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MECHANICAL CHARACTERISTICS IMPROVEMENT FOR EXTRUDED PRODUCTS MADE OF REINFORCED POLYAMIDE

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Abstract: *Abstract: The materials analyzed in this paper are from the reinforced polymers class, which are often processed through extrusion. The plastic material used is polyamide 6.6 in natural state and reinforced with glass fibers. Three different degrees of reinforcement are used; respectively 10, 20 and 30% glass fibers. In the present research the authors want to present the influence of the reinforcement degree upon some mechanical characteristics of the products made by extrusion. Considering the homogeneity of the polymeric melt the product's quality will be analyzed. During the extrusion process a series of parameters (extrusion speed, the pellets feed, processing temperature etc.) are involved and they must be taken into account to achieve calibrated and qualitative products.*
Keywords*: reinforced polymers, extrusion, polyamide, glass fiber.*

1. INTRODUCTION

The materials analyzed in the paper are from the reinforced polymers class, namely polyamide. It was choose this type of polymer due the wide range of currently available on the world marked and for the reason of the necessity of increasing the mechanical characteristics of the industrial products. To choose a properly equipment in order to process a peculiar product, the followings should be considered: the material, the geometry and the dimensions as well as the number of parts.

From all the manufacturing processes the most commonly used for the polymeric materials are the extrusion and the injection molding. Usually injection molding is used, but for parts with a great length and a proper geometry, the extrusion is preferred. This is a continuous technological process that makes possible the manufacture of the profiles with infinite length such as: tubes, pipes, sheets, isolation for electrical cables, and also molded products with a big length compared with the other dimensions.

A controlled mixture of polyamide 6.6 with different ratio of reinforcement fibers was realized for the experiments. As a result, three types of materials: PA 6.6 reinforced with 10, 20 respectively 30% fiber glass (PA 6.6 – 10, 20, 30% GF) were obtained. The purpose was to study the influence of the degree of reinforcement upon the mechanical characteristics of the extruded material. Glass fibers used for reinforcement are from the short fibers category. Their dimensions are: diameter between 8 and 14 μm and the length between 1-3 mm.

For the experiments an extruder Cincinnati Monos +45 mode type was used. This equipment has a single screw with a diameter of 45 mm. The geometry of the extruder is a special one, from the last generation, with a bimetallic cylinder realized from special alloys, resistant at corrosion and abrasion.

This type of equipment provides a very good homogeneity of the melted material because of the complexity of the worm gear's geometry and the very precise control of the temperatures for all four specific zones of the extrusion process (feeding zone, compressing zone, metering zone and forming zone).

With this extruder, tubes with diameters between 20 – 2000 mm and with different wall thickness can be obtained. For this research a tube with exterior diameter of 30 mm and a

wall thickness of 4 mm was realized. The processing temperature of the extruder can be set up until reach out the maximum value of 400°C for each zone separately.
The samples for the tensile test were cut, with a special mill, from each tube corresponding to each type of material.

2. THE TEMPERATURES ESTABLISHMENT

From the technical literature it is known that one of the technological parameters with a great influence upon the quality of the extruded product is the temperature. In our case, the temperature provided on the data sheet of the material, is in the range of 270 ÷ 290°C for the metering zone and 260 ÷ 280 °C for the forming zone, not being specified an exact value for this parameter. It is important to establish the temperatures for the metering and for the forming zone because the quality of the product is mostly achieved in these zones. [1], [2].

To determine the optimum values for the processing temperatures, the ANOVA method (Analysis of Variance) was used. The ANOVA dispersion analysis is part of the collection of statistical and mathematical techniques used to develop, improve and optimize the technological processes. The values of the processing temperatures achieved after the ANOVA analysis is presented in table 1.

Table 1

Temperatures determinate with the aid of ANOVA analysis

No. crt.	***Temperature in the metering zone [°C]***	***Temperature in the forming zone [°C]***
1	270	280
2	280	270
3	290	260
4	270	260
5	294	270
6	280	256
7	266	270
8	290	280
9	280	284

Optimization of any technological process is based on a mathematical model. The mathematical models can be used not only to determine the optimal working conditions, but also as an important source of information, necessary to optimize the technological processes. In the case of our study it was used the Design Expert software version 8.0.5 which is a software application that uses a series of statistical techniques for design and analyze the experiments that involve a large number of factors [2].

The results from the tensile test for PA 6.6 – 30% GF are presented before by the authors [3], but they will be considered in this research in order to compare with the results for the other degree of reinforcement for the same material.

3. EXPERIMENTAL RESULTS

Using the ANOVA strategy to optimize the extrusion process, the observation is that the most concluding results after the tensile test are obtained when the value of the temperature in the metering zone is set at 280°C and in the forming zone is 270°C. In conclusion this pairs of temperatures represent the optimal values of the processing temperatures for the extrusion of the considered material. A properly setting of the values for the temperatures lead to the manufacture of high quality extrusion products, with a calibrate profile and a very good mechanical strength.

With the established values of the optimal processing temperatures, the mechanical characteristic for each material was determined and the influence of the reinforcement degree upon the mechanical characteristics of the extruded product was found out.

The tensile test was performed upon samples cut from the extruded products. The variation diagram load–elongation was traced for each material. From all the experiments (tensile test), the values were considered for each type of material (PA 6.6 – nature, PA6.6 – 10% GF, PA 6.6 – 20% GF and PA 6.6 – 30% GF).

In order to present the influence of the reinforcement degree upon the mechanical characteristics of the material, the results obtained for the polymeric material in a natural state (without reinforcement fibbers) were also considered and they are presented in figure 1.

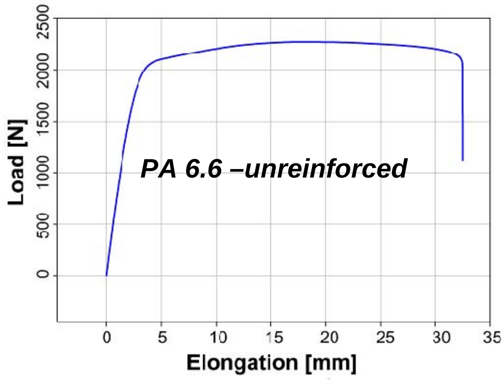

Fig. 1. Variation diagram load– elongation of extruded product from PA 6.6 unreinforced material

In the case of the tensile test for PA 6.6 – 10 % GF material (figure 2), it can be observed the fact that the elongation of the specimen is 4,14 mm, with 87.24% smaller than the elongation of the material in natural state PA 6.6 with the elongation of 32.46 mm (figure 1). The value of the broken force, in this case is 2348 N, with 4.08% higher than in the case of extruded product realized from PA 6.6 natural.

From figure 2 it can be seen that the elongation for PA 6.6 – 20% GF is 4.04 mm which is with 87.55% smaller than natural PA 6.6. The maximum value of the force at break is 3005 N which is with 33.2% higher than for natural PA 6.6. .

For the specimen made of PA 6.6 – 30% GF, the maximum elongation is 3,61 mm which is with 88.88% higher than natural PA 6.6. The force at break is 3804 N with 68.61% higher than for natural PA 6.6 (figure 2).

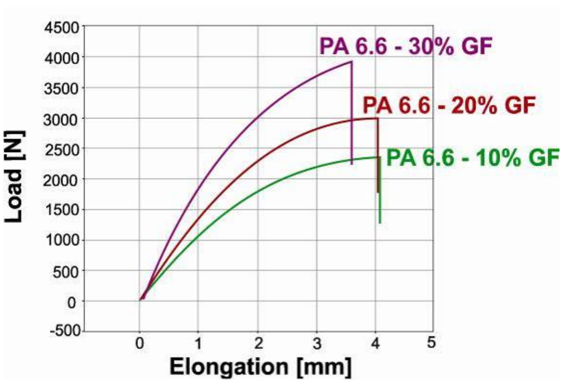

Fig. 2. Variation diagram load –elongation for PA 6.6 reinforced with 10, 20, 30% glass fibers

The results from above are presented in table 2.

Table 2

Results of the tensile tests for natural PA 6.6 and PA 6.6 reinforced with 10, 20, and 30% glass fibers

Material	Load [N]	Elongation [mm]	Tensile strength [MPa]
PA 6.6 - natural	2256	32.46	56.4
PA 6.6 – 10 % GF	2348	4.14	58.7
PA 6.6 – 20 % GF	3005	4.04	75.1
PA 6.6 – 30 % GF	3804	3.61	95.1

It is clear that the material is more resistant if the reinforcement degree is higher, but the deformation that can be supported is smaller [2].

For example, in the case of extruded product realized from PA 6.6 with 10% GF, is obtained a growth of mechanical resistance with 4.08%, and in the case of PA 6.6 with 20% is obtained a growth of 33.2%, reaching up in the case of extruded product from PA 6.6 – 30% GF until a value of 68.61% (figure 3).

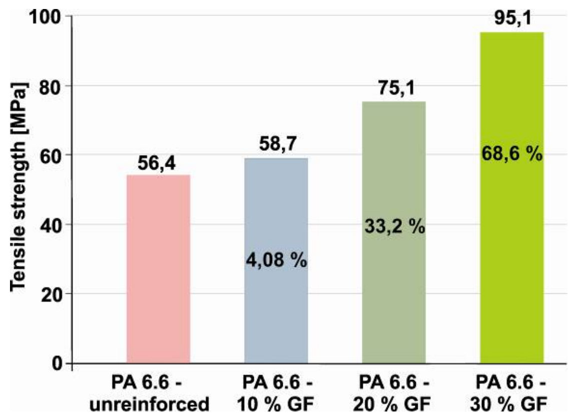

Fig. 3. Variation of the tensile test

From all presented above it can be said that with the growing of the reinforcement degree of the polymeric materials and also with a proper choose of the technological parameters (temperature in our case), the mechanical characteristics of the extruded product are significantly growing.

4. CONCLUSIONS

It is known that for a material in its natural state like PA 6.6, the mechanical strength has low values, so the material is not proper to be used for parts that need a high mechanical resistance, however the elongation show a good formability.

To increase the mechanical resistance it is necessary to insert the reinforcement fibers. It can be said that with the increase of the reinforcement degree, during the tensile test, the material's elongation is decreasing while the mechanical resistance is increasing.

The maximum value for the tensile strength is achieved when the temperature in the metering zone is 280 °C and that from the forming zone is 270 °C. In this case, besides of a very good homogeneity of the material it is obtained an optimum extrusion pressure and also a good calibration of the extruded profile.

Considering all the results presented above, the following recommendations for manufacturing the reinforced polyamide products can be done:

- If the goal is to obtain products with a high mechanically strength than a degree of reinforcement of 30% will satisfy. This also leads to a small value for the elongation so the products should not be forced to deformations;
- For the products made of polyamide that requires a good mechanical resistance but also a good malleability, a smaller reinforcement degree is needed.

A very important factor in manufacturing products from reinforced polyamide is the temperature, so knowing the optimum values of it makes possible to manufacture products with a high quality. There can be also obtained calibrated profiles and very good mechanical characteristics for the products.

4. REFERENCES

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ÎMBUNĂTĂȚIREA CARACTERISTICILOR MECANICE ALE PRODUSELOR EXTRUDARE DIN POLIAMIDĂ ARMATĂ

Rezumat: Materialele analizate în cadrul acestei lucrări fac parte din categoria polimerilor armați. care se prelucrează prin extrudare. Materia prima utilizata este poliamida 6.6 armată cu fibră de sticlă. În cadrul cercetărilor se urmărește evidențierea influentei gradului de armare asupra caracteristicilor mecanice ale produselor extrudate. Se va analiza în același timp si calitatea acestora din punctul de vedere al omogenității topiturii polimerice. Pe parcursul procesului de extrudare intervin o serie de parametrii (viteza de extrudare, rata de alimentare cu granule, temperatura de prelucrare, etc.) de care trebuie ținut cont pentru a obține produse calibrate si de calitate. Produsele din poliamidă 6.6 armate cu fibră de sticlă scurtă au caracteristici mecanice superioare aceste caracteristici fiind interdependente cu gradul de armare.

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