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THE WASTE RUBBER USED TO IMPROVE THE PROPERTIES OF COMPOSITE MATERIALS

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ABSTRACT. Recycling of rubber dust finds an interesting application in the field of composite materials. Incorporation of rubber aggregates in a matrix, confers to the composite material remarkable physico-mechanical and thermo-hydrous properties. In this work we presented a green technology for the waste rubber conditioning, sources and a possibility of use in composite materials parts.

Keywords: *rubber waste, composite materials, recycling*

INTRODUCTION

Mixtures of rubber, steel and textiles, used tires are not dangerous waste [1]. However, they present a danger to the environment and health in the event of fire or incineration (pollutant emissions of gas and possibly of an oily liquid).

The composite materials have unquestionable advantages compared with metallic materials (low mass for a high rigidity). However, some of their properties remain weak (tolerance at damage, for example).

With the aim of modifying these properties, we propose, in this study, doping during manufacture of certain types of laminated composites. The doping process consists in the addition of some specific particles during the molding process of the composites, figure 1.

In this study, we used recycled rubber particles from worn tires; these particles were obtained by cryogenic crushing. The goal is the improvement of the properties in the case of the shocks and vibrations. This study presents firstly, the technique of composite materials doping. Secondly we showed that it is possible to inject resin on a dry reinforcement starting from all Liquid Composite Molding (LCM) processes without deteriorating the installation of these elastomeric particles within material. Finally certain results of mechanical tests will be presented.

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Figure 1. Doping material. (a) rubber particles; (b) bonding agent.

A first series of quasi-static experiments carried out on doped glass/ epoxy specimens showed that for a rate of well defined doping ratio, the mechanical characteristics values are between 10 % and 20 %. These values were confirmed by damages under shock tests [2].

Taking in account the fact that this study proposes a new way for recycling of used tires we consider that the work we done can contribute to environmental protection. Moreover, it appears that beside used tires many structural parts, in small or great quantities, can be considered for processing by this technique (elements of automobile such as body, bumpers, etc). The obtained plates can also be used in new adhesive bonded assemblies with single or double lap.

RESULTS AND DISCUSSION

In order to evaluate the influence of the rubber particles in the laminate, on the mechanical behavior, several types of mechanical tests were carried out: inter laminar shear test, tensile tests under transversal direction, tree point bending test and delamination propagation in mode I and II [4].

The un-doped epoxy/glass plate and the manually doped plates with rubber particles were tested to determine the mechanical properties. The results are presented in tables 1 and 2.

Table 1.

Mechanical properties of the composite plates
(Young Modulus, Poisson ratio and fracture stress).

	Un-doped	**10% doping**	**20% doping**	**30% doping**
E_{11}^{T} **(MPa)**	14680	14260	13850	13500
ν_{12}	0.12	0.12	0.12	0.12
σ_{11}^{R} **(MPa)**	347	319	295	275
$E_{flexion}$ **(MPa)**	14206	12002	10650	8202
σ_{12}^{R} **(MPa)**	92	65	40	35

Concerning the results in tensile load, the most significant modifications are those with fracture. The fracture stress decreases with the mass rate of particles. However, this type of material, having a nonlinear behavior, relieves only a small influence on the yield stress.

Some important modifications of the mechanical characteristics are also raised on the results in bending and inter laminar shearing. The particles were placed in the composite without any particular surface chemical treatment. A suitable surface chemical treatment will support the adherence of the matrix on the rubber particles, which should improve the composite behavior in shear.

Table 2.

Critical energy release rate in mode I and II (Shear Modulus).

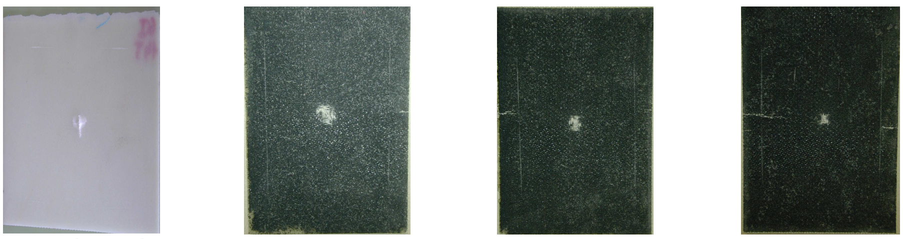
	Without doping	**10 % doping**	**20 % doping**	**30 % doping**
G_{Ic} **(J/m²)**	850 - 1200	800 - 1100	-	-
G_{IIc} **(J/m²)**	3000	2400	1500	1000

Some breaking tests were also realized in order to determine the influence of these particles presence on the delamination propagation (DCB for mode I and ENF for mode II) [4]. The values of the refund rates of the critical energy in mode I and II are given in table 2. The rubber particles insertion modifies the energy in mode I but on the other hand the energies values in mode II are strongly decreased as soon as we exceed a 10 % particles mass rate.

However, it was established during the tests, that the presence of the particles in the material stabilize the propagation of the delamination in mode II (the propagation of the delamination in mode II is often unstable for the ENF test and the delamination propagates as soon as it is initiated under the central support).

The final objective of this study, with recycled rubber particles, was to improve the impact behavior. For that, we made some plates of 150 mm × 100 mm in size, which were tested in a falling weight machine. The plates are positioned (simple plane support) on a plate base of the assembly revealing a free window of 125 mm x 75 mm.

In figure 2, we presented evolution of the damage on the opposed face to the impact for various particle percentages. Concerning the presence of 20 % of particle in laminate mass, any fracture of fibers is observed.



Un-doped 20 % 30 % 40 %

Figure 2. Visualization of defect after impact.

The process used to obtain doped plates, with 10 %, 20 %, 30 % or 40 % mass rubber particles, using the procedure described in the experimental section, are illustrated in figures 3 and 4.

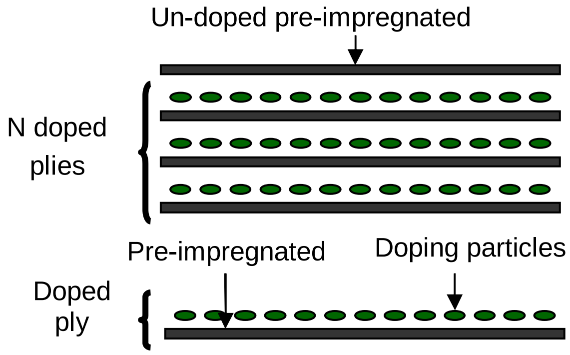


Figure 3. Impregnation process scheme.

We consider that the epoxy resin is sufficiently viscous to maintain in place the doping particles during the various phases of handling.

Figure 4. Manual doping of impregnated laminates.

The infusion technique belongs to the family of Liquid Composite Molding (LCM) as well as Resin Transfer Molding. The resin transfer through the dry immobilized reinforcement in the mold is ensured, in this case, by a vacuum pump and does not require an additional pressure. This technique, not very expensive, makes possible the usage of flexible mold (polyamide or PVC) ensuring the compaction of the fabric folds that are infused and maintained in place on the rigid mold by the same vacuum network. The principle of infusion is schematized in figure 5.

The infusion process was retained because the development of composite-made parts, in small series, makes possible the visualization of the polymer flows, see figure 6, (against transparent flexible mold), in the second time to show the immobilization of the elastomeric particles during the injection phase and finally is applicable as well for structural and for "large diffusion" parts.

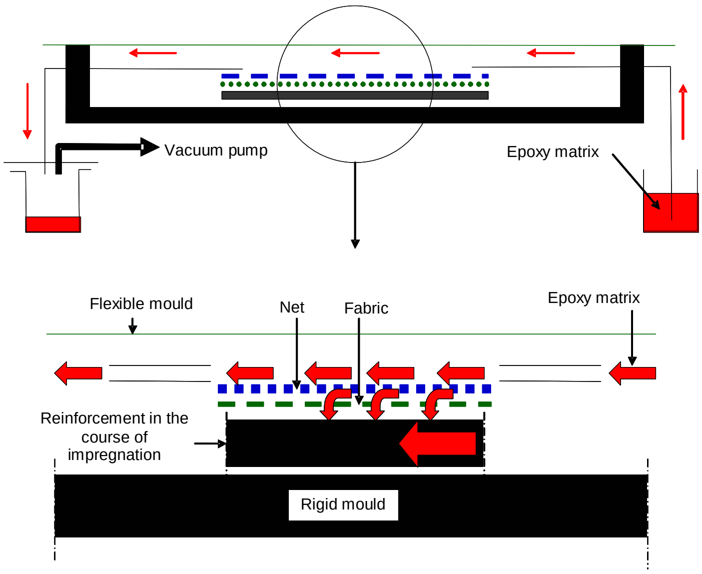


Figure 5. Infusion process scheme.

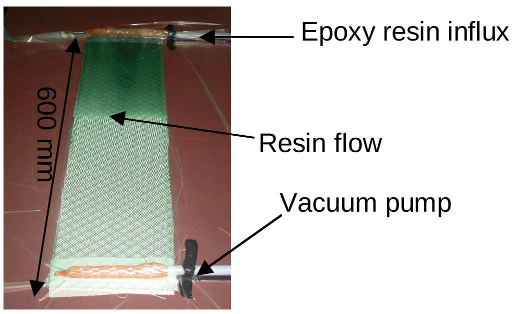


Figure 6. The infusion process.

For this molding process, a series of un-doped specimens is also carried out in order to be used as reference.

CONCLUSIONS

This study made possible the development of two manufacture techniques of composite materials doped with rubber particles. The objective was to validate the manufacture procedures and to raise the influence of the elastomeric particles presence on the mechanical behavior.

This study proposes the possibility of worn tires recycling, which currently creates a large concern with regard to environmental protection. It is well highlighted that the composites doping can allow a strongly improvement of certain characteristics (held with the shock shown in this study).

Also some more important tests regarding the particles influence on the mechanical behavior of the composites were performed.

The incorporation of rubber aggregates in a matrix, confers remarkable physico-mechanical and thermo-hydrous properties to the composite material. Thus, for example the presence of rubber particles improves the composite resistance in particular climatic conditions like cycles of freezing and also appreciably reduces the material density.

EXPERIMENTAL SECTION

Two families of specimens were carried out: the first, made from un-doped and doped glass/epoxy starting from a twill 2 fabric, pre-impregnated, ref. 5492 1808 42/120 provided by CTMI company and the second made from satin 5 glass fiber, un-doped and doped, impregnated with epoxy resin by the infusion method.

For the two specimens families, doping via elastomeric particles (rubber coming from worn tires) was carried out in an artisanal way (powdering by hand).

The polymerization of the epoxy polymer was realized by curing in an oven at 120 °C.

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