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THE INNFLUENCE OF THERMOPLASTIC MATERIAL GRIND PERCENTAGE OVER THE WARPAGE OF INJECTION MOLDED PIECES

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***Abstract*—**The paper presents the influence of thermoplastic material grind percentage over the warpage of injection molded pieces. Mixtures were made in different plastics grind material percentage, 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%, made by two thermoplastic materials: polyoxymetylene, (POM), and acrylonitrile-butadiene-styrene, (ABS) . The measurement of warpage was carried out using a laboratory orthometer. After measurements have found that warpage decrease with increasing of grind percentage in case of both plastic materials.

Keywords- grind percentage of thermoplastic material, injection molding, “ABS”, “POM”, , warpage

I. INTRODUCTION

THE warpage of injection molded piece began in cooling inside the mold stage. A long cooling time inside the mold leads to decreasing of warpage. This is due to the fact that the piece is cooled in the rigid walls of the mold, forced to preserve the geometric shape, to a temperature as uniformly as possible throughout the mass of the piece. It is very important that the core of injected piece to be brought to a low temperature to avoid deformations due to the expansion forces.

Outside the mold the warpage is caused by:

1) *uneven shrinkage in volume during the cooling of pieces from the melt temperature to the ambient temperature.*

The shrinkage of injection molding piece is define as a decrease of the volume of plastic melt due the cooling. The shrinkage is influenced by injection mould process parameters in accordance with next relation, [1]

$$C_V = 1 - \frac{V_p}{V_m} = \frac{\alpha_v^{k_{pi}}(T_m - T_o)}{1 + \alpha_v^{k_{pi}}(T_m - T_o)} \qquad (1)$$

Where:

α_v- coefficient of volume dilatation, indicate the influence of temperature over the melt of thermoplastics materials,

k_{pi}- coefficient that indicate the influence of injection and holding pressure over the coefficient of volume dilatation,

T_m- melt temperature,

T_0- ambient temperature,

Coefficient of volume dilatation has a value that characterize each thermoplastic material, and is influenced by the degree of purity of the material.

2) *uneven shrinkage due to different shrinkage in the longitudinal and transverse direction, Fig.1, [2].*

This occurs particularly in the case of crystalline thermoplastic materials. This imbalance creates a state of tension in the injected piece that leads to its deformation. Amorphous materials have uniform shrinkage in the two directions. For this reason the selection of thermoplastic material is very important to obtain parts with dimensional and geometric deviations prescribed value.

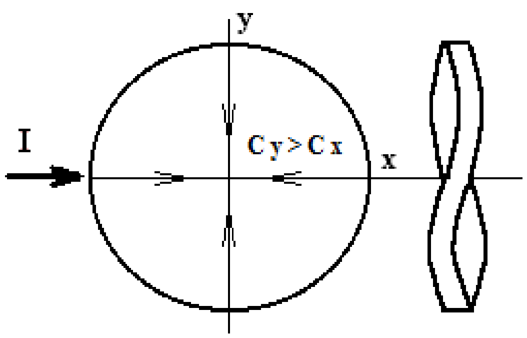

Fig. 1. Uneven shrinkage due to different shrinkage in the longitudinal and transverse direction.[2]

3) *geometric shape of the injection molded piece, due to variations in sectional plane, Fig.2, and accumulation of material in corrugated or reinforced areas, Fig.3., [3].*

Wall thickness variation has influence over the warpage, this occurs in places where we have a larger mass of molten material. The outer walls of the injection molded piece are play rapidly cooled, the middle part being at a higher temperature, thus forcing the deformation.

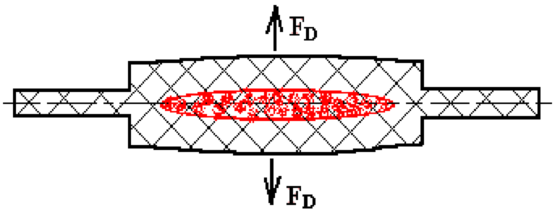

Fig. 2. Warpage due to the variations in sectional plane.[3]

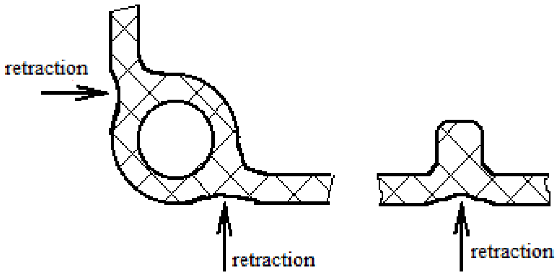

Fig. 3. Warpage due the accumulation of material in corrugated or reinforced areas.[3]

4) *inside the mold cooling conditions: the difference in temperature between the two halves of the mold, temperature differences between points on the surface of the injected piece will lead to deformation due to the difference of time necessary cooling,*
5) *residual stresses in injection molded piece*.

II. EXPERIMENTAL RESEARCH

Experimental research conducted with support from SC Plastor SA Oradea, with a special mold, built for verification of mechanical properties of thermoplastic materials and dimension of injection molded pieces, according to standard ISO 294-4:2001, [4]. Specimens are made using an injection molding machine ENGEL CC 100 Type ES80/50HL, manufactured in 1995, Fig. 4.

Were injected six samples with varying percentages of grind, presented in Table I. For each samples were made 10 injections.

TABLE I
CONTENT OF THE SAMPLES

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

Warpage measurement was performed on a standardized form part, Fig.6, using an orthotest, Fig. 7. in Laboratory of Tolerance and Dimensional Control of Faculty of Managerial and Technological Engineering, Oradea. Guidelines were followed to measurements using an orthotest, [5]. All tests were performed at room temperature.

Fig. 4. Injection molding machine ENGEL CC. 100 Type ES 80/50 HL

First thermoplastic material that was studied is ”POM”, semi-crystalline plastic material, injected at a temperature of 200°C, mold temperature 50°C, total cicle time 33,8”, cooling time inside the mold 15”. For all samples or kept the same injection parameters.

Fig. 5. Injected samples of “ABS”

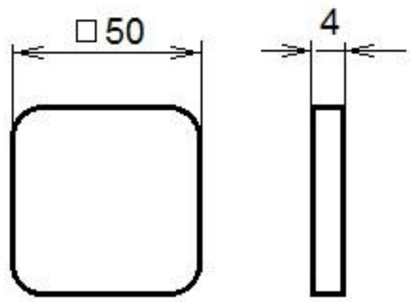

Fig. 6. Injection molded piece dimensions used for warpage measurement.

Fig. 7. Warpage measurement with orthotest [5]

”POM”, is used in industrial application for plastic gears, fittings for water lines, single lever mixer elements, bearings and bushings because have dimensional stability, slip properties, wear resistance, resistance to water, high toughness [6].

Also is used in automotive industry for seat belt retractor systems, fixing clips, door lock components, fuel gauge sensor, etc., because have high mechanical strength, good resilience, good wear resistance, high toughness and hardness, good resistance to fatigue, high toughness, even at temperatures of -40°C, good abrasion and wear properties, excellent chemical resistance to greases and fuels [7].

Toughness values on notched Izod impact at room temperature are between 60 – 120 J/m, tensile at yield is between 54 - 78 MPa, elongation at yield 8 - 23 % , the hardness Shore D is between 80 - 95. has low shrinkage between 1.8 - 2.5 %. Chemical properties are satisfactory.

In Table II are presented the arithmetic average value of warpage with grind percentage of “POM”.

The graphic of warpage variation with grind percentage in case of “POM” is presented in Fig. 8.

TABLE II.
WARPAGE VARIATION WITH GRIND PERCENTAGE IN CASE OF POLYOXYMETYLENE.

Percentage [%]	Warpage [μm]
100% new material	9,41
80% new material+20% grind	8,92
60% new material+40% grind	8,64
40% new material+60% grind	8,58
20% new material+80% grind	8,43
100% grind	7,89

The second thermoplastic material that was studied is “ABS”, amorphous plastic material, injected at a temperature of 230°C, mold temperature 60°C, total cicle time 38”, cooling time inside the mold 20”. For all samples or kept the same injection parameters.

“ABS” is used in automotive industry for instrument panels, Pillar trim, dashboard components, door liners and handles, seat belts components, spoilers, wheel trims, rear light housings, because have high quality aesthetics good color, gloss 40 - 96 %, good processability and heat resistance.

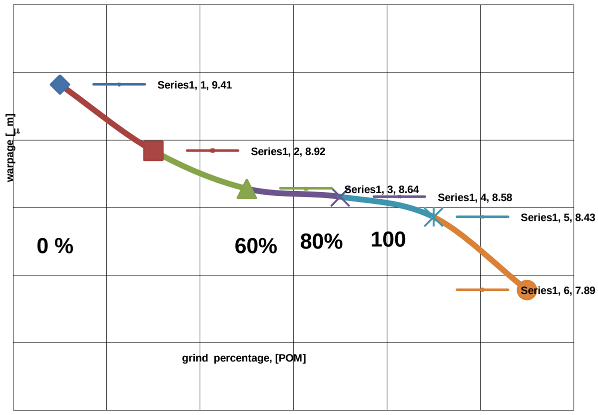

Fig.8. The graphic of warpage variation with grind percentage in case of polyoxymetylene [POM].

Toughness values on notched Izod impact at room temperature are between 200 - 215 J/m, tensile at yield is between 29.6 - 48 MPa, elongation at yield 1.7 - 6 % , the hardness Shore D is over 100. ABS has low shrinkage between 0.7 - 1.6 %. Chemical properties are satisfactory. [8].

In Table III are presented the arithmetic average value of warpage with grind percentage of “ABS”. The graphic of warpage variation with grind percentage in case of “ABS”, is presented in Fig. 9.

TABLE III
WARPAGE VARIATION WITH GRIND PERCENTAGE IN CASE OF ACRYLONITRILE-BUTADIENE-STYRENE

Percentage	warpage [%] [μm]
100% new material	4,09
80% new material+20% grind	3,64
60% new material+40% grind	3,37
40% new material+60% grind	3,16
20% new material+80% grind	2,84
100% grind	2,64

III. RESULTS AND DISCUSSIONS

The recovery of plastic materials used in industry and in domestic household is one of the great challenges of contemporary society. Annually are discarded and disposed million pounds of plastic, which is one of the main polluters of soil, water and air for combustion of such waste. For this reason the recovery of plastics and their reintroduction into the production circuit and is a major priority for all countries, to this objective of waste recovery are allocating large sums of money, both for their selective collection and new methods for recovery and retrieve their new products. 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.

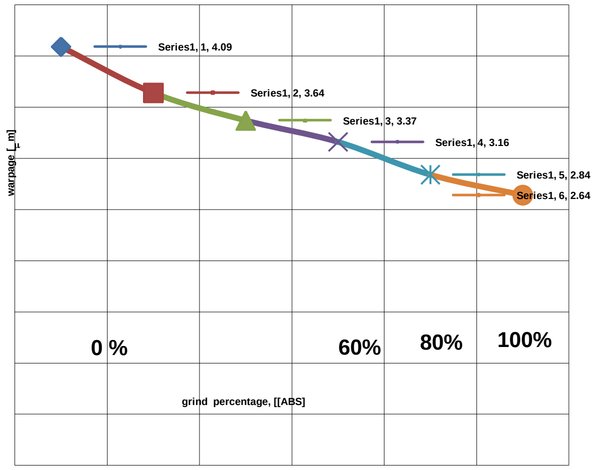

Fig.9. The graphic of warpage variation with grind percentage in case of “ABS”.

Discussing about the technical parts used in various industrial fields in the newly created according to the structure of the material will be variations in the tensile strength, the impact resistance of the surface hardness of the workpiece. 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.

After the measurements of warpage performed on “POM”, reveals a continuous decrease of this, from 9,41µm to 7,89µm. Be observed a greater difference between the first two values, (9,41µm -8,92 µm), then intervals with much smaller declines of war-page, values very close (8,64 - 8,58 - 8,43µm), greatest difference occurring at the last value o grind percentage, 7, 89µm.

The difference between the maximum and minimum value is only 1,52 µm, insignificant value for molded parts. This means that can be use injection molded parts made from new material and a certain percentage of grind.

Warpage decrease may be explained due to the fact that thermoplastic material was processed by injection once, suffering an minimal thermal degradation, and mechanical degradation after grinding [9].

The same thing is observed in the case of “ABS”, reveals a continuous decrease of this, from 4,09 µm to 2,64 µm, difference is relatively small, only 1,45 µm. Be observed a greater difference between the first two values, (4,09µm - 3,64 µm), then intervals with much smaller declines of warpage, values very close (3,64 – 3,37 – 3,16µm). The difference between the maximum and minimum value is only 1,45µm, insignificant value for molded parts. This means that can be use injection molded parts made from new material and a certain percentage of grind. Warpage decrease may be explained due to the fact that thermoplastic material was processed by injection once, suffering an minimal thermal degradation, and mechanical degradation after grinding.

REFERENCES:

[1] D. Chira- *Comand optimization of the injection molding machine* PhD thesis, University “Lucian Blaga”, Sibiu, 2006,

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

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

[4] *** SR EN ISO 294/4:2001,- *Plastic Materials. Injection moulding of test specimens of thermoplastic materials - Part 4: Determination of moulding shrinkage.*

[5] S. Pater - *Equipment and measurement systems*, University of Oradea Publishing House, Oradea, 2009, p. 51-54.

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

[7] *** www. Omnexus.com - *Plastics and Elastomers online expert.*

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

[9] Chira, D., Băban, M., *Theoretical consideration and experimental researches regarding the variation of injection molded piece warpage with injection pressure and cooling time.* Annals of the Oradea university.fascicle of management and technological Engineering, Volume V (XV), 2006, ISSN 1583-0691, pag. 857-860