THE USE OF NANOMAGNETIC FLUIDS TO ENHANCE THE PRODUCTION OF COMPOSITE PARTS COMPONENTS MADE BY RTM

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ABSTRACT

A research has started to demonstrate the possibility of obtaining nanocomposites using the RTM – Resin Transfer Moulding process and considering the inclusion of nanomagnetic fluids with different fluid substract. The use of the magnetic nanofluids mixed with a thermosetting resin and applying a magnetic field that will force the flow in the directions that are needed will be reported. The research will address the influence of magnetic fluids in process parameters, mainly with cure conditions, as well as the influence in mechanical properties. Being RTM more and more used to produce advance composite materials, particularly for aeronautic applications, there is a need to assure that full permeability (micro and macro) is obtained, to avoid dry fibres and voids), in other words to get a sound part. It will also be necessary to see if the nanomagnetic particles will stay in the structure after cure or if it they will be force to go to an area to be cut afterwards. If they remain in the structure a research will have to be done to tailor magnetic properties. The finds obtained so far will be described in the paper together with the problems that will need further research.

1. INTRODUCTION

The general class of nanocomposite organic/inorganic materials is a fast growing area of research. Significant effort is focused on the ability to obtain control of the nanoscale structures via innovative synthetic approaches. The properties of nano-composite materials depend not only on the properties of their individual parents, but also on their morphology and interfacial characteristics. This rapidly expanding field is generating many exciting new materials with novel properties. The latter can derive by combining properties from the parent constituents into a single material. There is also the possibility of new properties which are unknown in the parent constituent materials. The inorganic components can be three-dimensional framework systems such as zeolites, two-dimensional layered materials such as clays, metal oxides, metal phosphates, chalcogenides, and even one-dimensional and zero-dimensional materials such as (Mo3Se3-)n chains and clusters. Experimental work has generally shown that virtually all types and classes of nanocomposite materials lead to new and improved properties when compared to their macrocomposite counterparts. Therefore, nanocomposites promise new applications in many fields such as mechanically reinforced lightweight components, non-linear optics, battery cathodes and ionics, nano-wires, sensors and other systems [1].

Research started with the idea to explore the possibility to achieve some new materials in the context of Nanotechnology Construction using the possibilities of orientation of the Nano-Magnetic Fluids in magnetic field as a function of the necessary properties for the specific applications [2].

The future of the nanomagnetic fluids presence in a mass of composite materials can be analyzed for the potential applications in aeronautics or to promote the RTM process. The use of magnetic fields to evaluate, through NDT, the quality of the products made by RTM, as well

as to increase the potential application of composite materials where magnetism is important (such as radar, magnetic levitation trains, kinetic energy accumulators and electric engine rotors), are, amongst others, objectives to pursue [3].
Magnetic fluids, also known as Ferro fluids, are ultrastable colloidal suspension of ferro/or ferromagnetic particles – e.g., magnetic (Fe_3O_4) – in various carrier liquids. The ultra fine magnetic particles, of (30 – 150) Å, "integrate" themselves in the structure of the carrier liquid and together with Brownian motion, ensure indefinitely the colloid stability even in strongly non-uniform magnetic fields.
The medium behaves like a quasi-homogeneous strongly magnetizable liquid due to the presence of approximately (1017 – 1018) magnetic particles in one cubic centimeter and combines the properties of magnetic materials with those of fluids in a rather spectacular way.

2. EXPERIMENTAL PROCEDURE

The research has been focused on the compatibility that can exist between the two categories of magnetic nanofluids, "NMF – MEC" (magnetic nanofluid with methyl ethyl ketone) and respectively "NMF – EE" (magnetic nanofluid with ethyl ether) and the resins "S 226 E", "RTM 6", "272". To determine a Gel Time for the new categories of composites, we obtained a variety of combinations of resins and magnetic nanofluids, verifying the percentage of magnetic nanofluid and/or the fluid carrier. The researchs were allowed to work up to the process to obtain a new category of nanocomposites and composites, which are based on standard resins that contain nanomagnetic fluids. These materials have been polymerized in standard conditions and magnetic field. The mechanical tests have been conducted in the Mechanical Tests Laboratory at INEGI- CEMACOM, based on ISO 178 – 1975 standard, using an INSTRON 4208. These tests have been performed as three point bending (flex) tests. Dynamic mechanical test, were made in PL MK II (polymer laboratories) analyzer fitted with a composites heart. Optical and scanning electrons analysis microscopy was also carried out.
The method we developed to manufacture nanocomposites is a two step one, based on the nanotechnology of magnetic fluids. Special type, highly volatile and strongly polar magnetic fluids were prepared in the first step, which proved to be compatible with the resins used for nanocomposite manufacturing.

2.1. MAGNETIC NANOFLUIDS – BASIC COMPONENTS

The use of magnetic nanofluids as one of the basic components of the manufacturing process has several reasons. In magnetic fluids, the nanoparticles have the required dimensional distribution and are very well dispersed in the resin compatible carrier liquid. Also, due to the magnetic properties of nanoparticles, application of a magnetic field during the polymerization process opens the possibility to obtain composites with ordered nanostructures because the magnetic field – magnetic dipole and dipole – dipole interactions include a chain - like ordering of nanoparticles. If micrometer range reinforcement elements are introduced in the composite, their ordering is also possible due to the first order magnetofluidic levitation effect, specific to magnetic fluids [4]. Methyl-ethyl ketone (MEC) and ethyl ether (EE) were selected as resin compatible carriers, which are highly volatile and strongly polar liquids. Styren and cyclohexane have been studied and will be presented in a futur article. The stable dispersion of magnetic nanoparticles in such a carrier made use of the experience accumulated in the preparation of short chain length alcohol based magnetic fluids [5]. A petroleum based magnetic fluid of medium concentration of nanoparticles (solid volume fraction approx. 7%) was used as primary, non-polar magnetic fluid. The magnetic nanoparticles of Fe_3O_4 and γ-Fe_2O_3, covered with chemisorbed oleic acid monolayer, were flocculated with acetone and

extracted from the petroleum carrier. The first surfactant layer covered magnetic nanoparticles were redispersed in methyl-ethyl ketone and ethyl ether, respectively using dodecilbenzene sulphonic acid (DBS) as secondary, physically adsorbed surfactant layer. The redispersion / secondary stabilization process was conducted at a temperature of 60oC, under continuous stirring. The stability of the resulted strongly polar magnetic fluids was achieved by using the adequate quantity of secondary surfactant, established experimentally, corresponding to the ratio mass of secondary surfactant (DBS) / mass of oleic acid covered magnetic nanoparticles 0,25. The obtained medium concentration magnetic fluids on methyl-ethyl ketone (solid volume fraction ≅ 5.7%) and ethyl ether (solid volume fraction ≅ 6%) solvents were used with various resins, such as S226E, RTM6 and 272. The quantity of magnetic fluid added to the resins was up to 2% mass concentration and produced favourable changes of the polymerization process, as well as of the properties of the resulted nanocomposite materials.
Magnetorheological (MR) measurements performed on the two kinds of samples, using the cylindrical MR cell described in [6], showed that magnetic fields induced structurization processes are more pronounced in the case on the methyl-ethyl ketone based sample [7].

3. RESULTS AND DISCUSSIONS.

3.1. GEL TIME TESTS

The results obtained during the gel time determinations for RTM 6 resins are shown in fig. 1.

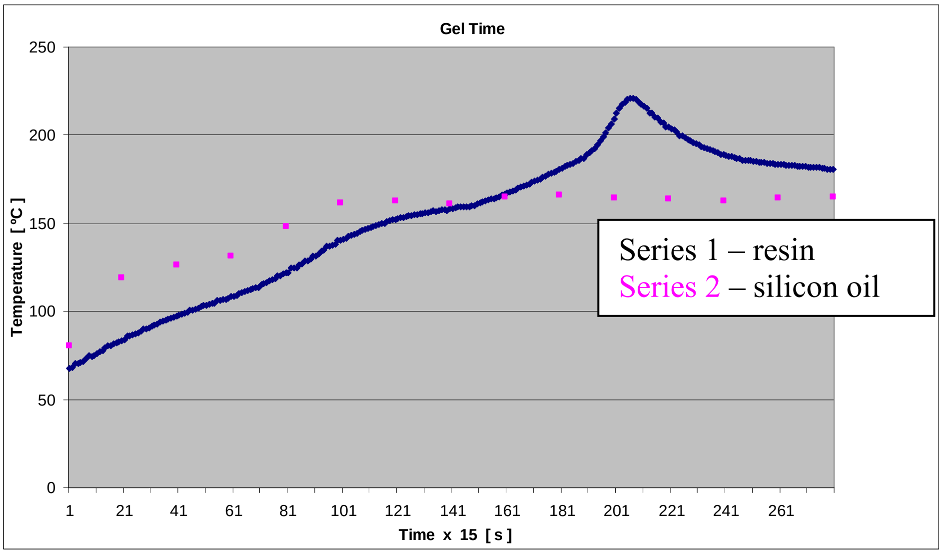

Fig.1. Variation of the resin temperature in the gel time (RTM 6.)

It is possible to note the influence of the nanoparticles percentage respectively of the type of magnetic nanofluid concerning the evolution of gel time with respect to specific critical temperatures for each resin. Practically, it is possible to note a modification of values regarding the evolution of temperature and of critical values for certain concentrations.

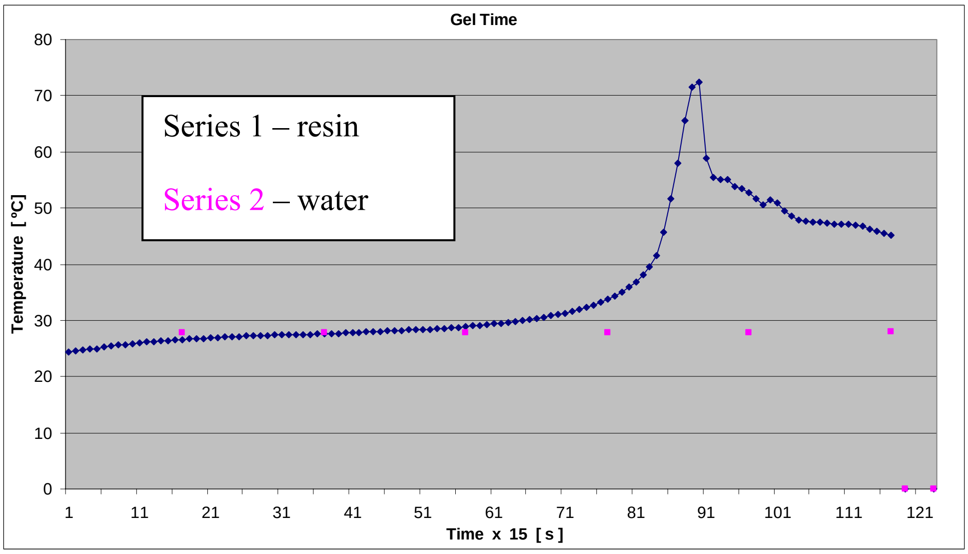

Fig. 2. Variation of the resin temperature in the gel time. S 226 E with 1% NMF – MEC

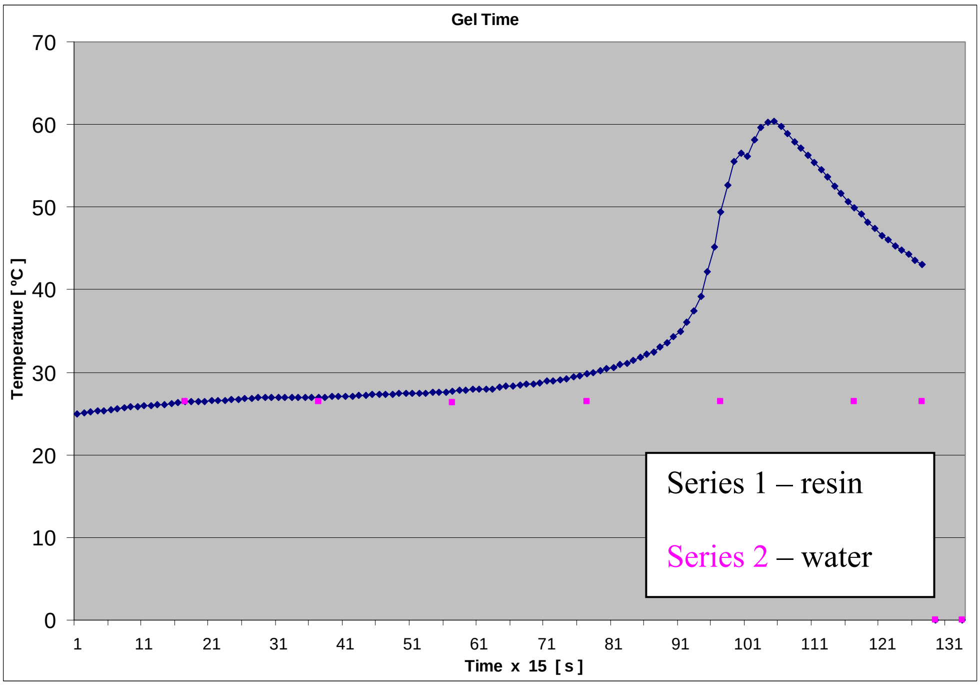

Fig. 3. Variation of the resin temperature in the gel time. S 226 E with 2% NMF - MEC

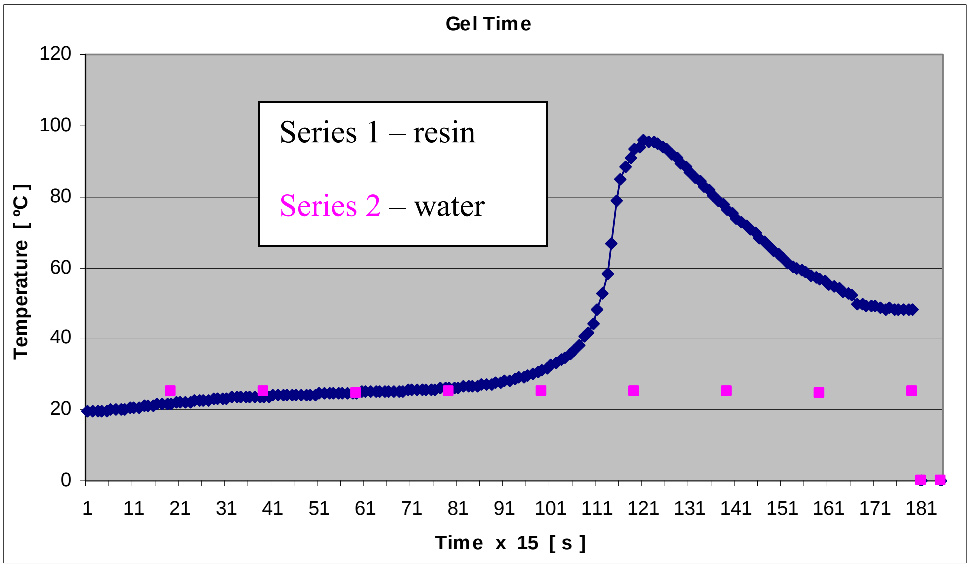

Fig. 4. Variation of the resin temperature in the gel time. S 226 E with 1% NMF – EE

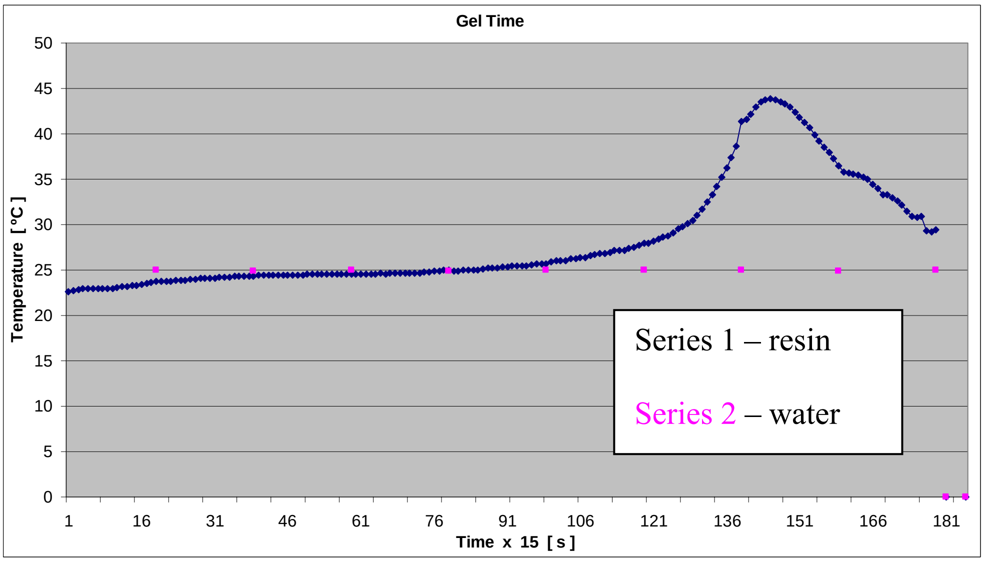

Fig. 5. Variation of the resin temperature in the gel time. S 226 E with 2% NMF - EE

3.2. MECHANICAL PROPERTY

To increase the information with respect to the mechanical behaviour of resins and nanocomposites, DMTA tests were performed. The behaviour of the analyzed materials is shown in figures 6 to 8.

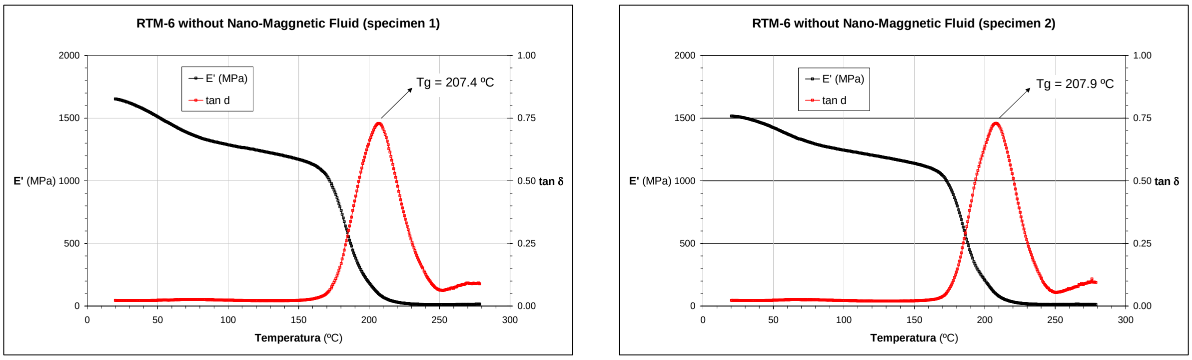

Fig. 6. Graphic representation form DMTA tests results (RTM 6.)

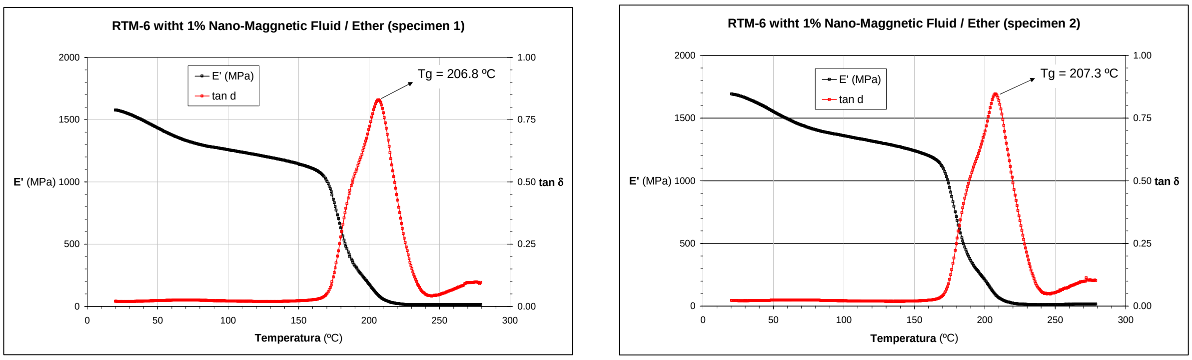

Fig. 7. Graphic representation form DMTA tests results (RTM 6 with 1%NMF-EE.)

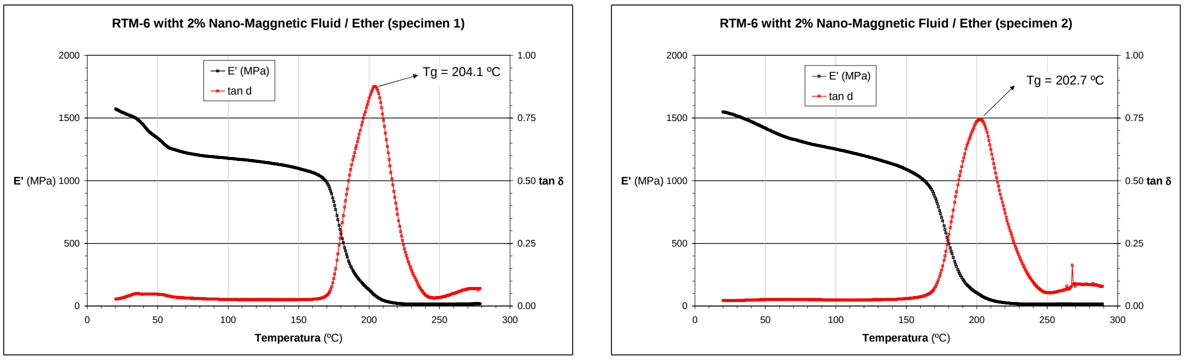

Fig. 8. Graphic representation form DMTA tests results (RTM 6 with 2%NMF-EE.)

3.3. ELECTRONIC MICROSCOPY

The behaviour at the rupture of the resin RTM 6 and of the nanocomposites obtained with the nanomagnetic fluids was studies also by electronic microscopy.

The most representative samples for RTM 6 resin are shown in figures 9 and 10. The present samples present a small distortion at the rupture.

Fig. 9. Samples for electronic microscopy

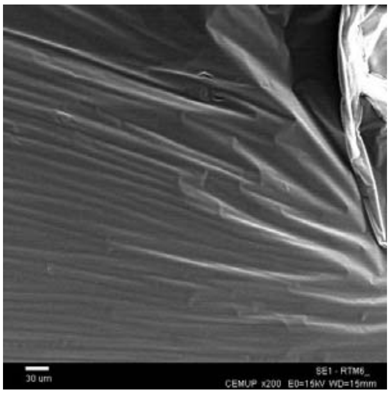

Fig. 10. [x 200]

The most representative samples for RTM 6 resin with 1% NMF-MEC are shown in figures 11 to 12.

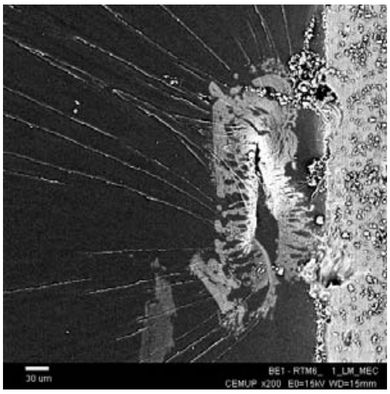

Fig. 11. [x 200]

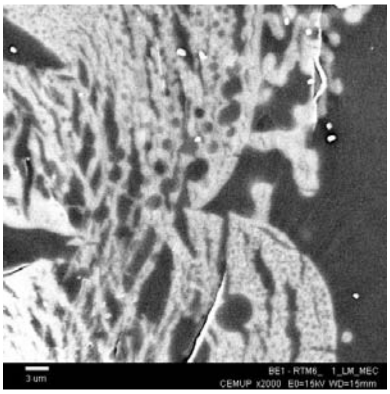

Fig. 12. [x 2000]

The most representative samples for RTM 6 resin with 1% NMF-EE are shown in figures 13 to 14.

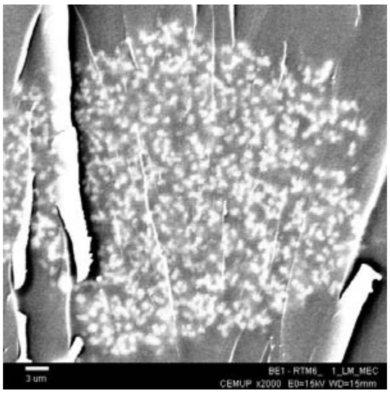

Fig. 13. [x 2000]

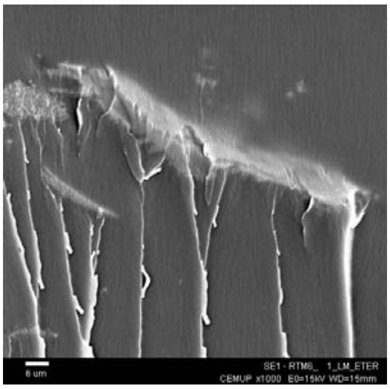

Fig. 14. [x 1000]

It is possible to note that there is a different compatibility between the two categories of magnetic nanofluids and the RTM 6 resin, inspite the fact that agglomerations of nanoparticules can modify the mechanical behavior of nanocomposite.

CONCLUSIONS

A decrease of the exothermic peak temperature was observed and may be due to the presence of the Fe3O4 nanomagnetic particles and the Fe micro particles, which lead to the increase of the heat transfer coefficient. The values obtained in tests, achieved in normal condition for the various resins, nanocomposites and composite; show the difference in the Gel Time behaviour. According to every piece, there is a possibility to find relationship between the quantity of resin, catalyst, accelerator and nanomagnetic fluid, to the technologic control of process to obtain the pieces by RTM.

Pictures obtained by the electronic microscopy, put in evidence the conditions in which there is a good compatibility between resins and the nanomagnetic fluids. A good mixture necessary between resins and the nanomagnetic fluids, to obtain a nanocomposite where the mechanical properties are not reduced by the presence of nanoparticles concentrations. The presence of nanomagnets in the nanocomposites can help in future the X ray tests, to survey the mechanical comportment, for pieces obtained by RTM process. At the same time it's possible to think in a surveillance with regard to the penetration of the resin in the metallic forms during the RTM process.

The presence of nanomagnets inside the nanocomposite can determine in magnetic field different mechanical properties in comparison with the classic situation (without magnetic field). Using this new concept to manufacture nanocomposites, a new category of materials is in developement. These materials achieve a connection between the standard technology to obtain the polymeric composites and the technology of the nanomagnetic fluids, allowing the manufacturing of new materials.

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