents, it can be said that the materials containing low concentrations of these modifying agents should not show significant variations of studied parameters. From generated results it is noticed that, in the case of composite materials modified with ferrites, subjected to the bending test, breaking is influenced by the type and amount of modifying agents.

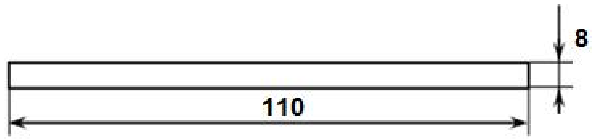

Figure 1: The shape and size of test specimen used for bending tests

3. RESULTS AND DISCUSIONS

The specimen tension state was not balanced, primarily due to the variation of the bending moment from a cross section to another, and secondly due to the fact that, for a given cross-section, the tensions linearly varies in elastic range. Comparing unchanged epoxy system and modified materials, the presence of the modifying agent lead to a deteriorations in the material structure, thus the results of mechanical bending are weak.

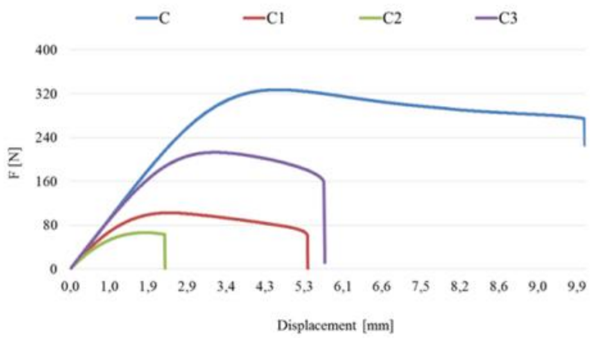

Figure 2: Flexural behaviour of C type epoxy matrix materials

Figure 2 shows flexural behaviour of C type epoxy matrix (load – displacement). In figure 3 the most important parameters of C type epoxy matrix during the bending tests are plotted. Comparing the modified materials, it can be seen that the best answers from the three-point bending tests were provided by C3 material, modified with two types of modifying agent (barium and strontium ferrites). This can lead to the idea of an interphase between modifying agent - epoxy system, a phenomenon that does not occur for C1 and C2 materials.

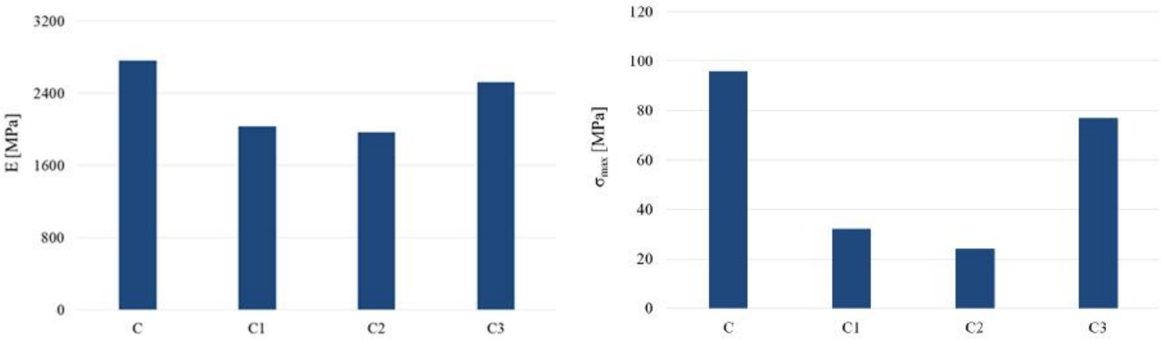

Figure 3: Bending modulus variation and bending strength of C type epoxy matrix materials

Concerning the elasticity modulus values of C type epoxy matrix, we can say that C3 material, modified with strontium and barium ferrites, presents a better elastic behaviour compared with C1 and C2 materials. This fact is the ideal result of the reaction of the two used modifying agents and the polymer matrix, which gives the possibility to use C3 material in various fields. Comparing C1 material (modified with barium ferrite) with C2 material (modified with strontium ferrite) may notice that the elasticity modulus is almost the same. Hence the idea that a smaller amount of the modifying agent in the polymer volume (5%), but also the used modifying agent type, lead to a slight decrease in the elasticity modulus. From figure 3 we see that C3 material, containing the two modifying agents, presents the greatest bending strength. This can be confirmed by ferrites properties on one hand and due to the modifying agents - matrix interphase, on the other hand. For C1 and C2 materials, elastic behaviour is weak compared with C3 material, which additionally presents better bending strength.
From figure 4 (load – displacement) of E type epoxy matrix, we see a completely different behaviour of the modified materials, compared to unmodified epoxy system. Depending on the modifying agent, materials have, either better bending strength rather than elastic behaviour, or better elastic behaviour and a low bending strength.

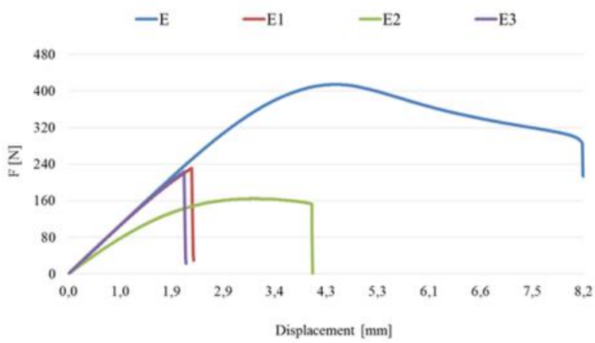

Figure 4: Flexural behaviour of E type epoxy matrix materials

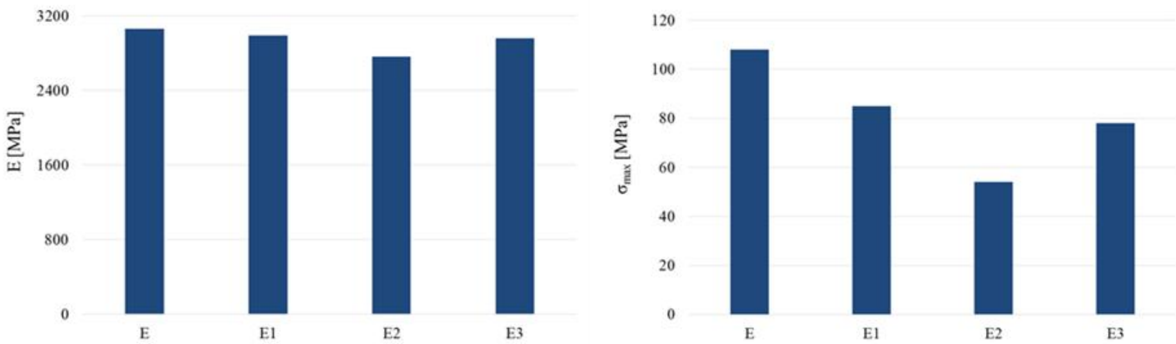

Figure 5: Bending modulus variation and bending strength of E type epoxy matrix materials

The two parameters that characterize the bending behaviour of materials modified with ferrites are graphically represented in figure 5. If the comparison is made strictly on modified materials, then we can say that E1 and E3 materials support a higher load than E2 material, presenting instead a lower displacement. Regarding elasticity modulus values for E type materials, there are not high variations. A slight decrease of the elastic modulus values are seen for E3 material, which may be due to the higher mass fraction of the modifying agent (10%), compared with (5%) for the other two materials (E1 and E2). In the case of E2 material where the used modifying agent was strontium ferrite, there are some improvements in elasticity modulus. This can be explained by comparison with the values of the elasticity modulus of the unmodified epoxy systems. The same material, E2, presents good resistance at maximum bending strength. For E1 material, where only one modifying agent was used (barium ferrite), it can be seen that the bending strength decreases as compared with E2 and E3 materials. This can lead to the idea that, barium ferrite deteriorates mechanical properties and thus decreases the possibilities of materials exploitation.
Figure 6 shows flexural behaviour of HT type epoxy matrix. HT type materials presents an atypical behaviour of other studied materials. This behaviour is confirmed by the two parameters extracted from the force – loading curves: elasticity modulus and maximum bending strength (figure 7).

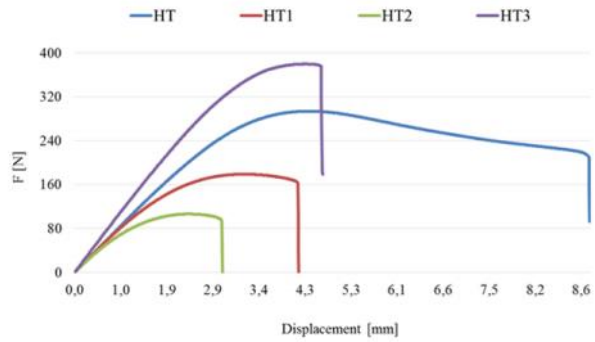

Figure 6: Flexural behaviour of HT type epoxy matrix materials

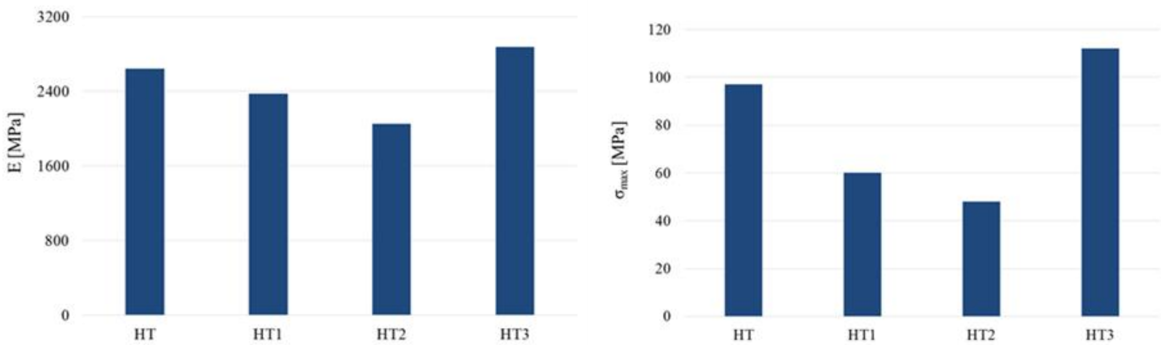

Figure 7: Bending modulus variation and bending strength of HT type epoxy matrix materials

For HT1 material, which contains barium ferrite, and HT3 material containing combinations of the two types of ferrites, the elasticity modulus elasticity values are almost identical, except that the HT3 material presents good resistance to maximum bending strength.

4. CONCLUSIONS

Regarding the influence of used epoxy matrix, we can say that the best answers that result from three-point bending tests were obtained for E type materials, followed by HT type epoxy matrix and finally C type epoxy matrix. Ferrites forms strong links with E epoxy system. HT3 material has good elastic properties and simultaneously shows good behaviour to mechanical bending compared with other studied materials (HT1 and HT2) of same epoxy matrix. When comparing the three types of epoxy matrix used in this paper, it is noted that E type ferrite modified materials presents a different behaviour compared to the other two types of material containing C and HT epoxy matrix because, regardless of the used modifying agents type or concentration, the behaviour is rather fragile. Examining the results after three-point-bending tests, it appears that the presence of modifying agents may influence polymerization with different effects in improving the quality interphase of the material.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the financial contribution of the Project 12 P01 024 21 (C11)/ 31.08.2012 (code SMIS 50414).

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