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DETERMINATION OF THE MECHANICAL CHARACTERISTICS OF POLYAMIDE 6.6 PLASTIC REINFORCED WITH SHORT GLASS FIBERS 30%

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***Abstract**: Plastic materials are widely used in the automotive industry because of the ability to quickly manufacture parts with high complexity. The strength of these parts has been an area of improvement. One solution is reinforcing the plastic material with high strength fibers such as glass or carbon. This study analyses mechanical characteristics of polyamide 6.6 plastic reinforced with short glass fibers 30% as compared with its non-reinforced counterpart. A significant gain in strength was found for the reinforced parts.*

***Key words**: plastic injection, mechanical properties, reinforced polyamide 6.6, glass fibers, Scanning Electron Microscopy (SEM).*

1. INTRODUCTION

The materials analyzed in the paper are from the reinforced polymers class, namely polyamide. This type of polymer was chosen due to its mechanical characteristics and its wide availability on the global market. When choosing the equipment for machining a particular product, one needs to consider the material, geometry and dimensions and number of parts.

Injection molding is the most commonly used process in manufacturing for polymeric materials. Currently, short fiber reinforced polymeric materials are widely used in a variety of industries such as automotive. The reinforcement with different organic or inorganic compounds improves the mechanical characteristics, depending on the functional role and the type of the finite product. Glass-fiber is the most common type of fiber used in structural constructions as it considerably increases the strength of the material [1], [2], [3].

Both long and short fibers can be used for reinforcing plastic materials. Short fibers can be used in the injection molding process of plastics combining the advantages of the process with the superior characteristics of composite materials [4].

The present work looks at the mechanical properties of polyamide 6.6 plastic reinforced with short glass fibers 30% as compared with its non-reinforced counterpart.

2. MATERIALS AND METHODS

The current study determined the mechanical characteristics of both plain (non-reinforced) type of polyamide 6.6 as well as polyamide 6.6 reinforced with 30% short glass-fibers (SGF). The test samples were obtained through injection molding and the dimensions are in accordance with the SR EN ISO 527-2000 standard. The glass fibers in the structure of the polymeric material that have been used are between 8-14 µm in diameter and lengths between 1-3 mm. The tensile strength of the

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samples was determined using a tensile test machine Instron type 3366.

An electron microscope was used to analyze the orientation of the fibers and the cohesion of fibers in the breakage area.

The microscopic analyses were made with a VEGA 3SB electronic microscope manufactured by TESCAN. It is equipped with a tungsten filament electron source. It also has an analytic camera with step-up motorization and modern optical equipment.

To compare the influence of the degree of reinforcement on the mechanical characteristics of the material, the obtained results were compared between the polymeric material without reinforcement fibers and with 30% SGF. Five test samples were used for each type of material.

The load–elongation variation diagram was drawn for two types of material. The results of mechanical traction tests for both materials are shown in Figure 1 and 2 respectively.

3. TEST PROCEDURE AND RESULTS

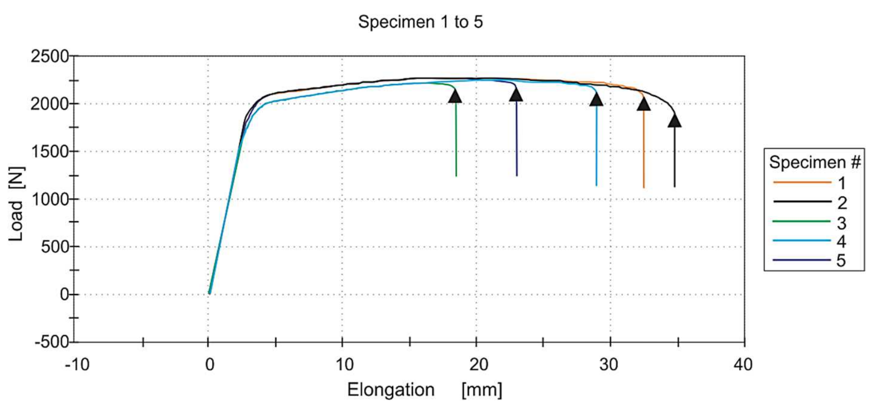

Figure. 1. Load diagram– Elongation of PA 6.6 non-reinforced

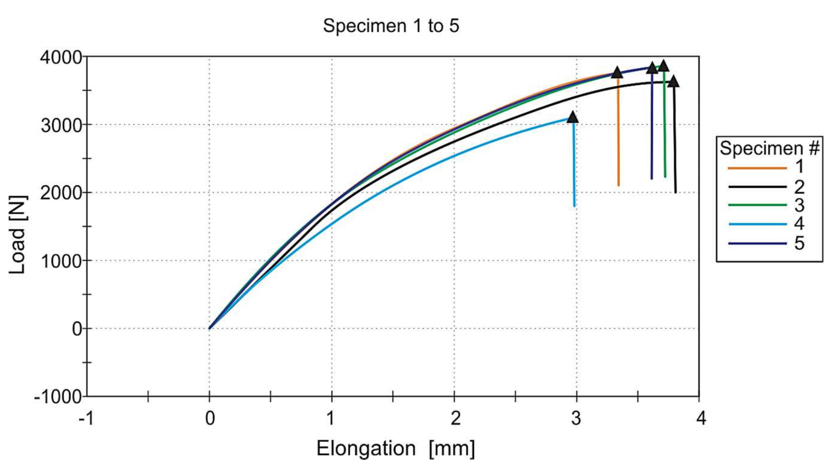

Figure. 2. Load diagram – Elongation for PA 6.6 with 30% SGF

The two graphs show that, while the elongation of the non-reinforced parts is significantly higher (tens of millimeters), the load required for breaking the sample is much higher in the case of the reinforced samples. The average values for the load, elongation, and tensile strength for the two types of materials are summarized in Table 1.

Other scientists were also concerned with improving the mechanical characteristics of a plastic material by reinforcing it with various compounds [5].

The difference between the two materials for the analyzed characteristics was also tested for statistical significance. An independent sample t-test was used to see if there is a statistically significant difference in load, elongation, and tensile strength between the two materials at a 0.05 significance level.

Table 1

Tensile tests results for PA 6.6 non-reinforced and SGF-PA 6.6 30 wt. %

Material	Load [N]	Elongation [mm]	Tensile strength [MPa]
PA 6.6 non-reinforced	**2268**	**32.46**	**56.7**
SGF-PA 6.6 30 wt. %	**3888**	**3.61**	**97.2**
P-value	**<0.001**	**0.001**	**<0.001**

A statistically significant difference was found for all three variables (Table 1). An increase of 71,4 % in the value of the mechanical resistance of the reinforced material can be observed (Figure 3). The degree of the reinforcement can be chosen depending on the functional of the finite product [9]. By reinforcing the plastic material, the elongation is significantly reduced. For some materials this is an important characteristic, and a balance should be obtained between the mechanical resistance of the part and the parts ability to elastically deform during operation. All these values need to be considered from the design stage and strictly depend on the functionality of the part [6], [8].

Values greater than 45-50% glass fibers risk compromising the technological process of injection molding and are not recommended [11].

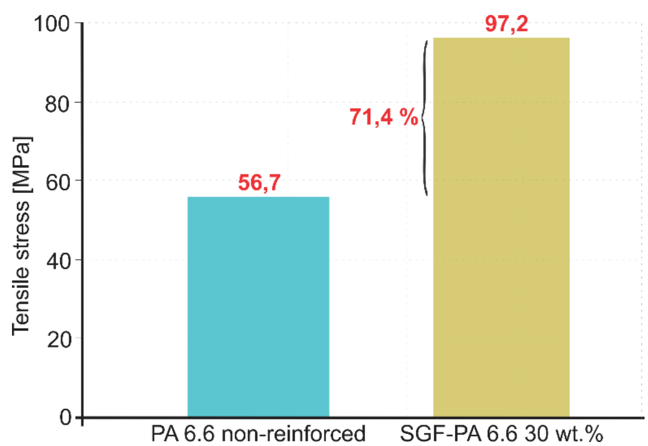

Figure. 3. Mechanical resistance variation for SGF-PA 6.6

The arrangement of the reinforcing fibers plays an important role in the mechanical strength of the injected part [11]. The quality of the part depends on the technological injection parameters that need to be set to optimal values [9]. An analysis with performing a Scanning Electron Microscope (SEM) revealed an uneven dispersion of the glass fibers in the material. The resulting images (Figure 4) show no gaps between the fibers and material

indicating high adherence of the fibers to the polymeric matrix.

As the distance between the glass fibers is smaller, and the fibers have a high capacity to store energy, they release the received heat into the polymeric matrix during the process. The fibers tend to orient themselves in flow direction of the polymer melt. The higher the degree of reinforcement, the more fibers will clash with each other and thus deviate from this orientation, resulting in a random orientation [7].

The higher the degree of reinforcement, the greater the deviation from the direction of flow, some fibers even ending up being perpendicular to it as shown in figures 4 and 5.

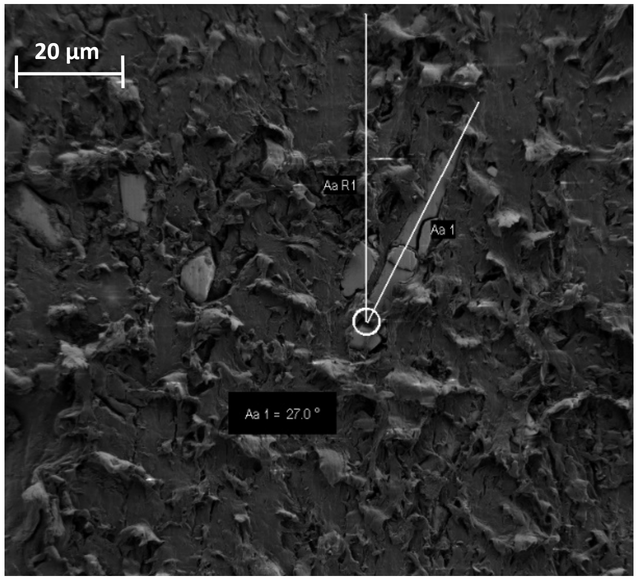

Figure. 4. The reinforcement fibers orientation on the part surface in SGF-PA 6.6 wt30% **(Aa=27°)**

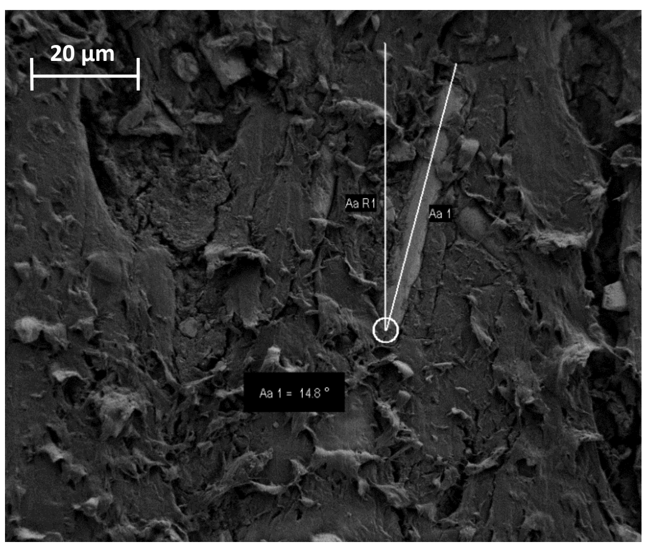

Figure. 5. The reinforcement fibers orientation on the part surface in SGF-PA 6.6 wt30% **(Aa=14.8°)**

Adhesion of the fiber in the polymeric material plays an important role in the mechanical strength of the part [11]. A SEM analysis in the sample breakage zone showed a good embedding of the reinforcing fibers in the polymeric material (Figure 6).

The different orientation of the reinforcing fibers in a part because constitute an advantage as the part can resist strains in different directions, within the specified limits.

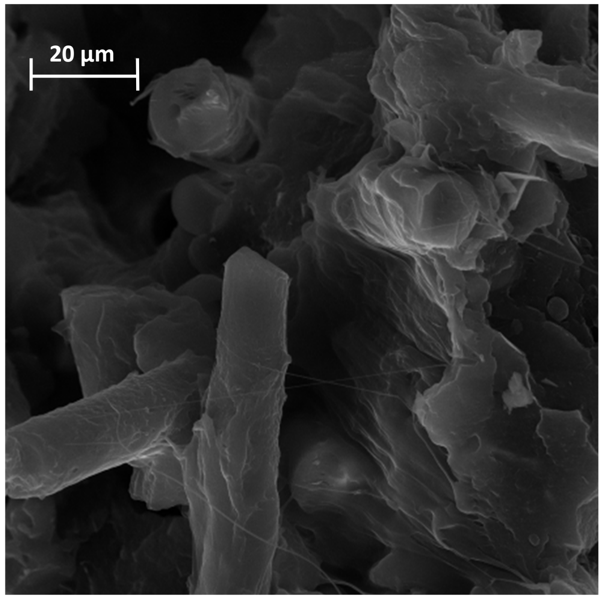

Figure. 6. The reinforcement fibers orientation in the breaking area of the test sample in SGF-PA 6.6 wt. 30%

4. CONCLUSIONS

This study looked at two types of materials: the non-reinforced polyamide 6.6 and polyamide 6.6 reinforced with 30% short glass-fibers. The strength of both materials was tested using a tensile strength machine and their mechanical characteristics were compared. The independent sample t-test was used to determine if the difference is statistically significant.

The study showed that in materials with up to 30% reinforcement material, fibers have a longitudinal orientation to the direction of the polymeric melt. Above this threshold the fibers tend to deviate from this orientation and tend to become randomly oriented.

By increasing of the reinforcement degree of polyamide 6.6 with a maximum of 30% glass fibers, the mechanical properties of the resulting part are increased resulting in an improved quality of the manufactured products. Even though the strength of the plastic material is significantly increased the elongation is reduced.

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DETERMINAREA CARACTERISTICILOR MECANICE ALE POLIAMIDEI 6.6 ARMATE CU FIBRE SCURTE DE STICLĂ 30%

Rezumat: Materialele plastice sunt utilizate pe scară largă în industria auto datorită procesului rapid de fabricare a pieselor de complexitate ridicată. S-a avut in vedere îmbunătățirea rezistenței acestor piese. O soluție a fost armarea materialului plastic cu fibre de înaltă rezistență, cum ar fi sticla sau carbonul. Acest studiu a analizat caracteristicile mecanice ale poliamidei 6.6 armată cu fibre scurte de sticlă 30% în comparație cu cele nearmate. S-a constatat o creștere semnificativă a rezistenței pentru piesele armate.

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