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Make Harmony between Technology and Nature, and Your Mind will Fly Free as a Bird
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STARCH - EPOXY COMPOSITES

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Abstract: *The actual trend in composites industry is to use modified polymers as matrix to form materials and structures with better properties. In this regard this study is oriented toward finding ways to improve polymer properties based on natural tendency of starch to create its own structure when is dispersed into a liquid phase. A bi-component epoxy system was used to form particulate composites with various starch concentrations. Physical and mechanical properties of formed materials were investigated using appropriate methods to identify the maximum amount of starch to be added without changing the basic properties of epoxy matrix. The results are encouraging further studies regarding the possibility to use starch as primary dispersion in pre-polymer mixture in order to ensure better dispersions for powders which generally tend to aggregate.*

Key words: *epoxy, starch, mechanical properties, tribological properties, physical properties*

1. INTRODUCTION

The thermosetting matrix composites are largely used because their properties even if they are difficult to neutralize. Unlike the thermoplastics, generally, they show a better thermal stability, better tribological behaviour making them suitable for long life applications.

Filling the polymer with various substances in various forms (powders, whiskers, and flakes) was, at the beginning, a way to reduce the amount of polymer used to form a structure but this method became a way to modify the basic properties of the polymer leading to improvements regarding thermal, electro-magnetic or tribological properties. The researchers had spent much time on modelling the properties of a particulate composite on the basis of its components' properties and many solutions were purposed (Torquato *et al*. 2003; Torquato, 2000; Feng *et al*. 2005; Milton 1981). For all the models some simplifying assumptions had to be made limiting the models' predictions. For instance, there are not models regarding the connection between the nature and dimensions of dispersed particles and the nature and the properties of the polymer. In the case of thermoplastics the fillers are dispersed into the melt of the polymer and it is possible to control the dispersion conditions by controlling the temperature of the mixture (Fetecau *et al.*, 2010). In the case of thermosetting materials the powders (it is the most important case) are dispersed into a pre-polymer mixture allowing a possible chemical interaction between the polymer and powders molecules. Some of the powder materials could absorb some of the pre-polymer mixture (such as CNT) leading to more dense materials. Generally thermosetting materials are bi-component systems which have to be mixed in certain amounts to polymerize. This fact is making possible three different ways to disperse the powders – into a component, into the other, or in the pre-polymer mixture – leading to different properties of formed material.

Another aspect is more important regarding the powder fillers namely they may create nanostructures inside the matrix (Winey & Vaia, 2007; Lefebvre, 2004) if they chemically interact with the thermosetting components. In this regard it has to be said that generally the powder's particles tend to aggregate inside the polymer volume changing the polymer quasi-continuous structure and leading to worst mechanical properties. A way to solve this problem is to treat the powders in order to make them more dispersible inside the pre-polymer volume; another way is to use two fillers one as dispersant and the other one to change de properties. In this category talc and clay might be included with benefits regarding the fire resistance and wear resistance of formed polymers (Pukanszky, 2007). The mixing rule (Callister, 2007; Vasiliev & Morozov, 2001) is giving some information regarding the amplitude of a property if the properties of the components and their ratios are known. But the mixing rule does work for micron dimensions of dispersed particles and in such dispersion the particles act as defects inside the polymer matrix leading to poor mechanical properties. If at micron level it might be said that the interaction is solid-liquid type which may be describe in terms of adhesion and cohesion forces while at nano level the interaction might be at the level of molecules leading to nano-structures with significant changes of formed material's properties.

2. MATERIALS

The EPIPHEN RE 4020 – DE 4020 was used as matrix and corn starch as filler to form particulate composites with volume ratios starting with 1% and ending with 50%; from 1% to 5% the increment is one unit while from 5% to 50% the increment is five units. As dispersing technique in all the cases the amount of starch was mechanically dispersed for 20 minutes into the pre-polymer mixture of the epoxy system. The named epoxy system has 45 minutes gel time so the mixture was moulded while its viscosity was not too high. After the polymerization the samples were extracted from moulds and they were thermally treated according to producer's recommendations in order to reach their best properties.

3. MEASUREMENTS AND RESULTS

Electrical and thermal properties of formed materials were investigated using recommended methods in order to identify the effects of starch filling over the epoxy matrix. Fig. 1-3.

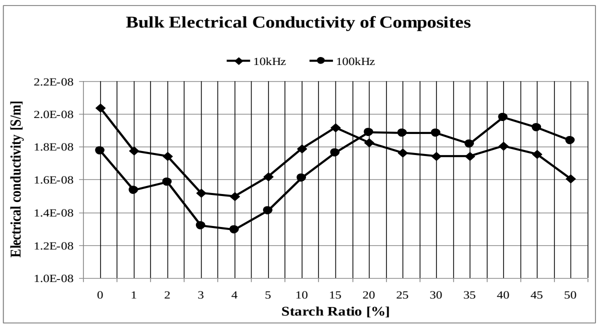

Fig. 1. Electrical conductivity of composites

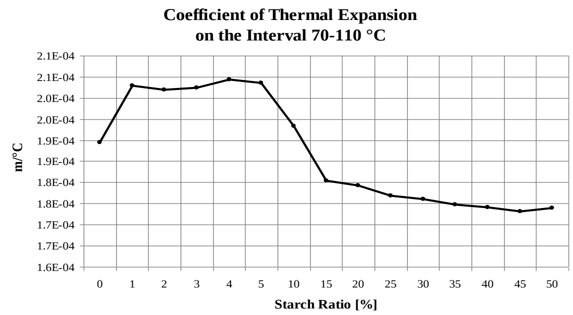

Fig. 2. Coefficient of thermal expansion of composites

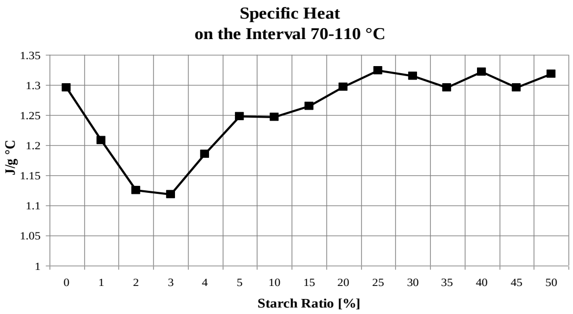

Fig. 3. Specific heat of composites

Starch amount	Modulus [GPa]	Energy [J]
0%	7.50E+02	1.54E-01
1%	7.00E+02	1.46E-01
2%	7.17E+02	1.52E-01
3%	7.60E+02	1.66E-01
4%	7.11E+02	2.22E-01
5%	7.39E+02	2.35E-01
10%	7.35E+02	1.57E-01
15%	7.49E+02	1.12E-01
20%	7.48E+02	1.36E-01
25%	8.04E+02	8.70E-02
30%	7.89E+02	6.50E-02
35%	7.87E+02	7.23E-02
40%	8.19E+02	7.48E-02
45%	8.41E+02	7.03E-02
50%	8.39E+02	6.40E-02

Tab. 1. Bending properties of composites

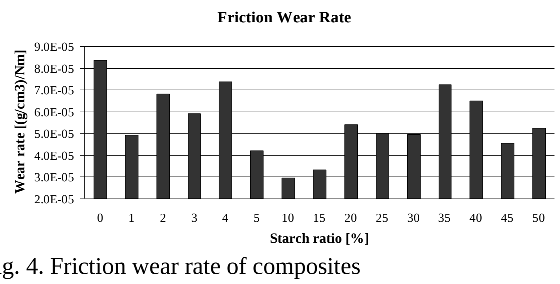

Fig. 4. Friction wear rate of composites

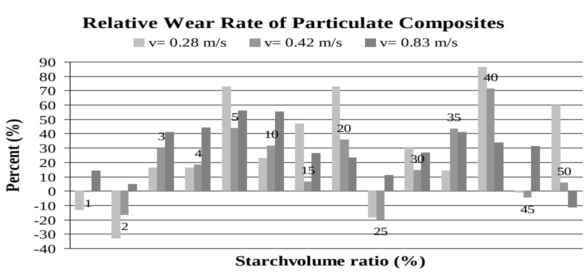

Fig. 5. Relative abrasive wear rate of composites

The bending properties were investigated and the main results are presented in Table. 1. Also the tribological behavior of materials was studied and frictional and abrasive wear rates are presented in Fig. 4-5. As in the case of physical properties the test methods are standard ones.

4. CONCLUSIONS

Even the design problem is complex the presented results are encouraging further studies regarding filled polymers and reinforced materials with filled polymer matrix to achieve more advantages when forming a material. For this study the starch was dispersed directly into the pre-polymer mixture and it was expected that none interaction took place, the starch particles were covered by polymer chains.

The aim of this study was to establish the highest starch concentration which is not changing the epoxy's basic properties. It seems that the answer is 10% from specific weight, thermal stability, electric conductivity, bending and frictional properties but is not good enough from the abrasive behaviour point of view. Anyway the study is just a preliminary analysis before using starch just to disperse other fillers which generally tend to aggregate as CNT or ferrite or to use functionalized starch to transport at the polymer chains level some positive or negative ions able to improve the electrical conductivity.

Using filled matrix it is possible to design and form reinforced materials with certain properties only by means of type and amount of the filler. Also using the lay-up method of forming with pre-polymer or filled pre-polymer mixture it is possible to obtain materials with certain properties at different depths inside the material (high electric conductivity at external layers, high magnetic properties in the core etc) but having the same type of polymer chains in all the volume and ensuring by this a right transfer of efforts inside the material.

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