ANNALS OF THE UNIVERSITY OF ORADEA
Fascicle of Management and Technological Engineering
ISSUE #3, DECEMBER 2014, http://www.imtuoradea.ro/auo.fmte/

ANALYSIS OF MECHANICAL PROPERTIES OF POLYAMIDE DEPENDING OF THE GRIND PERCENTAGE OF MATERIAL

Dan CHIRA[1], Gheorghe Radu Emil MARIES[2],
[1]University of Oradea, Romania, dchira@uoradea.ro
[2]University of Oradea, Romania, maries.radu@rdslink.ro

***Abstract*—**This paper presents the influence of the grind percentage over mechanical properties, obtained by mold injection of various articles in the automotive industry, made of polyamide 6.6. The specimens were made with the following composition: 100% new material, new material 80% + grind 20%, new material 60% + grind 40%, new material 40% + grind 60%, new material 20% + grind 80% and grind 100%. Mechanical properties were carried out using the methods of determining the tensile properties and determining the Izod impact properties**.**

It was found that shock resistances decrease with increasing of grind percentage and tensile strength increases with increasing of grind percentage.

***Keywords* —** grind percentage, izod impact test, polyamide 6.6, type HTV 5H1 Black Grivory (PA 6.6 HTV), tensile tests,

I. INTRODUCTION

TOGETHER with other industries (electrotechnics, electronics, machine building, household articles, sporting and tourism articles, packages) auto industry is one of the largest consumers of plastics materials. The mechanical properties of molded parts, as well as dimensional and geometric accuracy depend on the structure of the plastic material and the parameters of the injection process. The structure of the injected plastic material is directly influenced by the amount of new material used, the percentage of plastic material to be recovered and added to the new, various ancillary materials, additives, and even the amount of dye added. Theoretical description of the influence of the percentage of recovered plastic material on the mechanical properties of the piece is extremely difficult, currently there is no unanimity of researchers in the field. The difficulty is that the only factor which gives us a theoretical connection with the material structure is the coefficient of volume expansion, indicating the effect of temperature on the volume of molten material, This slight variations depending on the plastic structure, the percentage of new material and material recovered over these overlapping effects of temperature and injection pressure injection.

The most used technical polymers in the manufacture of various components car are : polyamides, thermoplastic polyurethanes, polyoxymethylenes, polypropylene, methyl polymethacrylate, ethyl cellulose, plasticized polyvinyl chloride, acrylonitrile butadiene styrene, etc. The most used technology in the processing of these polymers is injection molding, [1].

The polyamides are characterized by good dimensional stability, have a high level of stiffness when are reinforced with glass fibers, are resistant to mechanical compression, mechanical wear , shock and vibration, are hard materials, by heat remain hard and tenacious, without visible changes, up to 80-90 º C [2], [3]. In addition with glass fibers the polyamides improve its tensile strength, flexural strength, modulus of elasticity, and hardness. Have good chemical resistance to salt water, oils, hydrocarbons, lakes, weak bases, esters, ethers, alcohols and motor fuels. Are good electrical insulators. [4].

All these properties recommended polyamides to be used for the manufacture of various plastic parts in the automotive industry. A current problem in the injection molding process of thermoplastic polymers remains the recovery of plastic waste.

These plastic wastes are presented in various forms: injection channel networks, incomplete parts, spare parts showing the burr or manufacturing defects, [5]. Reused into the injection molding process, as a grind, is commonly used in practice. The reused of the grind material can be mixed with new material, or may inject only the ground material.

This paper aims to analyze the variation of mechanical properties, according to the variation of the grind percentage, (once only injected), using the methods of determining the tensile properties and determining the Izod impact properties, for polyamide "PA 6.6 HTV".

This polymer is used for injection molding of specific articles of the automotive industry, as: fuel dispenser, car acceleration control system intake manifold, heat shield, components of hydraulic pump, surfaces of engine protection, the alternator mounting bracket, hydraulic clutch cylinder, pedal support, padded armrest, the center console, he glove compartment locking system, gearshift lever, rack lights, lock the tailgate, headlight adjustment screw, ventilation system, etc.

II. Experimental Researchs

Specimens are made of polyamide PA 6.6 BLACK GRIVORY 9205,type HTV 5H1 using an injection molding machine ENGEL CC 100 Type ES 80/50 HL, manufactured in 1995, Fig. 1.

Fig.1 ENGEL CC 100Type ES 80/50 HL, injection machine.

"PA 6.6 HTV" is reinforced with 50% glass fibers. It is stiffness and resistant to high temperatures, is chemically stable to heat, good dimensional stability with increasing of temperature, low water absorption, good chemical resistance to fluids used in automotive : gasoline, oil, brake fluid. From this type of polyamide are made car parts which require good dimensional stability with increasing of temperature and are in contact with chemical agents.

Were injected six samples with varying percentages of grind, presented in table I. These samples will be tested to mechanical stress.

TABLE I
Content Of The Samples Used

Samples	Sample content
Sample 1	100% new material
Sample 2	80% new material + 20% grind
Sample 3	60% new material + 40% grind
Sample 4	40% new material + 60% grind
Sample 5	20% new material+ 80% grind
Sample 6	100% grind

The injection molding of "PA 6.6HTV" was made after the material has been dried at 80 ° C for 4 hours, [6]. The injection molding was carried out according to the following parameters: injection temperature (zone 1 = 330 ^{o}C, (zone 2 = 330 ^{o}C, (zone 3 = 340 ^{o}C, nozzle = 340 ^{o}C), mold temperature 85 ^{o}C, injection pressure 500 bar, holding pressure 400 bar, injection cycle time 35 s, cooling time inside the mold 10 s. During the injection molding of the sample the injection parameters were keep constant.

All the injected samples, Fig. 2, were subjected to the following types of mechanical determinations: the Izod impact test on unnotched specimens and tensile strength at break. All tests were performed at room temperature.

Fig. 2. Injected samples of "PA 6.6 HTV"

A. The Izod impact test

The Izod impact test was performed on unnotched specimens, Fig. 3.

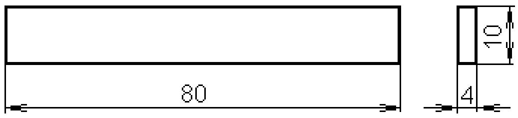

Fig.3 Specimen model for the Izod impact test.[7]

The tests were carried out in accordance with SR EN ISO 180 standard, [7], using a pendulum impact tester, model PENDOLO P400, manufactured by HAMMEL, England, Fig. 4.

Fig.4. Izod impact tester, model PENDOLO P400, HAMMEL, England,

According to the user manual, the initial potential energy of the pendulum is 7,5 J, and the initial angle of pendulum arm is 150^{o}.

According to SR EN ISO 180, the Izod impact test on unnotched specimens is based on the following equation:

$$a_{iU} = \frac{E_c}{h \quad b} \times 10^3 \qquad (1)$$

where:

E_c - the absorbed energy (J) when the specimen breaks

h - the specimens thickness (mm)

b –the specimen width (mm)

The software of the PENDOLO P 400 device automatically displays the values of the absorbed energy when the specimens break. The specimens were fixed in parallel mode. Ten specimens were tested for each sample and the result was expressed as arithmetic mean.

B. Measurement of the tensile strength at break

The tests of tensile strength at break for our samples of polyamide have been achieved with WPM – VEB Thuringer Industrie werk, Ranenstein gerat R 37, Typ 2092, tensile testing machine, Fig. 5.

The tests were carried out in accordance with SR EN ISO 527-1:2000 and SR EN ISO 527-2:2000 [8], [9] standards, on specimens with form and dimensions presented in Fig. 6.

For all samples the speed test was 200 mm/min. For each sample was tested 10 specimens and the results was expressed as arithmetic mean.

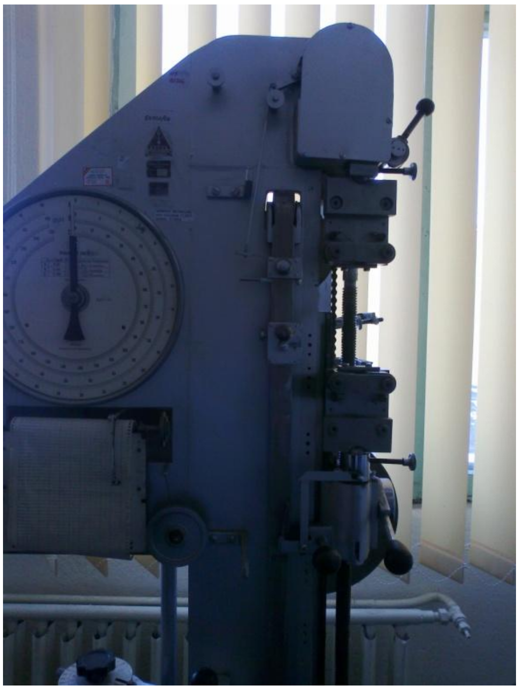

Fig.5. WPM – VEB Thuringer Industrie werk, Ranenstein gerat R 37, Typ 2092, tensile testing machine,

The tensile strength at break was calculated using the equation:

$$\sigma = F/A, \quad (2)$$

where:

F – the force, (N), measured at the break point of specimens,

A – the initial cross-section area, (mm^2), of the specimens,

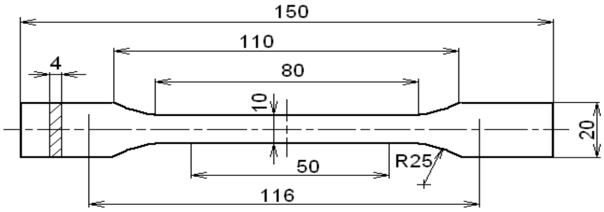

Fig. 6. Specimen model for tensile strength at break testing.[8]

III. Results And Discutions

After testing of specimens made of “PA 6.6 HTV”, to Izod impact test, the following results were obtained for the absorbed energy (E_C) when the specimen breaks, and the Izod impact test on unnotched specimens (a_{iU}), table II.

In the case of polyamide PA 6.6 GRIVORY HTV 5H1 BLACK 9205, the increase of gring percentage from 0% to 100%, lead to a slight decrease of impact strength for all six samples, from 43,425 kJ/m² for first sample, to 36,550 kJ/m² for sample 6.

The explanation of this phenomenon could be due to the fact that grind material was previously processed by injection once, suffering an minimal thermal degradation from processing, and in the same time an mechanical degradation after grinding. The graphical representation of the variation of Izod impact strength is presented in Fig. 7.

TABLE II
IZOD IMPACT ABSORBED ENERGY

Samples	PA 6.6 GRIVORY HTV 5H1 BLACK 9205	
	E_c (J)	a_{iU} (kJ/m²)
Sample 1	1,737	43,425
Sample 2	1,722	43,050
Sample 3	1,657	41,425
Sample 4	1,622	40,550
Sample 5	1,577	39,425
Sample 6	1,462	36,550

After testing of specimens to tensile strength at break the following results were obtained, table III.
The increase of gring percentage from 0% to 100%, lead to increase of tensile strength from 7328,64 N to 9204,42 N, and admissible tensile strength (σ) from 183,21 MPa to 230,11 MPa. The graphical representation of the tensile strength is presented in Fig. 8.

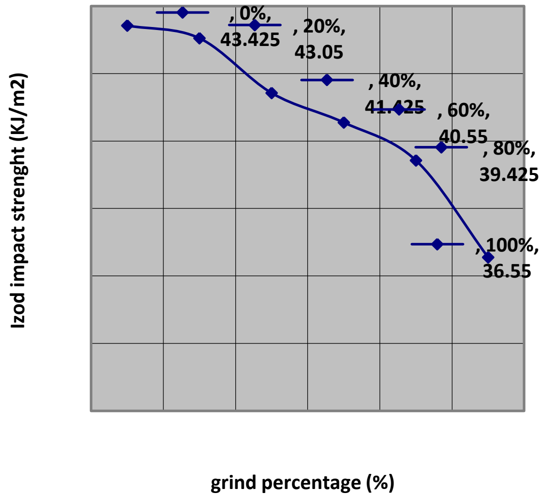

Fig. 7. The Izod impact strength graphic variation according to the variation of grind percentage.

TABLE III
THE VARIATION OF TENSILE STRENGTH

Sample	PA 6.6 GRIVORY HTV 5H1 BLACK 9205	
	F (N)	σ (MPa)
Sample 1	7328,64	183,21
Sample 2	7868,25	196,70
Sample 3	8271,64	206,79
Sample 4	8302,40	207,56
Sample 5	8696,16	217,40
Sample 6	9204,42	230,11

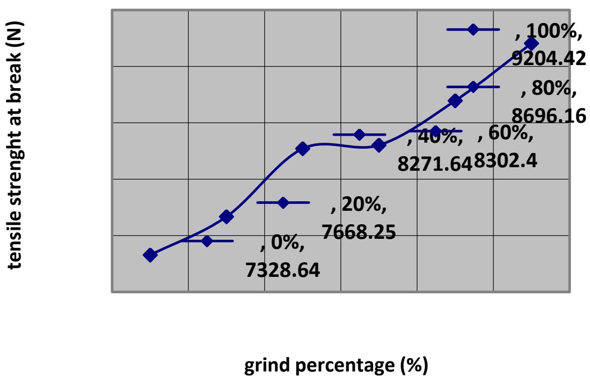

Fig. 8. The tensile strength at break graphic variation according to the variation of grind percentage.

IV. CONCLUSIONS

Were analyzed and studied the variation of mechanical properties, according to the variation of the grind percentage, once only injected, for "PA 6.6 HTV" polymer used for injection molding of specific articles in the automotive industry.

Specimens are made using an injection molding machine ENGEL CC 100 Type ES 80/50 HL. The specimens had the following composition: 100%new material, 80% new material + 20% grind, 60% new material + 40% grind, 40% new material + 60% grind, 20% new material + 80% grind, 100% grind.

The Izod impact tests were made on unnotched specimens, using a pendulum impact tester, model PENDOLO P400, manufactured by HAMMEL, England. In the case of "PA 6.6 HTV", the increase of gring percentage lead to a slight decrease of impact strength.

The tests of tensile strength at break have been achieved with WPM – VEB Thuringer Industrie werk, Ranenstein gerat R 37, Typ 2092, tensile testing machine. The increase of grind percentage lead to increase of tensile strength and admissible tensile strength.

REFERENCES:

[1] J.F. Pichon - *Injection des matieres plastiques*, Dunod, Paris, 2001, p.163-200.

[2] V. Manoviciu, Gh. R. E. Mărieș , - *Composite materials with organic matrix*, Ed. Universității din Oradea, Oradea, 2005, p.135-141.

[3] J. P.Trotignon, J. Verdu, A. Dobracginsky, M. Piperaud,- *Matieres Plastiques. Structures-proprietes, Mise en oeuvre, Normalisation,* Editions Nathan, Paris, 1996, p.80-84.

[4] I. Șereș, - *Injection molding thermoplastic materials, technologies, tests,* Editura Imprimeriei de Vest, Oradea, 2002, p.93

[5] M. Baban, D. Chira, - *Theoretical consideration and experimental researches regarding the variation of injection molded piece mass with injection pressure and cooling time.* Annals of the Oradea University.Fascicle of Management and Technological Engineering, Volume XV, 2006, ISSN 1583-0691, pag.146.

[6] L. Marsavina, A. Cernescu, E. Linul, D. Scurtu, C. Chirita C., *Plastic Materials, nr1*, 2010, p.85.

[7] *** SR EN ISO 180:2001, - *Plastic Materials. The Izod impact test*

[8] *** SR EN ISO 527-1:2000,- *Plastic Materials. Tensile strength at break test. Part 1: General principles.*

[9] *** SR EN ISO 527- 2:2000,- *Plastic Materials. Tensile strength at break test. Part 2: test conditions of plastic materials used in injection molding.*