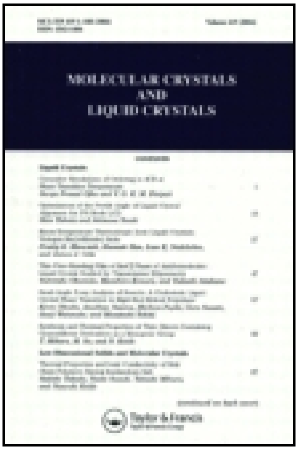

Molecular Crystals and Liquid Crystals
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl20

The Use of the Nanomagnetic Fluids and the Magnetic Field to Enhance the Production of Composite by RTM - MNF

N. Crainic [a] , A. T. Marques [b] , D. Bica [c] , L. Vekas [c] , P. J. Nóvoa [d] & C. P. De [e]

[a] UPT - Politehnica University of Timisoara, Timisoara, Romania

[b] FEUP - Faculty of Engineering of University of Porto, Porto, Portugal

[c] Laboratory of Magnetic Fluids, Center for Fundamental and Advanced Technical Researches, Romanian Academy - Timisoara Branch, Timisoara, Romania

[d] INEGI - Institute of Mechanical Engineering and Industrial Management, Leça do Balio, Portugal

[e] CEMUP - Centro de Materiais da Universidade do Porto, Porto, Portugal

Version of record first published: 18 Oct 2010

Mol. Cryst. Liq. Cryst., Vol. 418, pp. 29/[757]–40/[768], 2004

ISSN: 1542-1406 print/1563-5287 online
DOI: 10.1080/15421400490478911

THE USE OF THE NANOMAGNETIC FLUIDS AND THE MAGNETIC FIELD TO ENHANCE THE PRODUCTION OF COMPOSITE BY RTM – MNF

N. Crainic (NATO grant holder at INEGI in 2001)
UPT – Politehnica University of Timisoara, Timisoara, Romania

A. T. Marques
FEUP – Faculty of Engineering of University of Porto, Porto, Portugal

D. Bica and L.Vekas
Laboratory of Magnetic Fluids, Center for Fundamental and Advanced Technical Researches, Romanian Academy – Timisoara Branch, Timisoara, Romania

P. J. Nóvoa
INEGI – Institute of Mechanical Engineering and Industrial Management, Leça do Balio, Portugal

C. P. Moreira de Sa
CEMUP – Centro de Materiais da Universidade do Porto, Porto, Portugal

This research have started with the idea to exploit the possibility to achieve some new materials in the context of Nanotechnology Constructions, with the aid of the RTM – Resin Transfer Moulding process and the inclusion of nanofluids, considering the possibilities of orientation of the Nanomagnetic Fluids in magnetic fields, as function of the desired properties for the specified applications possessions. The future of the Nanomagnenetic Fluids presence in the mass of composite materials, can be analyzed for potential applications in aeronautics or can be frequently used to promote the RTM process. The research was focused on the compatibility that can exist between the various categories of nanomagnetic fluids and the resins used for the RTM procedure. It will have to address the influence of magnetic fluids in process parameters, mainly with cure conditions, as well as the influence in mechanical properties. With the

Address correspondence to N. Crainic, – Politehnica University of Timisoara, Timisoara, Romania. E-mail: ncrainic@saratoga.ro

present research, which will be described in the paper, it is expected to demonstrate the possibility of obtaining nanocomposites with the aid of the specific technology of RTM process and the inclusion of magnetic nanofluids. There will be know-how of strategic importance for this particular technology and will be also presented the mechanical characterisation of this particular nanocomposite.

Keywords: compatibility; composite material; nanomagnetic fluids; resin

1. INTRODUCTION

The definition of nano-composite material has broadened significantly to encompass a large variety of systems such as one-dimensional, two-dimensional, three-dimensional and amorphous materials, made of distinctly dissimilar components and mixed at the nanometer scale. 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 $(Mo_3Se_3-)_n$ 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 utilization 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].

We used the previous experience that exist in Porto in the domain of composites at INEGI – Instituto de Engenharia Mecanica e Gestao Industrial, in the Department CEMACOM – Unidade of Materias Compositos, with the one that exist in Timisoara, in the domain of the Nanomagnetic Fluids, at Romanian Academy – Timisoara Branch, Center for Fundamental and Avanced Technical Research, Magnetic Fluids Laboratory, and in "Politehnica" University of Timisoara, in the domain of composites [4].

2. EXPERIMENTAL PROCEDURE

The research was focused on the compatibility that can exist between the two categories of magnetic nanofluids, "NMF – MEC" (magnetic nanofluid with methyl ethyl cetone) respectively "NMF – EE" (magnetic nanofluid with ether ethylic) and the resins "S 226 E", "S 226", "RTM 6", "272" respectively "CRYSTIC 5260". To determine a Gel Time for the new categories of composites, we obtained a variety of combinations of resins and magnetic nanofluids. The researchs were allowed to work up to the process for 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. All samples have been obtained at the Composite Laboratory of INEGI – CEMACOM (Gel Time tests and plates), and then they have been processed to be used to the mechanical tests and to the microscopic research. The mechanical tests and DMTA tests have been conducted in the Mechanical Tests Laboratory at INEGI – CEMACOM, based on ISO 178 – 1975 standard, on an INSTRON installation. These tests have been performed as three point bending (flex) tests. The samples meant for optical and electronic microscopy have been prepared in the INEGI – CETECOFF Department. The optical microscopy has been performed in FEUP, Universidade do Porto, Faculdade de Engenharia, and the electronic microscopy has been performed in CEMUP – Centro de Matariais da Universidade do Porto.

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 envisaged for nanocomposite manufacturing.

2.1. Magnetic Nanofluids – Basic Components of the Procedure

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 nanostructure 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 [5]. Methyl-ethyl ketone (MEC) and ethyl ether (EE) were selected as resin compatible carriers, which are highly volatile and strongly polar liquids. 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 [6]. 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

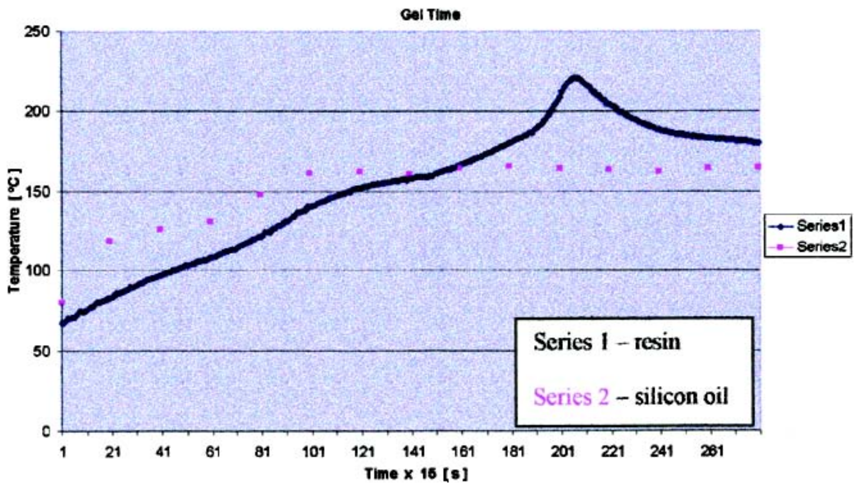

FIGURE 1 Variation of the resin temperature in the gel time **(RTM 6.)**.

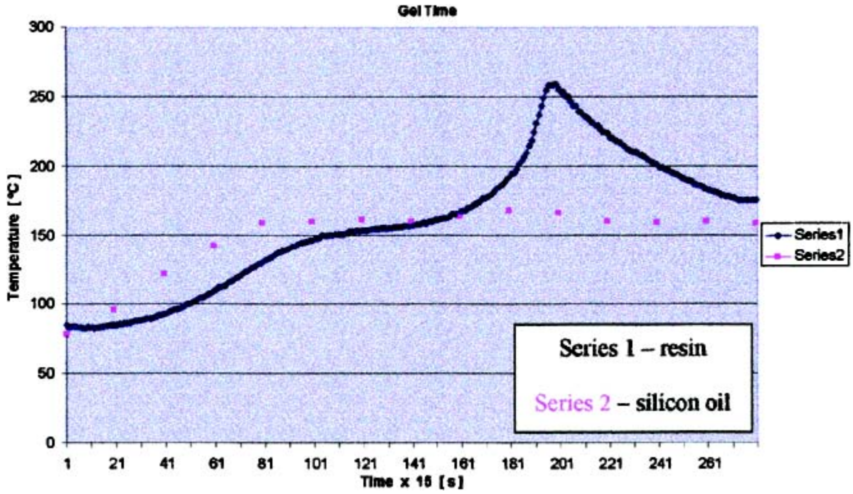

FIGURE 2 Variation of the resin temperature in the gel time **(RTM 6 with 1% NMF-MEC.)**.

acid (DBS) as secondary, physically adsorbed surfactant layer. The redispersion/secondary stabilization process was conducted at a temperature of 60°C, under continuous stirring. The stability of the resulted strongly polar magnetic fluids was achieved by using the adequate quantity of

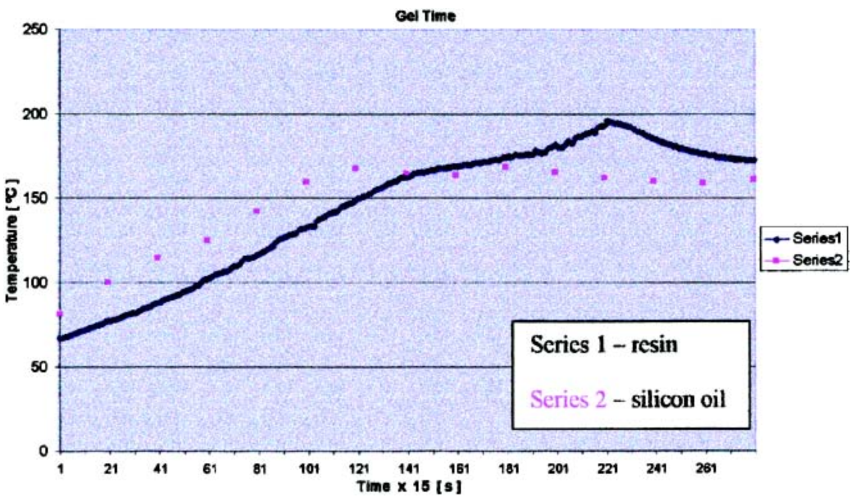

FIGURE 3 Variation of the resin temperature in the gel time **(RTM 6 with 1% NMF-EE.)**.

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, S226, RTM6 and 272. The quantity of magnetic fluid added to the resins was up to 2% mass concentration and produced favorable 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 [7], showed that magnetic fields induced structurization processes are more pronounced in the case on the methyl-ethyl ketone based sample [8].

3. RESULTS AND DISCUSSIONS

3.1. Gel Time Tests

The results obtained during the gel time determinations for RTM 6 resins are shown in Figures 1–3. 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.

3.2. Mechanical Properties

To clearly understand the comportment of nanocomposites we produced multiple samples. To increase the information with regard the mechanical behaviors of resins and nanocomposites have been made the DMTA tests. The behavior of analyzed materials is shown in Figures 4–6.

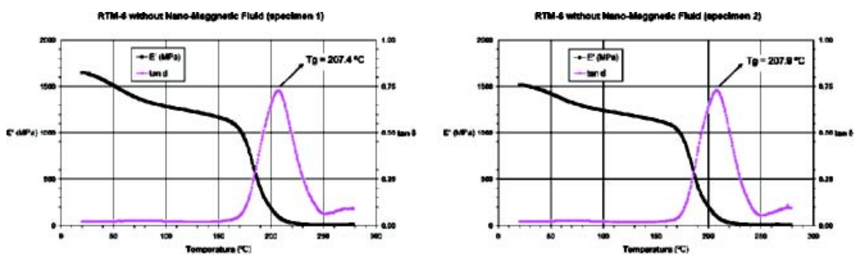

FIGURE 4 Graphic representation form DMTA tests results **(RTM 6.)**.

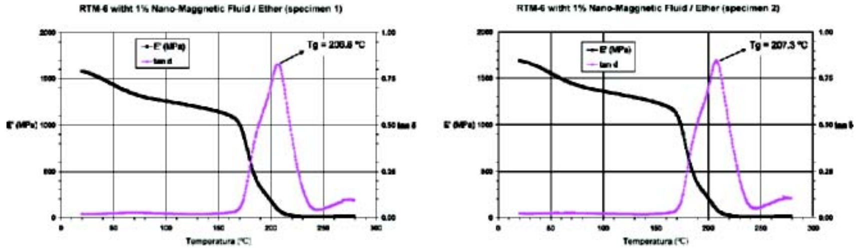

FIGURE 5 Graphic representation form DMTA tests results **(RTM 6 with 1% NMF-EE.)**.

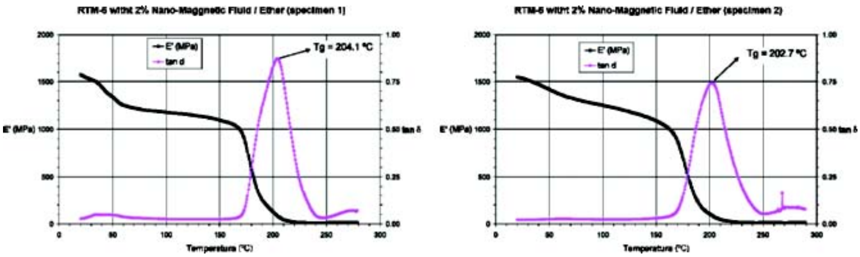

FIGURE 6 Graphic representation form DMTA tests results **(RTM 6 with 2% NMF-EE.)**.

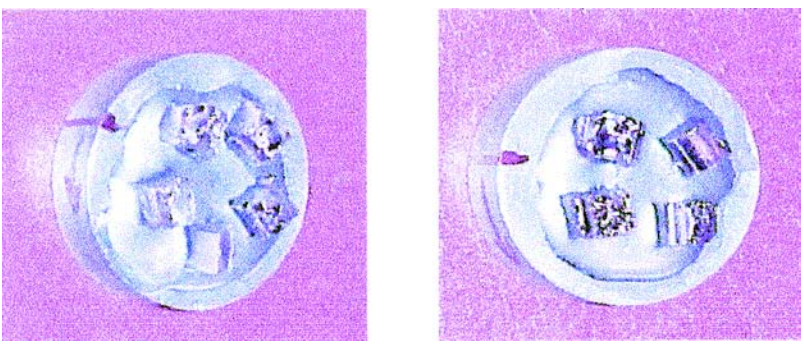

FIGURE 7 Samples for electronic microscopy.

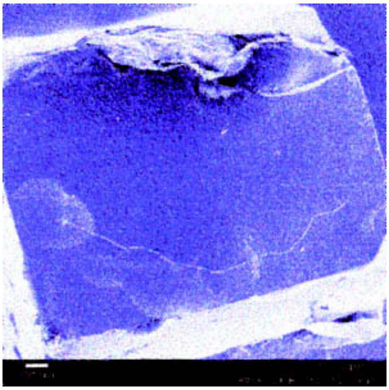

FIGURE 8 [x 20]

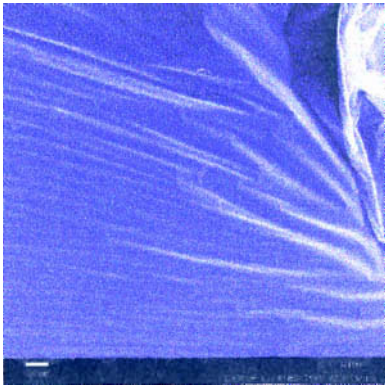

FIGURE 9 [x 200]

3.3. Electronic Microscopy

The behavior at the rupture for the resin RTMS 6 and for the nanocomposites obtained with the nanomagnetic fluids was studies also by electronic microscopy. The Figure 7 shows the samples prepared for the electronic microscopy.

The most representative samples for RTM 6 resin are shown in Figures 8–9. The present samples present a small distortion at the rupture.

The most representative samples for RTM 6 resin with 1% NMF-MEC are shown in Figures 10–15.

The most representative samples for RTM 6 resin with 1% NMF-EE are shown in Figures 16–21.

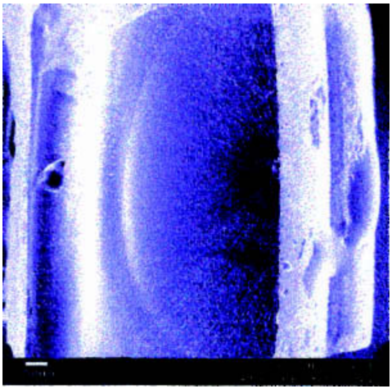

FIGURE 10 [x 20]

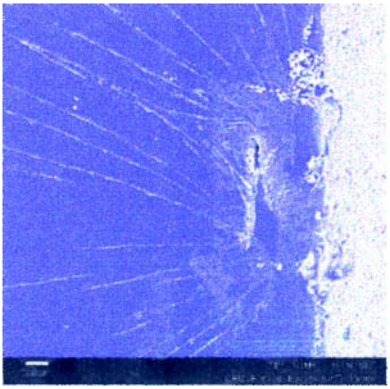

FIGURE 11 [x 200]

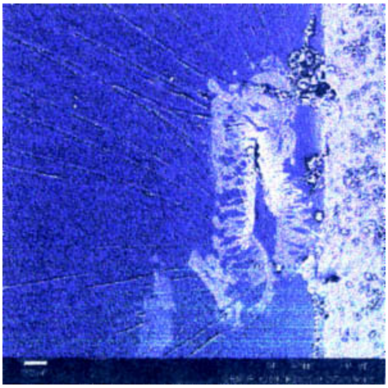

FIGURE 12 [x 200]

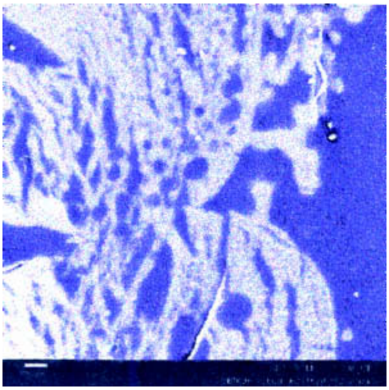

FIGURE 13 [x 2000]

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

CONCLUSIONS

The decrease of the temperature may be determined by the presence of the Fe_3O_4 nanomagnetic particles and the Fe micro particles, which lead to the raise of the coefficient of heat transfer. The values obtained in tests,

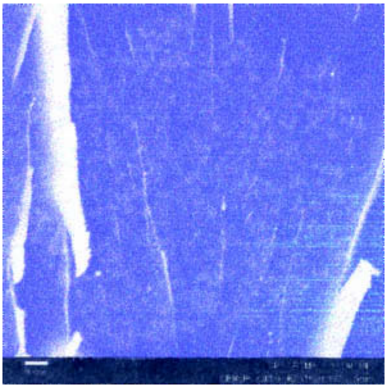

FIGURE 14 [x 2000]

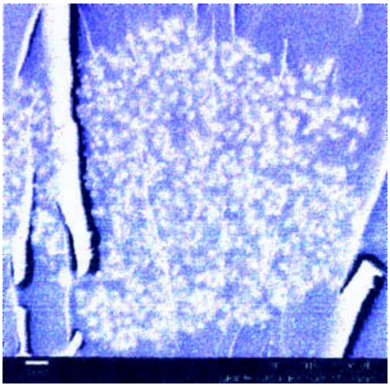

FIGURE 15 [x 2000]

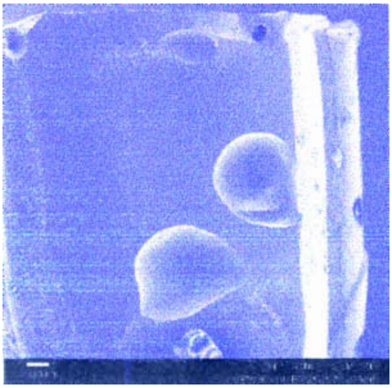

FIGURE 16 [x 20]

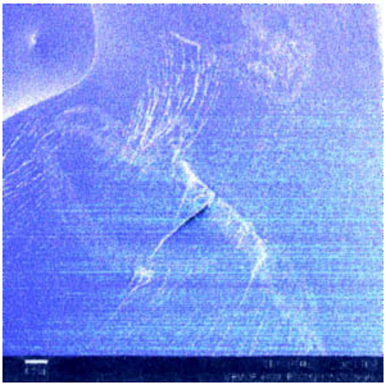

FIGURE 17 [x 100]

achieved in normal condition for the various resins, nanocomposites and composite, shows the difference in the comportment of Gel Time tests. Result the idea that for the industrial applications, the increase of the time for the injection of the resin can assures an easy control of the RTM process. According to every piece, there is possibility to find one interrelationship 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. It is necessary a good mixture between resins and

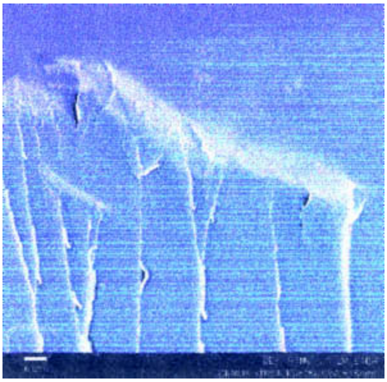

FIGURE 18 [x 1000]

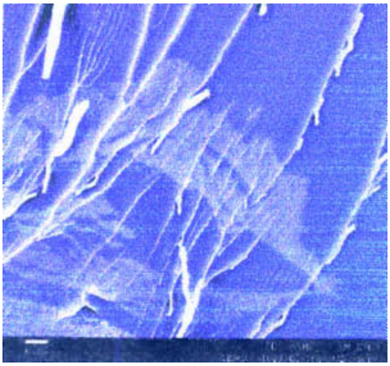

FIGURE 19 [x 1000]

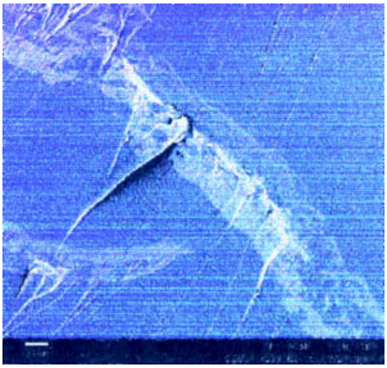

FIGURE 20 [x 200]

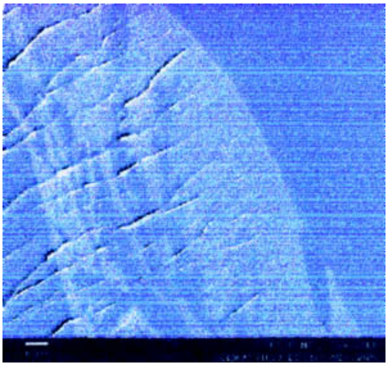

FIGURE 21 [x 1000]

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 the future the X- ray tests, to survey the mechanical comportment, for pieces obtained by RTM process. In the same time it's possible to think a surveillance with regard to the penetration of the resin in the metallic forms during the RTM process.

The presence of nanomagnets in the inside of the nanocomposite can determine in magnetic field different mechanical property in comparison with the classic situation, without magnetic field. Using this new concept to manufacture nanocomposites, a new category of materials is developed. 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. This new concept emphasizes the idea of "The Nanotechnology Construction".

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