Indian Journal of Engineering & Materials Sciences
Vol. 21, June 2014, pp. 272-276

Microstructure, mechanical properties and technology of samples obtained by injection from arboblend V2 nature

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Received 1 July 2013; accepted 11 February 2014

In all the activity areas, the use of recycled materials has become an important trend. From this point of view, the liquid wood is the material that will replace plastic in the near future. There are three types of liquid wood as follow: arbofill, arboblend and arboform. 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. The liquid wood has a positive impact over the environment compared to petroleum-derived plastics. In this paper, arboblend V2 nature is used. Experimental data show that the tensile strength reached 44.05 ± 0.48 MPa at 23°C and the material had a brittle behavior. The results obtained are better than PE-40 MPa, PVDF (poly vinylidene fluoride)-43 MPa, PCTFE (ethylene copolymer)-32 MPa. The friction coefficient registers a slight decrease approximately in the first 25 s and then throughout the completely tested period it registers a slight increase. The friction coefficient average using the disc rotating is 0.1627. Variation of friction coefficient is similar, the average friction coefficient being 0.1376. The results obtained are better than PA 12-(0.32-0.38); PP-0.3; PE-HD (high density polyethylene)-0.29; ABS- 0.5; PVDF (poly vinylidene fluoride)-0.23. Arboblend V2 nature seems to have a structure between amorphous and crystalline. Using software of machine equipment is determined the following phases with peaks highlighted, such as $C_{14}H_{26}CuO_{12}S_2$ with monoclinic crystal structure and another one with unknown crystal structure. The SEM analysis shows a uniform structure with small impurities with a random orientation. In the spectrum of chemical elements dominate, in percentage and atomic mass, carbon and oxygen followed by nitogen. According to the analyses performed and to the conclusions drawn, the arboblend V2 nature can replace the plastic materials in many industrial applications, such as the automobile industry, furniture industry, toys industry, electrical industry, computers, mobile phone, housing etc.

Keywords: Arboblend, Injection, Mechanical properties, Microstructure

Materials are substances that affect the development of a company by different objects necessary human obtained them by processing. The use of recycled materials has become an important trend in all activity areas, reason why the liquid wood (arbofill, arboblend and arboform) is the material that will replace plastic in the near future. 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 products made from these plastics. 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. The compound of wood and plastic prevents absorption of water and, therefore, increases the durability of the material. The only downside of liquid wood is the weight, being much heavier as compared to 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.

The fact that untreated wood or even wood scraps can be used in this process turns this application into a beneficial one for the environment. Another advantage is that the new processing technology improves fixation of wood fibers and insulates unpleasant odors[3]. Since the current plastics are produced from crude oil, which is a non-renewable substance, “liquid wood” which is a substance based on cellulose, lignin, a natural polymer that provides strength to the wood and industrial plants, in a few years it will replace the plastics so widely used in contemporary society[1]. The invention of the liquid wood material belongs to a team of researchers from the Fraunhofer Institute

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for Chemical Technology (ICT) in Pfinztal (Germany). Up to now, the main applications of liquid wood are watches, keyboards, toys, kitchenware, brushes and helmets, high quality terraces for houses, building panels for constructions without casting and furniture, automotive bodies (even and engine compartment, components like the battery holder[3,4]).

Experimental Procedure

The technical issue that the project is solving is the obtaining of benchmarks in liquid wood through monocomponent injection into molds, a process by means of which products with characteristics superior to those made of plastics are obtained. The arboform, arboblend and arbofill granules can be processed with injection moulding, extrusion, calendering, blowmolding, deep drawing or pressing into moulded parts, half-finished product, sheets, film soder profiles[5-7]. In this experiment arboblend V2 nature was used. Liquid wood pellets, which are mainly composed of lignin, discarded during the paper-making process, in combination with cellulose, wood waste from industrial plants. The 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 two hours, after that the pellets are pneumatically transferred by a pneumatic conveyor into a bunker of an injection machine, from where the material enters an injection cylinder. It is electrically heated at 150-170°C, afterwards injected into a mold, which is cooled with water at a temperature 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 present characteristics superior to those of plastic-injected products, harder, more flexible and have a better resistance to shocks. The lack of carcinogens in the product material and their biodegradability; the ability to perform multiple recycling of the product obtained and energy savings due the lower melting temperatures compared with other plastics[7].

The main parameters of liquid wood injection process which could be taken into account on research areas are as follow: melt temperature, mold temperature, injection speed, injection and holding pressure, cooling time, holding pressure time inside the mould and injection time.

The planning of the experiments was achieved by means of the Taguchi methodology. Nedelcu and Pruteanu[8], show the Taguchi experimental methodology and the graphs with copyright license.

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 thrice. The proposed matrix model takes into consideration six technological parameters with two levels (Table 1). In the experimental study, we determined the coefficients of a type (1) model:

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

where M is the general average, T_{top} is melt temperature, (^{o}C); t_{inj} is injection time, (s), t_r is cooling time, (s), S_s is screw speed, (mm), P_{inj} is injection pressure, (MPa), T_{mat} is matrix temperature, (^{o}C). The most significant influence on the process is exercised by the injection pressure followed by the melt temperature and the matrix temperature. Then comes, with less significant influences, screw speed, the injection time and the cooling time.

Then the orthogonality and number of degrees of freedom conditions were analyzed, there were 16 experimental tests to be made. The levels values for input parameters are presented in Table 1.

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-23°C) 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 of the specimens were prepared according ISO 527-3: 2003 recommendations to realize type 1B test samples (recommended for fiber-reinforced (thermo) plastics).

Table 1 – The levels values of input parameters

Input parameter Levels	T_{top} (°C)	t_{inj} (s)	t_r (s)	S_s (mm)	P_{inj} (kgf)	T_{mat} (°C)
First level	150	6	18	100	70	40
Second level	170	9	25	120	90	70

Figure 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 44.05 ± 0.48 MPa at 23°C. The tensile strain at fracture is 4.88 ± 0.3% at 23°C. Table 2 presents the total extension, A_t (%), tensile strain at tensile strength, A (%) and tensile strength, R_m (MPa). The results obtained are better than PE-40 MPa, PVDF (Poly Vinylidene Fluoride)-43 MPa, PCTFE (Ethylene Copolymer)-32 MPa, showed elsewhere[2] and presented by others[7,9,10].

In order to use the materials, it is highly important to know the constant of friction. Thus, to determine the tribological behavior of the liquid wood (arboblend type) there has been used the Universal UMT-2 (CETR-Center of Tribology, INC. USA) Tribometer equipment pin on disk type, because it is the most favorable due to the tribolelements' simplicity. Choosing the tribosystem, the material couple used for the fabrication of the component elements, of the friction conditions, of the ambient temperature and humidity has a very important role for test elaboration. 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 in an 180° angle. 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 pi-disk contact area r=15 mm, friction time t=300 s and 6 mm diameter sample dimension. The initial disk asperity was R_a=0.6 μm.

The mathematical relation used to calculate the specific pressure, sliding speed and friction length are:

$$F_z = pA \quad \ldots (2)$$

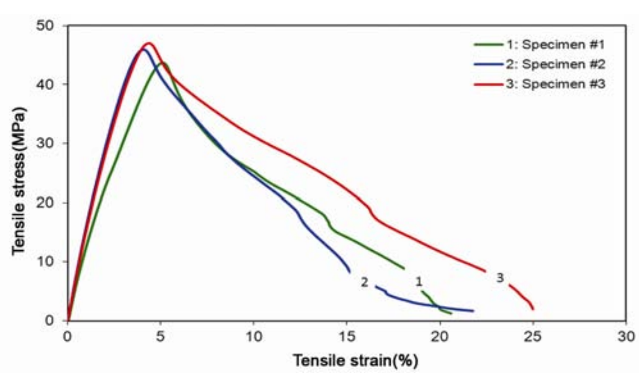

Fig. 1 – Tensile stress versus tensile strain at 23°C

$$T = L/v \quad \ldots (3)$$

$$N = 30\, v/r\pi \quad \ldots (4)$$

where p specific pressure (MPa); A is the contact area of pin on disc with the diameter by 6 mm, (mm^2); v is the sliding speed, (m/min) and r represents the radius testing, (mm).

The calculated value of the sliding speed is 94.2 m/min and the friction length is 471 m. 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 completely tested period it registers a slight rise. The average value of the friction coefficient by rotation is 0.1627. 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 0.1376. The variations of the friction coefficient presented do not include the noise parameters. The results obtained[2] are better than PA 12-(0.32-0.38); PP-0.3; PE-HD (high density polyethylene)-0.29; ABS- 0.5; PVDF (poly vinylidene fluoride)-0.23.

For the XRD analysis it was used the X'Pert Pro MRD Diffractometer made by Panalytical. The image obtained with this analysis is shown in Fig. 3. The scan was made on a 5 mm segment in a 2θ distance between 95.0036°-59.9932°. Analyzing the diffractogram, it results that the material seems to have a structure between amorphous and crystalline.

Table 2 – Statistic deviation of A_t, A and R_m

	Total extension, A_t (%)	Tensile strain at tensile strength, A (%)	Tensile strength, R_m (MPa)
Sample 1	20.57	5.16	43.66
Sample 2	21.77	4.56	43.91
Sample 3	26.28	4.92	44.59
Media	22.87	4.88	44.05
StDev	3.01	0.30	0.48

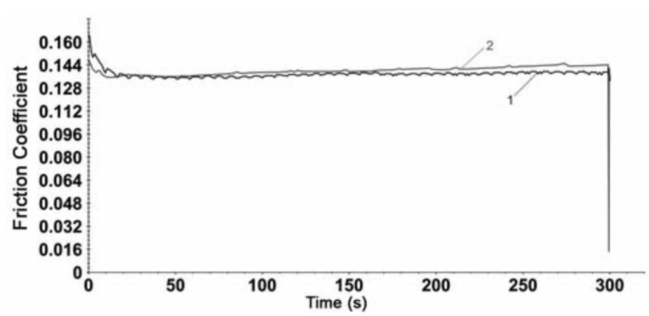

Fig. 2 – Variation of friction coefficient by (1) disk rotation and (2) disk oscillation

Using software of machine equipment was determined the following phases with peaks highlighted, such as $C_{14}H_{26}CuO_{12}S_2$ with monoclinic crystal structure and another one with unknown crystal structure.

For scanning electron microscopy (SEM) analysis was used an Electronic Microscope QUANTA 200 3D which works with double electron and ion beam (Fig. 4). The image was obtained taking into account the following parameters: the accelerating voltage (HV) of the 15 kV, secondary electrons (SE); the magnification power (mag) of 200X; working distance (WD) of 14.7 mm; LFD (large field detector) detector used for the analysis of the non conductive samples (polimers, textile fibres, powders etc.); tilt angle (tilt) of 0^o; the pressure inside the microscope room of 60 Pa. The SEM analysis shows a uniform structure with small impurities with a random orientation.

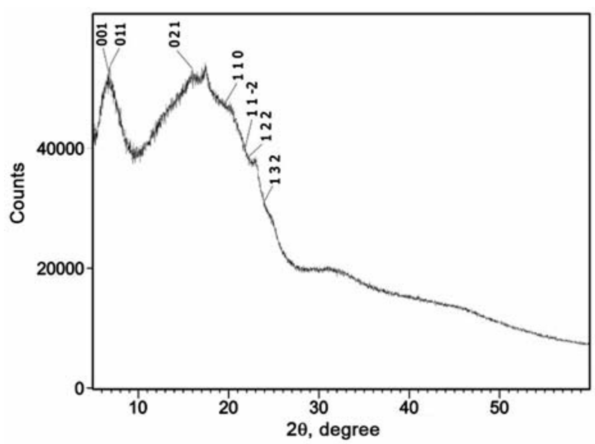

Fig. 3 – XRD analysis

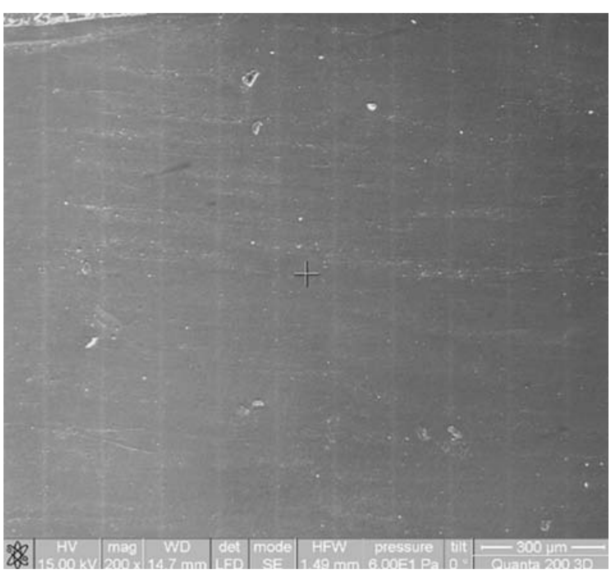

Fig. 4 – SEM image obtained with secondary electrons (SE)

Energy dispersive X-ray spectroscopy (EDAX) is an analytical technique used for the elemental analysis or chemical characterization of a sample. For measurement, an Electronic Microscope QUANTA 200 3D which works with double electron and ion beam was used. This way, the chemical elements range is presented in Fig. 5a in a 304 s range acquisition time. Figure 5b is presents the sample surface used to quantitative elemental chemical analysis with X-ray in the SEM. Table 3 presents

Table 3 – The weight, atomic percentages for chemical elements and ZAF correction

Element	Weight percentages, Wt, (%)	Atomic percentages, At, (%)
CK	65.84	71.89
NK	8.24	7.72
OK	23.72	19.45
NaK	0.59	0.34
SiK	0.3	0.14
ClK	0.74	0.27
CaK	0.56	0.18
Matrix	Correction	ZAF

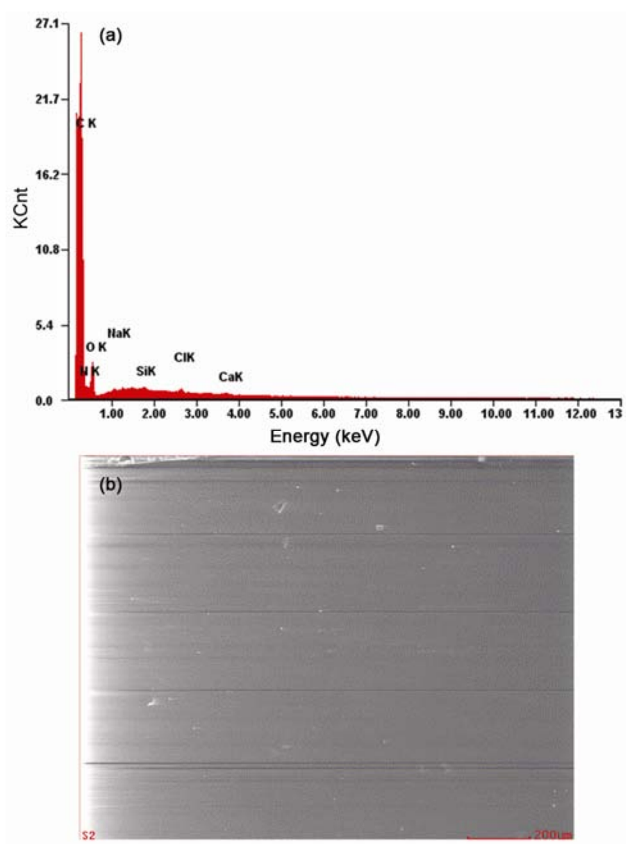

Fig. 5 – (a) Spectrum of chemical elements and (b) surface used to quantitative elemental chemical analysis

the weight and atomic percentages for chemical elements and ZAF correction also (Z-atomic number correction, A-sample matrix absorption correction, F-correction of secondary X-ray emission). The main chemical elements depending on the relative energy peaks are highlighted. In the spectrum of chemical elements dominate, in percentage and atomic mass, carbon and oxygen followed by nitrogen. According to the analyses performed and to the conclusions drawn, the arboblend can replace the plastic materials in many industrial applications, such as the automobile industry, furniture industry, toys industry, electrical industry, computers, mobile phone, housing etc.

Conclusions

Take into account the biodegradability, mechanical and thermal properties the liquid wood is the material that will replace the plastics soon. In addition, it is important to point out that in all activity areas the use of recycled materials has become an important trend. As material was used arboblend V2 nature. Experimental data show that the tensile strength reached 44.05 ± 0.48 MPa at 23°C and the material had a brittle behavior. From this point of view, the results obtained are better than PE-40 MPa, PVDF (poly vinylidene fluoride)-43 MPa, PCTFE (ethylene copolymer)-32 MPa. The friction coefficient average using the disc rotating is 0.1627. Variation of friction coefficient is similar, the average friction coefficient being 0.1376. The results obtained are better than PA 12-(0.32-0.38); PP-0.3; PE-HD (high density polyethylene)-0.29; ABS- 0.5; PVDF (poly vinylidene fluoride)-0.23. Arboblend V2 nature seems to have a structure between amorphous and crystalline. Using software of machine equipment was determined the following phases with peaks highlighted, such as $C_{14}H_{26}CuO_{12}S_2$ with monoclinic crystal structure and another one with unknown crystal structure. The SEM analysis shows a uniform structure with small impurities with a random orientation. In the spectrum of chemical elements dominate, in percentage and atomic mass, carbon and nitrogen followed by oxygen. The arboblend V2 nature can replace the plastic materials in many industrial applications.

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