International Journal of Modern Manufacturing Technologies
ISSN 2067–3604, Vol. VIII, No. 2 / 2016

THE MODELS OF MAIN EFFECTS OF DIFFERENT PARAMETERS OF "LIQUID WOOD" SAMPLES

Simona Plavanescu (Mazurchevici)[1], Constantin Carausu[2]

[1, 2] "Gheorghe Asachi" Technical University of Iasi-Romania, Department of Machine Manufacturing Technology, Blvd. Mangeron No. 59A, 700050 Iasi, Romania

Corresponding author: Constantin Carausu, c_carausu@yahoo.com

Abstract: The growing concern in terms of global pollution has sparked the interest of many scientific fields which develop more and more earths-friendly materials. On this category of top materials which presents high quality performances is included also the "liquid wood" material that could replace with success some ordinary plastics due to its superior properties to other one and to its biodegradability. There are three types of "Liquid wood" a high quality thermoplastic biocomposite. "Liquid wood" is a biopolymer composite divided in three categories, ARBOFORM®, ARBOBLEND® and ARBOFILL®, which have differed composition in terms of lignin percentage, being delivered by Tecnaro, material developer, as granules, [1].

The paper's research was focus on technological parameters influence on tensile strength of Arboform LV3 Nature samples as based material and Arboform LV3 Nature reinforced with aramid fiber. Processing Taguchi method allowed both Taguchi setting work parameters influence on elongation and modulus of elasticity as the size and influence their ranking. Transversal injection (90^0) lead to the increasing of materials stiffness if are taked into account the registered values of elongation and modulus of elasticity which are lower than of samples obtained by longitudinal direction of injection molding (0^0). The results of tensile strength for both, the base material and material obtained by reinforcing with aramid fiber injected at 0^o present σ_{max} values less spread and greater that in case of 90° injection angle, which means that most technological parameters are acceptable in case of longitudinal injection of the material.

Key words: Liquid wood, injection molding, tensile strength, technological parameters

1. INTRODUCTION

"Liquid wood" may be found in three different forms: ARBOFORM® liquid wood (based on lignin, natural additives and the natural fibers), ARBOBLEND® wood plastic composite (contains, depending on the degree of biopolymers, such as, for example, lignin, starch, natural resins, waxes and cellulose) and biopolymer compound ARBOFILL® (it is a compound of polymers and natural fibers, having the aspect of a natural cork), [1, 2].

"Liquid wood" (especially Arboform) is a biodegradable and recyclable thermoplastic material based on cellulose, lignin containing no carcinogens, as in the case of plastics derived from oil. It confers resistance to wood and industrial plants, and it is expected that in a few years it will replace plastics currently used on a wide scale in contemporary society, [3]. The invention of "liquid wood" belongs to a team of researchers from the Fraunhofer Institute for Chemical Technology (ICT) in Pfinztal (Germany).

So far, this eco-friendly material has been mainly used in: watches, keyboards, toys, kitchenware, brushes and helmets, high quality terraces for homes, building panels with no molding and furniture, automotive components (even the engine compartment, components, such as the battery holder, [4]), etc.

Injection molding of Arboform LV3 Nature parts from may be made on standard injection machinery. The injection temperature varies between (155÷170)°C. The process runs with an open nozzle having a diameter of between (2.5 – 4.0) mm. Injection pressure must high enough, so that the turning the screw be smooth. The injection pressure should be as high as possible (150 MPa) and the speed of injection, accordingly. Closing pressure should be approximately 30% of the capacity of the machinery with a corresponding time of only (0.5÷2) seconds. Cooling time should be 20% higher than for normal thermoplastic material.

Main problems that should be considered:

- Injection contraction is very low;
- Molds must have a release spring, useful to achieve fast working cycles;
- The application of not too thin plates to the mold is necessary due to Arboform's low contraction;
- Heated channel of nozzles works only in limited cases, [5].

A few general guidelines for optimizing the process of producing parts from Arboform by injection moulding parts are presented below:

• Pre-drying of granules is not recommended, with normal storage conditions (drying at 25°C);

• Adjusting the operating temperature of the injection machine with a low PE-LD melting point (low density polyethylene);

• The material should not be kept more than 15 minutes in the injection machine heated at processing temperature; is the material remains longer in the machine, an intermediary cleaning should be performed with PE-LD;

• Lignin compounds should not be stored together with other hot polymers.

2. EXPERIMENTAL PROCEDURE

Injection molding of Arboform LV3 Nature (A) and Arboform granules reinforced with aramid fibers (A+AF) was made according to DIN EN ISO 527-1:1993 standard, using the standard injection equipment SZ800H, available at the Fine Mechanics and Nanotechnology Laboratory, Faculty of Machine Manufacturing and Industrial Management, “Gheorghe Asachi” Technical University of Iasi.

Injection molding was performed according to the established research experimental plan using the Taguchi method, [7, 8]. The research plan includes a total of 16 experiments, L16-type fractional plan. We considered six parameters, each having two levels, as follows: $\mathbf{T}_{top}$, injection temperature (^{o}C), $\mathbf{D}_{inj}$, direction injection (0^{o} and 90^{o}), $\mathbf{P}_{inj}$, injection pressure (MPa), $\mathbf{t}_{inj}$ injection time (s), $\mathbf{t}_{cooling}$, cooling time (s), and $\mathbf{S}_{s}$, screw movement / injection rate (m/min).

Tensile testing was performed on universal testing machine MTS Insight 5.

3. RESULTS AND DISCUSSIONS

Study of the influences of working parameters on tensile strength of specimens, graphs of variation for the base materials and materials reinforced with aramid fibers are presented below.

According to the results [9, 10], the graphic distribution of the 16 tensile tests performed, for Arboform L, V3 Nature material are presented in figure 1. We may note that the material recorded the maximum value of tensile strength for experiment number 15 (20.93 MPa). Its value is influenced by the injection temperature (150°C), the injection direction (90°) and the injection pressure (100MPa).

In case of Young module (figure 2), its maximum value is 7.8 GPa being influenced by the injection temperature (150°C) and the injection direction (90°)

In figure 3, we observe that the results of tensile strength for reinforced material, injected at 0^{o} present σ_{max} values less spread, which means that most technological parameters are acceptable in case of longitudinal injection of the material. Injection at 90° makes the obtained samples to be more sensitive to process parameters changes, which requires optimization of injection process in this case.

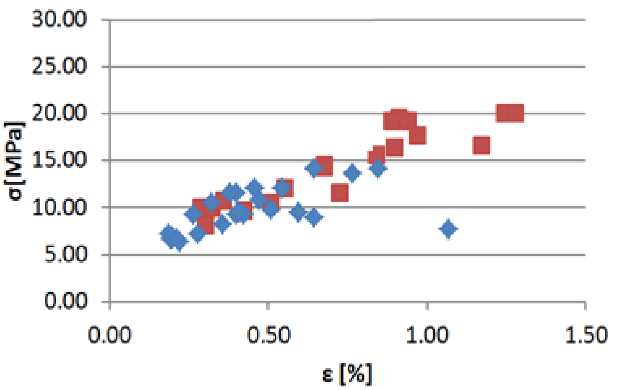


Fig. 1. The graphic distribution of tensile test results (σ_{max} vs ε_{max}) for Arboform L, V3 Nature: ■ Tensile, 0 degree injection molding; ◆ Tensile, 90 degree injection molding

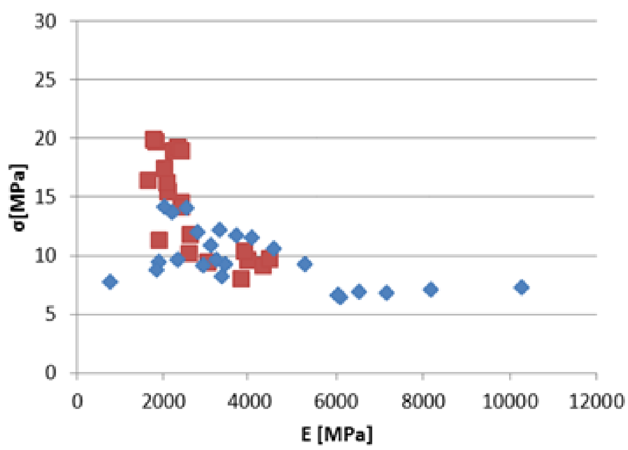


Fig. 2. The graphic distribution of Young modulus results for Arboform LV3 Nature: ■ Elastic modulus, 0 degree injection molding; ◆ Elastic modulus, 90 degree injection molding

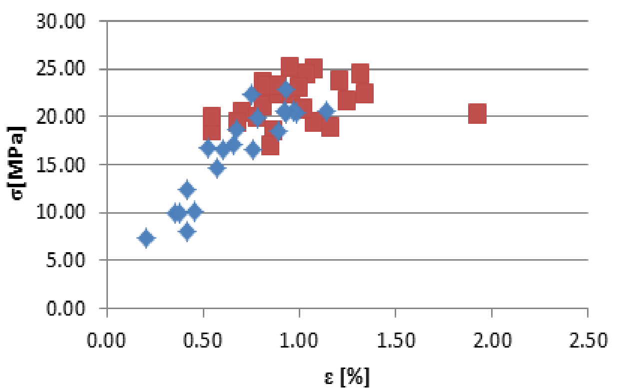


Fig. 3. Tensile strength vs Elongation, Arboform L, V3 Nature reinforced with aramid fibres: ■ Tensile, 0 degree injection molding; ◆ Tensile, 90 degree injection molding

The maximum Young's modulus recorded is 5.2 GPa, for experiment number 12, (figure 4). Elasticity module recorded no growth upon the incorporation of aramid fibers.

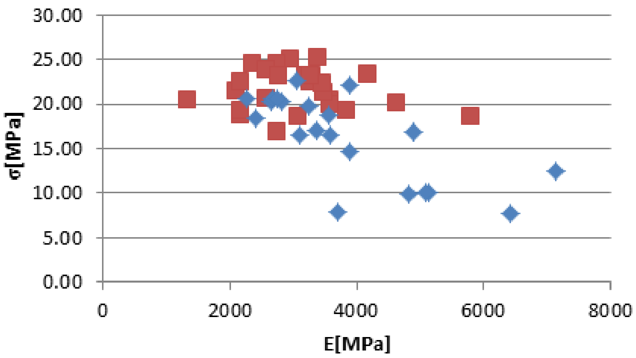


Fig. 4. Tensile strength vs Young modulus for Arboform L, V3 Nature: ■ Young modulus, 0 degree injection molding; ◆ Young modulus, 90 degree injection molding

Making a comparison between tensile strength of Arboform L, V3 Nature and tensile strength of the reinforced material, we may observe, figure 5, that the incorporation into the base material of 30% of aramid fibres leads to the considerable growth of tensile strength.

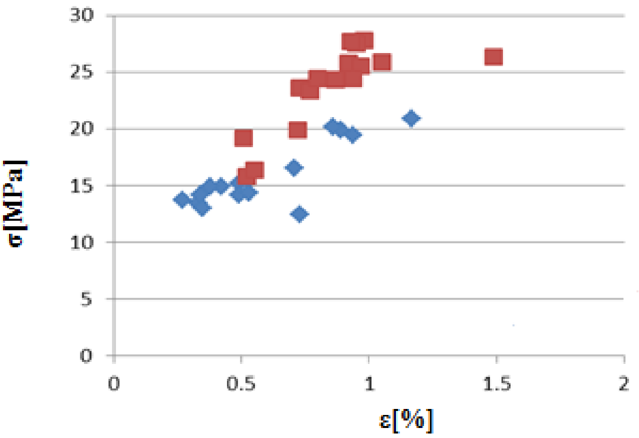


Fig. 5. Arboform L, V3 Nature vs. Arboform L, V3 Nature reinforced with aramid fibers, average values of tensile strength: ■ Arboform L, V3 Nature reinforced with aramid fibers; ◆ Arboform L, V3 Nature

Processing using the Taguchi method showed the influences of working parameters on tensile strength and enabled us to rank the influences by their size. Figure 6 shows these influences. For each level of the parameter, its average effect on tensile strength is presented. The model's average is 16.14 MPa. The samples obtained for the direction 90° have higher tensile strength than for the injection direction of 0°. At the increase of melting temperature T_{top}, injection pressure P_{inj}, rate of injection S_s and time of injection, breaking strength of samples increases. The increase of cooling time decreases the tensile strength of samples. The decreasing order of parameters by influence on breaking strength is: D_{inj}, $T_{top,}$ P_{inj}, S_s, T_{rac} şi T_{inj}. The last two parameters have a small influence on the analyzed subject.

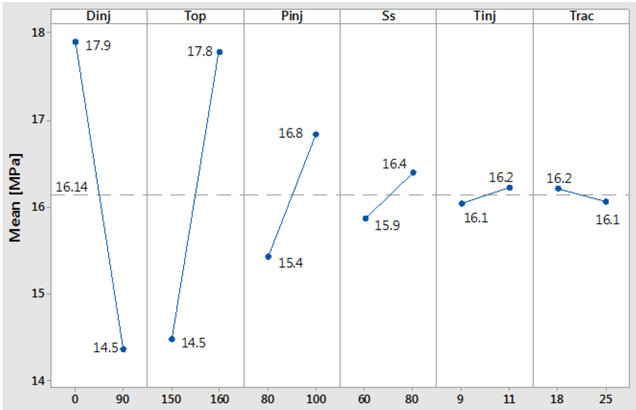


Fig. 6. Model of main effects of average technological parameters on tensile strength for Arboform L V3 Nature

For Arboform L V3 Nature reinforced with aramid fibre, (figure 7), the model average is 19.6 MPa.

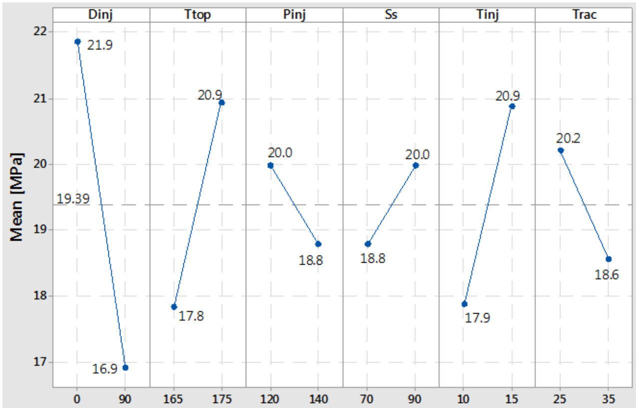


Fig. 7. Model of the main effects of technological parameters average on tensile strength for Arboform L V3 Nature reinforced with aramid fibre

The resulted samples with the direction 90° have higher tensile traction compared to the samples with the direction 0°.

At the increase of melting temperature T_{top}, rate S_s and injection time, the breaking strength of samples increase. The increase of injection pressure P_{inj} and cooling time decrease the tensile strength of samples.

The decreasing order of parameters by influence on the breaking strength is: D_{inj}, $T_{top,}$ T_{inj}, T_{rac}, P_{inj} and S_s, the last two parameters having similar influences in terms of size but in the opposite sense.

For the base material Arboform L V3 Nature, we found an increase of the average value of tensile strength from 16.14 MPa to 19.39 MPa, namely, an increase by 20.1%. The highest value of breaking strength is from 20.9 MPa to 23.8 MPa, namely, 13.9%.

By processing data from tensile testing, we obtained the elasticity model; processing by means of Taguchi method established the model's average of 3739 MPa (figure 8). The obtained samples with the direction of 90° have lower elasticity model than the models with the injection direction of 0°. S_s increase the elasticity module of samples. The increase of injection pressure P_{inj}, injection and cooling time leads to the decrease of the elasticity module of samples.

The decreasing order of parameters by influence upon elasticity module is: D_{inj}, S_s, T_{inj}, P_{inj}, T_{rac} şi T_{top}. The last three parameters have a reduced influence, close in size in the analyzed area.

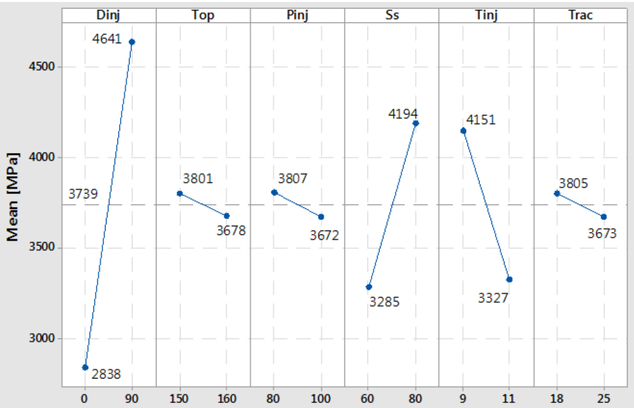


Fig. 8. Model of main effects of technological parameters average on the elasticity modulus for Arboform L V3 Nature

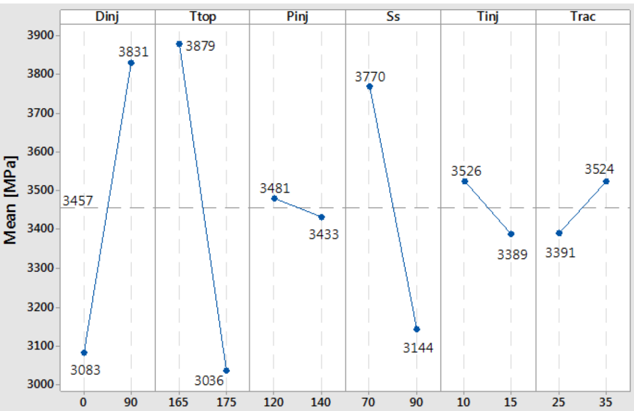


Fig. 9. Model of main effects of technological parameters average on elasticity modulus for Arboform L V3 Nature reinforced with aramid fibre

For the material reinforced with aramid fibre, the model average is of 3457 MPa (figure 9). The resulted samples with the direction of 90° have lower elasticity module than models with the longitudinal direction. The elasticity module of samples increases upon the increase of cooling time. The increase of injection pressure P_{inj}, injection pressure and rate S_s leads to the decrease of elasticity module of samples.

The decreasing order of parameters by influence on the elasticity modulus is: T_{top}, D_{inj}, S_s, T_{inj}, T_{rac} şi P_{inj}.

The last three parameters have a reduced influence, close in value for the analyzed area.

Also, after tensile testing, the elongation values were obtained. The model average of 0.56 % (figure 10, [9, 11]) was obtained for the main material Arboform L V3 Nature. The resulted samples with the 90° direction have a lower elongation than the models with longitudinal direction. At increase of melting temperature T_{top} and the injection time $T_{inj,}$ sample elongation increases. The increase of rate S_s and cooling time leads to decrease of sample elongation. The influence of injection pressure P_{inj} on elongation is negligible.

The decreasing order of parameters by influence on the elasticity module is: D_{inj}, T_{top}, T_{rac}, S_s and T_{inj}.

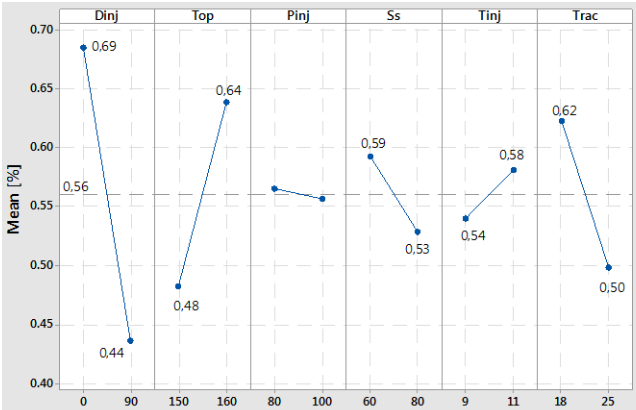
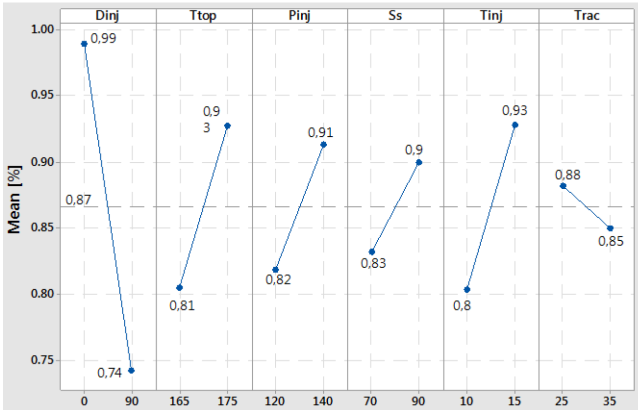


Fig. 10. Model of main effects of technological parameters average on elongation for Arboform L V3 Nature

Fig. 11. Model of main effects of technological parameters



average on elongation for Arboform L V3 Nature reinforced with aramid fiber

For the reinforced material with aramid fibers, the model average is of 0.87 % (figure 11, [9, 11]). The resulted samples having the direction 90° have lower elongation than the models with longitudinal direction. At increase of melting temperature T_{top}, injection pressure P_{inj}, rate S_s and injection time, sample elongation increases. The increase of cooling time leads to the decrease of sample elongation.

The decreasing order of parameters by the influence upon the elasticity modulus is: D_{inj}, T_{top}, T_{inj}, P_{inj}, S_s and T_{rac}.
We found that samples made of Arboform reinforced with aramid fiber have lower values of elongation (average 0.87) compared to samples from Arboform L V3 Nature (average 0.56).

3. CONCLUSIONS

By analyzing the tensile curves of biocomposite materials Arboform L,V3 Nature and Arboform L,V3 Nature reinforced with aramid fibers, we may notice that these have a typical form for materials with fragile breaking. Also, these materials have small breaking deformations and the sample has no bottleneck signs.
For the studied fragile materials, the characteristic curve is short, with low elongation at breaking and the only mechanical characteristic that may be accurately underlined is the breaking limit.
Comparing the tensile strength of Arboform and Arboform reinforced by 30% aramid fibers leads to considerable increase of tensile strength.
By studying the effects of technological parameters average on mechanical characteristics, it has been found that the material Arbform L V3 Nature reinforced with aramid fibers behaves better than the base material.

REFERENCES

1. Lars Ziegler, Helmut Nägele, Jürgen Pfitzer, TecnaroGmbH; Dr. Josef Innerlohinger, Lenzing AG:WPC and Bio-Polymer Composites –State of the Art and Today´s Applications, BioStructAdvanced Wood-Based Composites And Their Production
2. Seres, I., (1996), *Injectarea materialelor termoplastice*, Imprimeria de Vest Publishing House, Oradea, Romania.
3. SrikanthPilla, (2011), *Engineering Applications of Bioplastics and Biocomposites - An overview*, Handbook of Bioplastics and Biocomposites Engineering Applications, Published John Wiley & Sons, New Jersey, 1-14.
4. Kale, G., Kijchavengkul, T., Auras, R., Rubino, M., Selke, S.E., Singh, S.P., (2007), Macromolecular Bioscience, 7, 381.
5. Helmut, N., Jurgen, P., Lars, Z., Emilia Regina Inone-Kauffmann, Wilhelm Eckl, and Norbert Eisenreich, (2014), *Lignin Matrix Composites from Natural Resources - ARBOFORM®, Bio-Based Plastics: Materials and Applications*, First Edition. Edited by Stephan Kabasci, John Wiley &Sons.Ltd. by John Wiley & Sons, Ltd.
6. Ciofu, C., Mindru, D., (2013), *Injection and micro injection of polymeric plastics materials*, Int J of Modern Manufacturing Technologies, V(1), 49-68.
7. Glen, S.P., (1993), *Taguchi Methods, A hands-on approach to quality engineering*, Addison-Wesley Publishing Company, Massachusetts.
8. Nedelcu, D., Pruteanu, O., (2000), *Aspecte ale formarii canelurilor exterioare prin deformare plastica la rece utilizand metoda Taguchi*, Tehnica-Info Publishing House, Chișinău.
9. Plavanescu (Mazurchevici) Simona, (2016), *Contributii la studiul procesului de obtinere a pieselor ranforsate din materiale biodegradabile prin injectie*, Ph.D. Thesis, "Gheorghe Asachi" Technical University of Iasi.
10. Plavanescu, S., Fabrizio, Q., Nedelcu, D., (2015), *Tensile test for Arboform samples*, Acta Universitatis Cibiniensis-Technical Series, 66(1), doi: 10.1515/aucts-2015-0044, 147-152.
11. Nedelcu, D., Plavanescu, S., Carausu, C., (2016), *The influence of technological parameters on tensile strength of liquid wood specimens obtained by injection molding*, Proceedings of the ICMTE2016 International Conference, October 5-7, Seoul, Korea, pp. 18.

Received: July 25, 2016 / Accepted: December 10, 2016 / Paper available online: December 20, 2016