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STUDY ON THE OPTIMIZATION OF TECHNOLOGICAL PARAMETERS IN INJECTION PROCESS

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Abstract**—** The work presents in essence an optimization of injection important parameters for a complex piece on a machine injected with a suitable injection mould. It also outlines the important factors that influence the flow of plastic material to fill the matrix. For a case study we took a piece of polypropylene material type "filter", an injection machine type BA 500 CD. In ordrer to choose the optimal parameters of the injection, it has been used CAE and MPI/FLOW simulation programs. By adjusting the optimum parameters for the injection machine was obtained a quality injected piece and a lower cost price.

Keywords**—** thermoplastic materials injection, injection parameters, simulation

I. INTRODUCTION

The procedure for obtaining the parts of thermoplastics materials by injection into the mould has been greatly expanded due to the economic benefits, as well as the possibility of obtaining pieces of different shapes and sizes and in a wide range of plastics.

The quality of the injected parts is given, firstly, by the compliance and control of parameters of work for each phase of the injection cycle.

The complex shaped parts injection occurs in a wide range of defects, so that the parameters of the injection system must be checked and adjust the close limit in order to avoid as far as possible, these flaws.

The classical method of adjusting the parameters of the injection is done one at a time manually so that they appear many drawbacks: big time for assimilation of the product, additional consumption of materials, energy, etc.

These disadvantages listed leading ultimately to additional costs with the assimilation of the product and the price increasement of production of the product.

The disadvantages listed above can be eliminated or at least reduced, by using simulation programs of the technology of computer-aided injection leading to assimilation in the short time, minimum energy cost, consumption of small plastics due to the determination of optimum parameters of the injection.

II. THEORETICAL CONSIDERATIONS REGARDING THE FLOW OF THE THERMOPLASTIC MATERIALS AT INJECTION

The main phenomena that underlie the process of injection of plastic parts is the flow of material from the injection machine to the injected molded substrate of the piece. The science that deals with the study of deformation and flow phenomena of plastics injection is named rheology.

Rheological behavior of plastics directly influence the flow of plastic deformation at the injection mould.

The image of rheological behaviour of thermoplastic materials is presented in graphs or reograme, where they are shown the dependence of shear unit effort τ and the gradient of velocity γ, called rheopant.

Thus, the graph $\dot{\gamma} = f(\tau)$ represents the fluidity curve and is useful because it can determinate the viscosity of the material at different points of the curve, [3]. The most important factor that influence the flow of plastic injecting mold is viscosity.

$$\dot{\gamma} = f(\tau) \qquad (1)$$

The melting viscosity directly influence the flow of the plastic materials at injection, is given by the flow index (IC) which at injection process has the value, [5]:

$$IC = 1,0 \div 3,0 \qquad (2)$$

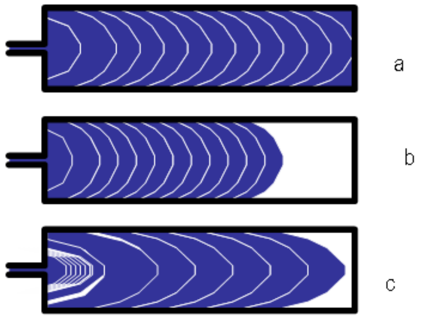
Flow index characterizes the reaction to the flow of various polymer in the melting phase. The connection between the flow and viscosity index is inversely proportional, so that at a high index flow results a small viscosity (η) according to the relationship [5], as follows:

$$\eta = 5*10^4 * \frac{\rho * G}{IC} \qquad (3)$$

where: ρ – melting density (g/cm³)
IC – flow index (g/10 min)

G- the weight of the plastometru piston (daN)

Viscosity influence over the shape of the material flow inside the die cavity filling is shown in “Fig.1”.



(a)- normal viscosity (b)- high viscosity (c)-low viscosity
Fig. 1.The influence of viscosity of flowing fronts

The moving of the front of the melt over time is described by a volum function of which variation over time is given by an equation of the form [6]:

$$\frac{\partial f}{\partial t}+\nabla(uf)=0 \qquad (4)$$

where: $0 < f < 1$, f-volum function; u- speed gradient.

The viscosity is influenced by several factors, such as: molar mass, molecular weight distribution, temperature, pressure, auxiliary materials, thermomechanical stress, etc.

Molecular weight influences the viscosity of melt material respectively the flow of material, [7] as follows:

$$\lg\eta = A + C*\lg Mm \qquad (5)$$

where: η – the melt viscosity
Mm – the average molecular mass
A, C – constants

Molecular structure influencing the viscosity so that at the increasing of the branching degree, the viscosity decreases.

Temperature influences the flow of melted plastic material, namely, increasing the temperature, the viscosity decreases.

The influence of temperature on the melting viscosity of polymers is very important because it determines the choice of parameters of injection system with great influence over the quality of the injected parts.

The relationship between viscosity and temperature for Newtonian fluids is given by the Arrhenius relationship [3]:

$$\eta = A*e^{\frac{E}{R*T}} \qquad (6)$$

where: A –frequency term
T – temperature
E – the activation energy of the flow

In the case of nonnewtonian fluids, viscosity depends on the tension or shear or rheopant and temperature [5], as follows:

$$\eta = A*e^{\left(\frac{E}{R*T}-\alpha*\tau\right)} \qquad (7)$$

where : α - constant;

Injection pressure increasing the pressure of the injection shrinks the intermolecular distances, increase the intermolecular forces of attraction, so molecular viscosity will increase. The effect of pressure on the viscosity is higher as the molecule is larger. This phenomenon must be taken into account in the state of technological parameters of the molding machine.

The relationship between pressure and viscosity is [6]:

$$\eta(p)=\eta(p_0)*\exp\left[a_{\dot{\gamma}}*(p-p_0)\right] \qquad (8)$$

where : $a_{\dot{\gamma}}$ –constant

The viscosity ressure function is an exponential function.

At polymeric materials increasing pressure with a value Δp has the same effect on viscositythe same influence with decreasing temperature with a certain value ΔT.

Auxiliary materials influencing viscosity thus:

- Plastefiant influences the viscosity according to relationship [5]:

$$\eta = A*\exp(-\beta*C_p) \qquad (9)$$

where : A, β – dependent constants of $a_{\dot{\gamma}}$

Cp - the mass concentration of plastefiant.

- Lubricant can be internal or external, and the effect is that the viscosity at a concentration greater than 3% viscosity decreases (less than 1% does not influence the viscosity) [5].

- Stuffing materials – the filling material strength increases as the viscosity increases according to the relationship [5]:

$$\eta = \exp\left(\frac{2{,}5*Cu}{1-K*Cu}\right) \qquad (10)$$

where: -Cu- filling material concentration
-K- constant.

– Colorants- included in the plastic materials rising the melting viscosity value.

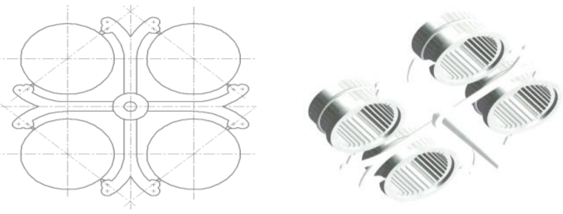
Thermomechanical stress influence - the viscosity of the polymer is influenced by the manufacturing process, and the subsequent thermomechanical stress from the process of injection. As the number of injection processing increases, the viscosity increases.

III. CASE STUDY

For the simulation study of injection process it is used an injected piece called „filter" , shown in "Fig.2" which is in production at company PRODCOM, Alba Iulia. The part is a filter element that belongs to a device with water filtration sand bed. The filter is[1] assembled with other parts from the device, thus the precise geometric shapes and sizes are required, contractions as small as possible in the assembly areas and minimum deformations over time.

Fig. 2. Filter

The injection of the piece is made into a mold with four nesting, through distribution channels, each nest has two points of injection, symmetrically arranged, according to the "Fig.3"



(a) -the nesting location scheme (b) -injected parts

Fig. 3. Wiring diagram of injection mold

By simulating of the injection and obtaining the optimum parameters of the injection ensures a high-quality and efficient production of the piece, resulting an optimal balance between quality, cost and minimum time of assimilation into production and on the market.

IV. METHODOLOGY AND STAGES OF THE SIMULATION WITH MOLDFLOW PROGRAM

The analyses of the melt plastic material in injection molded cam be of the type:

- Full flow
- Filling only
- Runner balance
- Molding window
- Gate location

In this paper we used only the first and the second option analysis.

The mold filling process is carried out by a computer using finite element method (FEM). Mold flow simulation program uses a geometric pattern, "mesh" type which is created automatically by the program, based on the geometry of the workpiece. The model of the analyzed piece can be created in any program of three-dimensional computer simulation, model that is imported as a surface IGES or STL in Mold flow analysis programme [1].

In order to analyze the flow of plastic material during it's injection in the mold it's necessary to cover several stages:

1. The import of 3D models of the piece

The geometrical model of the piece to be analyzed can be realized directly in Mold flow, using the module MPI/Modeler or in the CAD 3D program , afterwards imported in MDI/STUDIO module as a file STL or IGES.

2. The discretization of geometrical model (New Mesh).

It's a very important stage of the simulating process, because it can appear various deficiencies of the mash, for example: breaches , superposition of the elements, unorientated elements. This deficiencies doesn't permit the realization of the simulating and appear messages of errors.

3. The selection of the boundary conditions

In this stage we choose the point of the injection. The place will be represented by a yellow knot on model surface.

4. Stualysis Preparation Wizard

In this stage take place the choice of the material for the piece from the data base of the soft, the choice of the analysis type (Flow , Optinum profile analysis, Cool, Warp or Stress)

Choosing the Flow option, further will choose the oprion Filling only and the necessary parameters for the injection

The molding machine used is BA 500 CDK "Fig. 4" with following technical features, presented in Table I.

TABLE I
INJECTION MACHINE FEATURES

Crt. No	Characteristic	Value
1	clamping force	500 KN
2	max injection pressure	1484 bar
3	auger diameter	35 mm
4	plasticizing capacity	15 g/sec
5	injection capacity	122 g

Fig. 4. Injection machine BA 500 CDK

Once the plastic material used for injected part is set, polypropylene, Mold flow software choose from program library injection parameters refer "Fig.5".

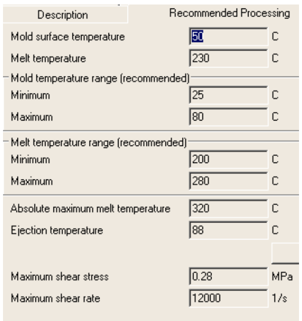


Fig. 5. Recommended injection parameters of material

Through a Mold flow program a simulation and at the same time an optimisation of the injection process was realised, resulting in final more charts for injection parameters that will be presented next.

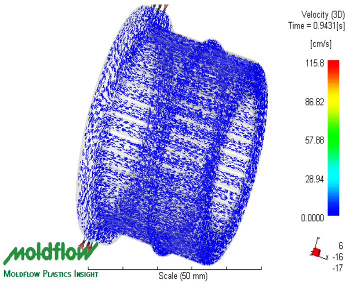


Fig. 6. Flow velocity

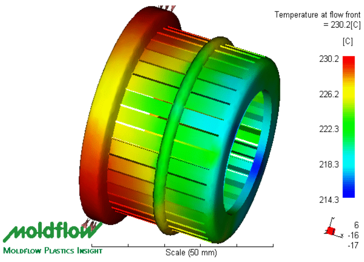


Fig. 7. Front flow temperature

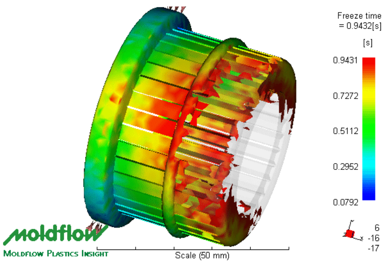


Fig. 8. Solidification time

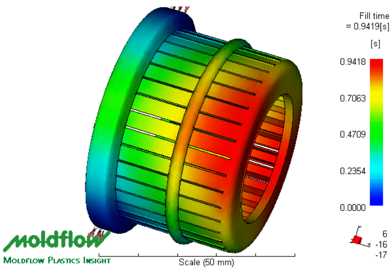


Fig. 9. Filling time

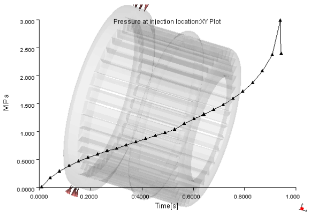


Fig. 10. Clamp force

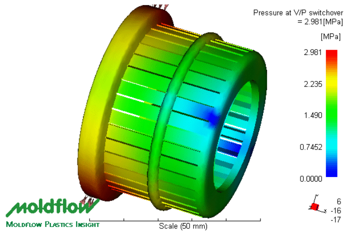


Fig. 11. The maximum filling presure

Summary of the results obtained following the injection mould in the simulation are presented in Table II.

TABLE II
THE PARAMETER VALUES OF THE FILLING PROCESS

Crt. No.	Parameter name	The parameter values for the filling process
1	flowing speed	115,8 [cm/s]
2	solidification time	0,9432 [s]
3	clamping force	2800 [MPa
4	filling time	0,9419 [s]
5	front flow temperature	230,2 [° C]
6	the maximum filling pressure	2981 [MPa]

V.CONCLUSIONS

As a result of the simulation optimal parameters for the chosen injection machine were achieved, presented in table II. Obtained parameters as a result of the simulation and used on the injection machine for the „filter" part have led to the following conclusions:
- reduction of injection cycle;
- increase the quality of the piece;
- constancy in time for quality and productivity;
- decreases the number of scrap pieces
- lower costs

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