Composites: Part B 47 (2013) 126–129

Contents lists available at SciVerse ScienceDirect

Composites: Part B

journal homepage: www.elsevier.com/locate/compositesb

Investigation on microstructure and mechanical properties of samples obtained by injection from Arbofill

Dumitru Nedelcu *

"Gheorghe Asachi" Technical University of Iasi, Department of Machine Manufacturing Technologies, Blvd. Mangeron, No. 59A, 700050 Iasi, Romania

ARTICLE INFO

Article history:
Received 9 May 2012
Received in revised form 20 October 2012
Accepted 29 November 2012
Available online 10 December 2012

Keywords:
A. Resins
B. Mechanical properties
B. Microstructure
D. Electron microscopy

ABSTRACT

The use of recyclable materials has become an important trend in all activity areas, reason why the arbofill, arboblend and arboform are the materials that will replace plastic in the near future. The tensile strength reached (28.05 ± 1.09) MPa at 23 °C and (13.50 ± 0.23) MPa at 60 °C, respectively and the results are not surprising because at room temperature (23 °C), the material had a brittle behavior, while with the increasing in temperature this feature has decreased. The friction coefficient by disk rotation registers a slight decrease approximately in the first 25 s and then throughout the whole tested period it registers a slight increase. The average friction coefficient by disk rotation is 0.145. The variation of the friction coefficient by oscillation is similar, whereas the average friction coefficient is 0.1523. As the diffraction analysis shows, the material does not have a complete amorphous structure and it has several typical phases between 15° and 30°. The specific diffraction technique used was X-ray diffraction. The SEM analysis shows a uniform structure with unidirectional dendritical ramifications and small secondary dendrites and the chemical elements range indicate a high presence, in mass and atomic percentages, of the carbon followed by the oxygen.

1. Introduction

The use of recycled materials has become an important trend in all activity areas, reason why the arbofill, arboblend and arboform are the materials that will replace plastic in the near future. These materials are different shapes of the liquid wood [4]. The main drawback of plastics and their processing methods is the existence in their composition of some carcinogens, their non-biodegradability and the difficulty in recycling these products. "Liquid wood" can be reused up to five times over, without affecting the mechanical properties of the material, as for example fire resistance and durability [1,2]. "Liquid wood" processing is derived from the rubber production procedure. Wood and plastic compounds prevent absorption of water and, therefore, increase the durability of the material. The only downside of "liquid wood" is the weight, as it is much heavier than ordinary plastics. At the same time, another drawback would be the price of production, nearly double that of polypropylene, the most common plastic material. However, if we think of the beneficial effects on the environment, compared to petroleum-derived plastics, the benefits clearly outrun these inconveniences [1].

The invention of the "liquid wood" material belongs to a team of researchers from the Fraunhofer Institute for Chemical Technology (ICT) in Pfinztal (Germany). So far, the main applications of "liquid wood" have been: watches, keyboards, toys, kitchenware, brushes and helmets, high quality terraces for houses, building panels for constructions without casting and furniture, automotive bodies (even engine components like the battery holder [3]). The arbofill granules can be processed with injection moulding, extrusion, calendering, blowmolding, deep drawing or pressing into moulded parts, half-finished product, sheets, film solder profiles [4]. The "liquid wood" manufacturing process does not use environmentally harmful chemical substances.

2. Technology and experimental research plan

The technical issue that the project is solving is the obtaining of "liquid wood" benchmarks through monocomponent injection into molds, a process by means of which products with characteristics superior to those made of plastics are obtained. "Liquid wood" pellets, which are mainly composed of lignin, discarded during the paper-making process, in combination with cellulose, wood waste from industrial plants, pellets also known as material under the name of arbofill, are introduced into a bunker where they are subjected to a hot-air drying process for 2 h, after which the pellets are pneumatically transferred by a pneumatic conveyor, into a bunker of an injection machine, from where the material enters an injection cylinder, electrically heated at 140–170 °C, being afterwards injected into a mold, which is cooled with water at a temperature

* Tel./fax: +40 232 217290.
E-mail address: dnedelcu@tcm.tuiasi.ro

1359-8368/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.compositesb.2012.11.023

of 15 °C, the water being transferred into the mold through a circuit provided with a cooler.

The advantages of this new technology are: the products obtained have characteristics superior to those of plastic-injected products, are harder, more flexible and have a better resistance to shocks; the lack of carcinogens in the product material and their biodegradability; the multiple recycling of the product obtained and energy savings due the lower melting temperatures compared with other plastics [6].

The planning of the experiments was achieved by means of the Taguchi methodology [8].

The model proposed by Viger and Sisson is also easy to study; this is the matrix model of the system comprising "I" factors: F_1, F_2 ... F_i each factor having n_i levels. Each experiment was conducted three times. The proposed matrix model takes into consideration six technological parameters with two levels. The coefficients of a type (1) model were determined within the experimental research:

$$Z_t = M + T_{top} + t_{inj} + t_r + S_s + P_{inj} + T_{mat} + P_{inj}T_{top} + P_{inj}t_{inj} + P_{inj}t_r + P_{inj}S_s + P_{inj}T_{mat} \quad (1)$$

where M is the general average; T_{top} is the melting temperature (°C); t_{inj} is the injection time, (s), t_r is the cooling time (s), S_s is the screw speed (mm), P_{inj} is the injection pressure (MPa), T_{mat} is the matrix temperature (°C) [9,13]. The most significant influence on the process is exercised by the injection pressure followed by the melting temperature and the matrix temperature. Screw speed, injection time and cooling time have less influence on the injection process.

3. Results and discussion

A series of experiments were undertaken to demonstrate the reliability of this novel material and evaluate its potential for industrial applications. Tensile tests were carried out to reveal mechanical properties.

The tensile tests were conducted at room temperature (RT) and 60 °C, respectively, using a computer-controlled testing machine (Instron 3382) with a constant crosshead speed of 5 mm/min according to ISO 527-3: 2003 recommendations. For each testing temperature, many specimens were tensile tested to determine the tensile strength and tensile strain at tensile strength (engineering). All specimens (3 resulting from each of the 16 experiments conducted according to Taguchi methodology) were prepared according ISO 527-3: 2003 recommendations to achieve type 1B test samples (recommended for fiber-reinforced (thermo)plastics). Fig. 1 shows the tensile testing results. Representative tensile stress vs tensile strain curves were plotted to reveal the homogeneity (uniformity) of mechanical properties. Experimental data show that the tensile strength reached (28.05 ± 1.09) MPa at 23 °C and (13.50 ± 0.23) MPa at 60 °C, respectively. The tensile strain at fracture increased from (4.71 ± 0.11)% at 23 °C to (7.10 ± 0.48)% at 60 °C, respectively. The standard deviations are shown in Table 1. The results are not surprising because at room temperature (23 °C), the material had a brittle behavior, while with the increasing in temperature this feature has decreased. Fig. 1 shows a macroscopic image of the break area using an OPTIKA microscope. This confirms that the break is brittle without deformations. The results obtained, at room temperature, are similar to those for polypropylene (PP) [5,7], the most used plastic material.

In order to use the materials, it is highly important to know the coefficient of friction. Thus, to determine the tribological behavior of the "liquid wood" (arbofill type) there has been used the Universal UMT-2 (CETR – Center of Tribology, Inc., USA) Tribometer equipment pin-on-disk type. Choosing the tribosystem, the material couple used for the fabrication of the component elements, the friction conditions, the ambient temperature and humidity have a very important role for the testing. The determination of the friction coefficient was made in dry slide conditions by the rotation of the disk made of OL60 and by its oscillation by a 180° angle [10,11]. The testing conditions were as follows: the pressing force F_z = 15 N, disk rotation n = 60 rot/min, the distance from the disk rotation axis to the pin-on-disk contact area r = 15 mm, friction time t = 300 s and the 6 mm diameter sample dimension. The initial disk roughness was R_a = 0.6 µm. A sliding speed of V = 94.2 m/min and a friction length of L = 471 m were calculated. The friction coefficient by the rotation of the disk (Fig. 2, curve 1) registers a slight fall approximately in the first 25 s and then throughout the whole tested period it registers a slight rise. The average value of the friction coefficient by rotation is 0.145. The testing time extension leads to friction coefficient value stabilization. The variation of the friction coefficient by oscillation (Fig. 2, curve 2) is similar, the average value of the friction coefficient is 0.1523. The variations of the constants of friction pre-

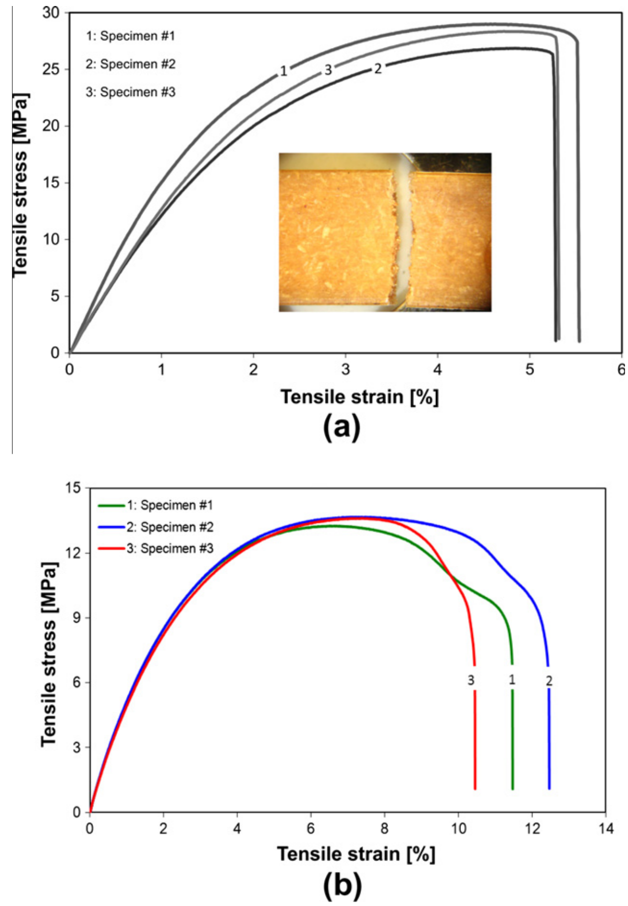

Fig. 1. Tensile stress vs tensile strain: (a) at 23 °C; (b) at 60 °C.

Table 1
Standard deviations.

	At (%)	A (%)	Rm (Mpa)
	5.52	4.58	28.97
	5.25	4.78	26.84
	5.30	4.76	28.33
Ave.	5.36	4.71	28.05
St. dev.	0.14	0.11	1.09