COMPARISON OF SELECTED MATERIALS INTENDED FOR THE MANUFACTURE OF PLASTIC HOLDER FOR REVERSE PARKING SENSOR WITH THE USE OF COMPUTER SIMULATION TOOLS

PETR BARON, JAKUB KASCAK

Faculty of Manufacturing Technologies with a seat in Presov,
Technical University of Kosice, Slovakia

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e-mail: petr.baron@tuke.sk

The article deals with suitability assessment of selected types of materials needed for the manufacture of plastic holder of parking sensor, which is located in the vehicle bumper. By applying the PTC Creo Mold Analysis simulation tool, the manufacturing process has been assessed to minimize potential errors affecting not only the appearance properties of the final part, but also its mechanical properties and, last but not least, the quality and success of the injection molding process. Application of computer simulation has verified the knowledge that decisive influence on mechanical and physical properties of the final part is in the selection of a suitable type of applied material as well as correct setting of technological parameters and, last but not least, the design of the mold itself.

KEYWORDS

Simulation of production processes, analysis, injection, shrinking

INTRODUCTION

The simulation of production processes is an important tool for achieving the goals of parallel or concurrent engineering. One of the main goals is the early detection of manufacturing process errors, which can occur in parallel with the planning process, instrument security, and so on.

In the case of plastic injection technology, a range of tools from the CAD / CAM / CAE system portfolio can be used to help engineers and developers for an on time identification of potential errors like bottlenecks. These errors may arise on the final plastic parts. Even during the design process, structural and technological changes can be applied, which can eliminate or at least minimize their undesirable consequences. This is the so-called pre-production analysis that can reveal potential production problems such as cold junctions, welds, air pockets, but also optimal positioning of intakes, optimal adjustment of technological parameters, and so on. Plastic injection technology has some specifics, especially from the point of view of effects with various influences and processes, on the final properties of the product. From the beginning of filling the cavity with molten plastic, the production processes begin to take place, which can be different at each point in the melt volume. Usage of the computer simulation tools in the manufacturing process, allows us on time detection and prediction of the process production and properties of plastic molding.

1 ANALYSIS OF SELECTED TYPES OF MATERIALS APPLIED FOR INSPECTION PROCESS

1.1 Characteristics of the analyzed types of polymers from the viewpoint of their application for monitored component

Based on our partner's request, we performed a suitability analysis. This simulation included application of three types of materials used in the manufacture of a reverse parking sensor holder located in the vehicle bumper (Figure 1). In order to manufacture the holders of mentioned sensors, we consider to use materials which are resistant to external influences, with good strength and hardness.

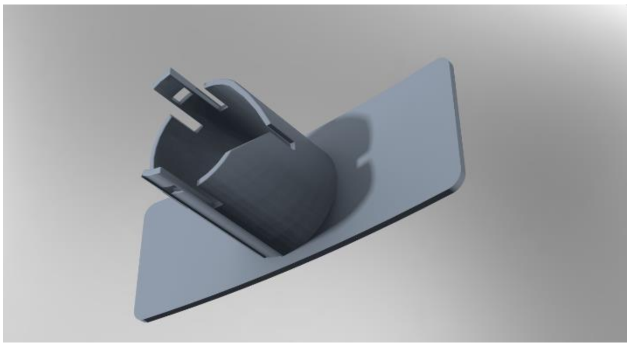

Figure 1. 3D model of reverse parking sensor holder

In some cases, various additives are applied, depending on the the desired dye. For a specific case, we compared the following types of materials:

- Topas 5013 – is a type of cyclic olefin copolymer, which is applied in the production of optical, packaging products, medical technology, or capacitors. The main advantages of this material include high heat resistance, high elasticity, low elongation at elongation, high hardness and surface resistance.
- Terluran 867M - belongs to a group of amorphous ABS thermoplastic copolymers, or also acrylonitrile butadiene styrenes. Features of this material allow its usage in automotive components, black and white technology, protective covers or also toys. This type of material is tough and impact-resistant, both of this properties can be modified by varying the proportion of acrylonitrile, butadiene and styrene components.
- Celanex 1600A – is a thermoplastic polymer with a polycrystalline structure that belongs to polybutylene terephthalate- based materials. Its properties are suited to a more demanding environment and resistant to solvents and oils. Its offering high hardness, strength, weather resistance and rapid crystallization in the injection process. According to the requirements it is possible to easily modify its coloration by adding dyes.

1.2 Implementation of computer simulation in the PTC Creo Mold Analysis environment

The computer simulation of plastic injection molding process for the selected part was realized in the PTC Creo software, rather in its Mold Analysis module. This module is an extension of the design package of knowledge and process of manufacturing plastic parts. The sequence of steps to perform simulations in a given environment can be summarized in the following report:

- Modification of the models design to refer the final molding (application of the change of dimensions by the value of shrinkage, design of additional bevels, design of functional elements of the model)
- Creation of Creo Mold Analysis (CMA)
- Selection and assignment of applied material from the material library
- Design of an inlet opening location
- Configuration of the analysis of the monitored process
- Initiation of analyzes
- Presentation of simulation results
- Generation of the report
- Data saving

The first step in configuration process of the meltblown polymerization analysis into cavity associated with the reference model is to select material from the material library. In the tree view, it is possible to select the material based on type and then its categorization by manufacturer. The material library identifies material characteristics (melting temperature, mold temperature, shear stress, viscosity, shrinkage values, etc.). The melting temperature determines the plasticity of the plastic before injection. Depending on the type of plastic, it ranges from 200 to 250 ° C. Too low temperature may cause incomplete filling of the mold cavity, too high temperature can damage the structure of the injected material. [Dillinger 2007] The temperature of the mold influences the velocity of plastic flow around the walls when filling the mold cavity and thereby changing the direction of the plastic macromolecule fibers. Form with low temperature can adversely affect the internal structure of the mold and consequently the surface resilience of the final product. The temperature of the mold is usually maintained in an interval of 80 to 120 ° C. At this temperature, the product is flexible and at the same time molded, and dropped out of the mold [Dillinger 2007]. The volume of thermoplastics is strongly dependent on temperature and pressure. Therefore, characterization of the pressure - volume - temperature (PVT) relationship is to calculate compressibility of the material during the injection process analysis. The PVT model describes the specific volume dependence on temperature and pressure (Figure 2).

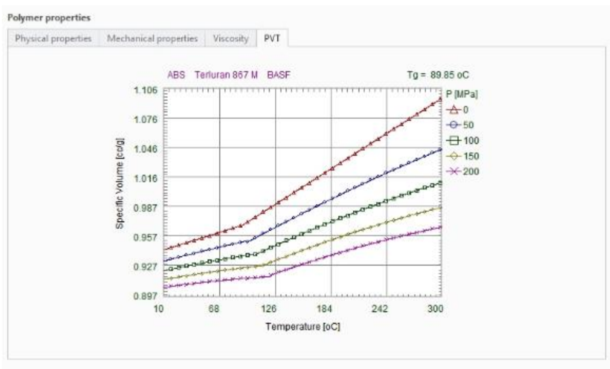

Figure 2. PVT model of Terluran 867M material

The result of the injection molding process of plastic parts depends on the optimal matching of properties defined by selected material, injection unit, injection mold, temperature, course and velocity of movement. Process parameters such as the position of moving parts and temperature change at many locations of the injection mold. This process is regulated according to the set of specific parameters. The most important parameters are the temperature, mold temperature and pressure of the injected material [Dillinger 2007].

After defining the placement of inlet orifice, which depends mainly on the applied mold construction, but also on used material, method of mold mounting and the determination of technological parameters (melting temperature, mold and injection pressure), it is possible to inicialize the calculation and simulation analysis. This process depends on the density of pixel network representing the plastic injection reference model.

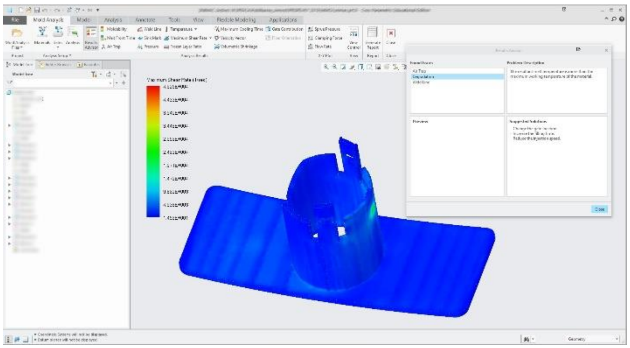

Figure 3. Analysis results of TOPAS 5013 material

In context of the reliability of filling molten polymer in the mold of the applied analysis, we pointed out that in all three cases there is no problem in filling the cavity with molten polymer determined by the shape and dimensions of reference model. The melt completely fills the cavity during the cycle of technological process.

In the case of Topas 5013, the analysis suggested a higher probability of deformation due to the application of higher operating temperatures. The melt temperature in some places is at the upper edge of recommended interval for the material (Figure 3).

In all three cases, simulation revealed the probability of errors in the form of air bubbles and welded joints at approximately the same points as in the model (Figure 4 - Figure 6)

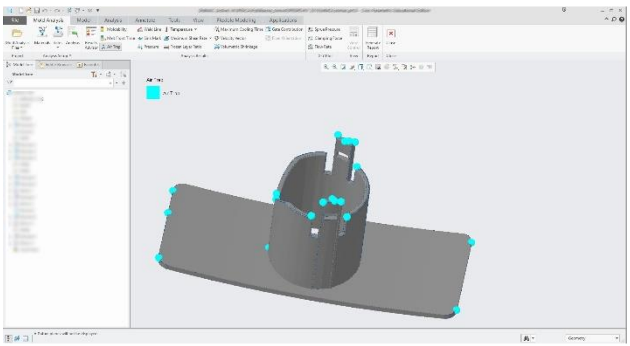

Figure 4. Prediction of air bubbles formation for the material Celanex1600A

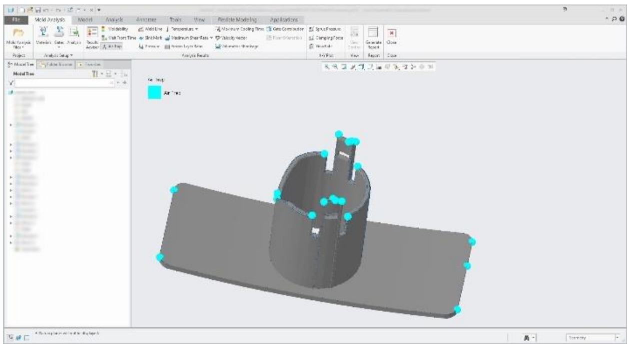

Figure 5. Prediction of air bubbles formation for the material Terluran867M

Welding joints are created when two or more streams of molten material are connected. This may be due, the flow of material from a several inflow opening and the distribution of a subsequent connection of the flow in mold cavity (non-uniform geometry) caused by structural components. This error has different manifestations. It may take the form of a slightly invisible weld or rounded edge, in the worst case it will create a crack. A weld joint is not only a visual defect, it can reduce component strength by 10 to 20%, depending on the place of occurrence. From a technological point of view, the influence of the polymer type, melt temperature and injection velocity are influenced by the strength of the welding joint [Dobransky 2013].

To minimize this type of error, we can apply the following steps:

- Increasing the melt temperature or mold temperature
- Shorten the filling cycle of injection cycle
- Use a material with a lower viscosity
- Increase the injection rate

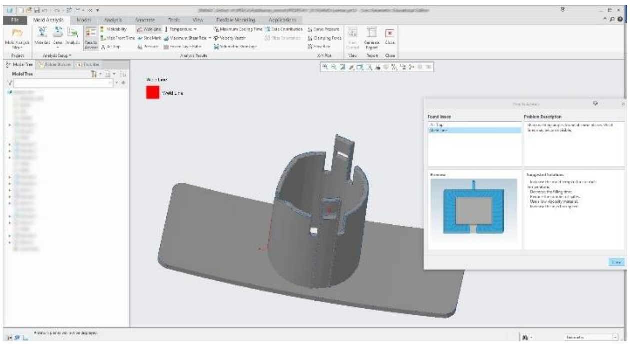

Figure 6. Localization of welded joints during the analysys of Terluran867M material

Another significant error that may affect the performance of plastic component is the formation of overflows on surface of the shaped part of the mold. Overflows may not affect the strength or function of the product, but are considered to be serious quality errors generated by the injection process. This negative phenomenon arises due to the shrinkage of inner plastic, the reinforced surface layer deforms due to the internal pressure of shrinkage during cooling process. This type of error can be minimized by shortening of the filling cycle during injection process.

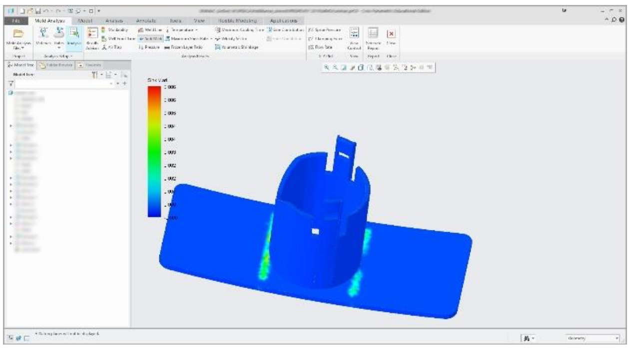

Figure 7. Localization of overflow sites in the material Terluran867M

The material which is showing sites with the specified type of error is, based on the analyzes performed, ABS Terluran 867M (Fig. 7).

The analysis results for estimated cooling time vary for the materials considered. Cooling time represents the time from cavity completion to ejection of the finished molding. This stage represents up to 80% of the total cycle time.

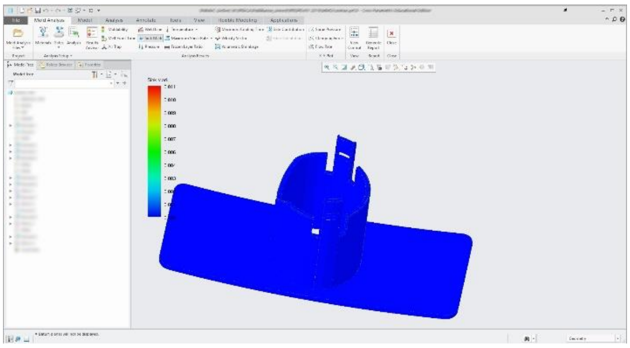

Figure 8. Localization of overflow sites in the material Celanex 1600A

The cooling time affects two major factors: the melt temperature and mold temperature. These parameters can be optimized for high quality outputs. The simulation serves to optimize the design of the tempering system (Figure 9 - Figure 11).

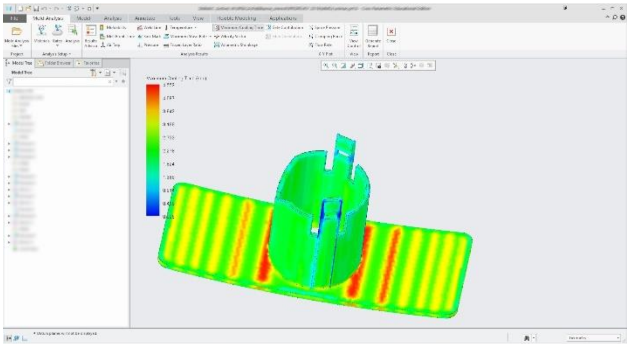

Figure 9. Calculation of cooling time for material Celanex 1600A

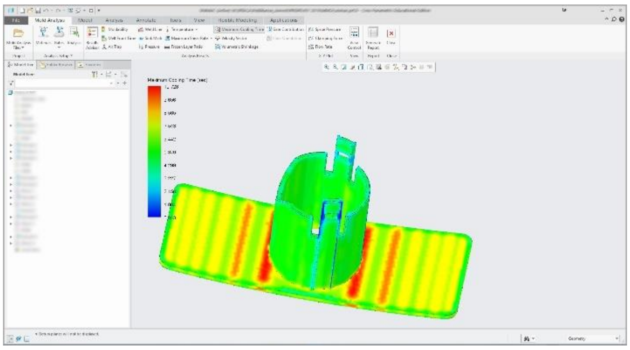

Figure 10. Calculation of cooling time for material Terluran867M

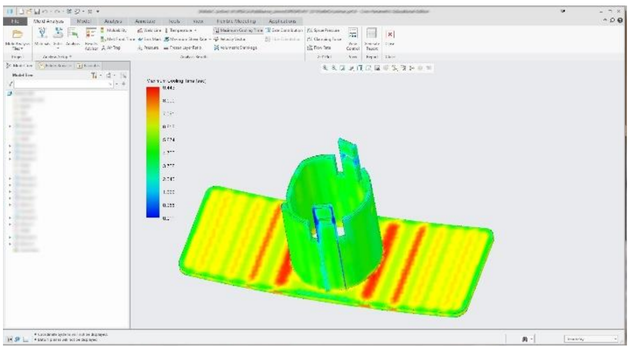

Figure 11. Calculation of cooling time for materia TOPAS 5013

A Sprue Pressure analysis can be used to determine an unusual increase in inlet pressure during filling of the cavity with polymer. The indicated pressure value usually does not exceed the maximum permitted injection pressure. This is set as a process parameter. If the recalculated inlet pressure rises to the maximum allowable injection pressure level and is held at this level until the end of the filling, the cavity filling phase of the molten polymer may be slowed or the mold may be insufficient (Figure 12).

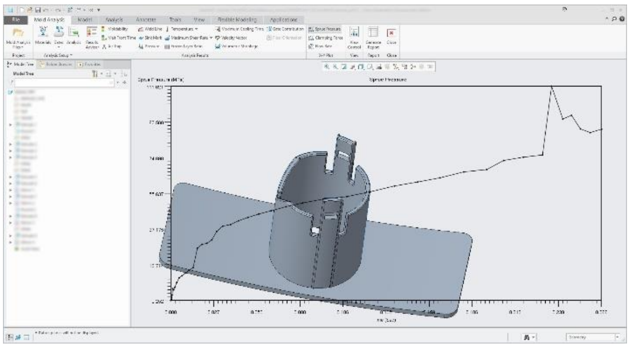

Figure 12. Flow rate of filling pressure depending on time – material Terluran867M

The Clamping Force analysis is used to determine the time, closure force dependence on time. The results of this analysis do not represent the level of injection molding force. The closing force ensures that the mold is held in the closed state during injection. If the calculated value of the closing force was greater than 70% of the maximum value of the injection molding force, the molten polymer may be extruded out of the cavity and the molding will be inoperable (spraying and rubbing). In Fig. 13 is a plot of the calculated value of the closure force, as a function of the time for the Celanex 1600A.

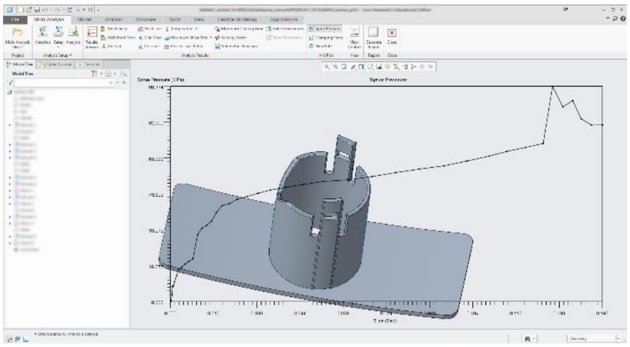

Figure 13. Dependance of the closing force intensity, depending on material- time, for Celanex1600A material

2 COMPARISON OF ANALYZED MATERIALS- DISCUSSION

Based on the analyzes performed, it can be stated that application of each of the materials examined will not cause a serious problem in relation to the final properties of the finished product. Of course, mechanical and physical properties are characteristic of each of the materials, which affect the configuration of the technological parameters so that the resulting shape, dimensions and mechanical properties of the final product meet the requirements prescribed by the design. In Tab. 1 is a summary of the physical and mechanical properties of the materials under consideration.

In the context of the application of computer simulation, it is also important that the identification of possible errors and undesirable deformations can make changes in the design of the tool i.e. molds for plastic injection molding technology. For example, in the production process design stage, it is possible to identify places with a cumulative temperature that negatively affect the resulting cycle time. This is in particular part of a piece with greater wall thickness. Such a simulation serves to optimize the design of the tempering system.

By analyzing the determination of maximum shear stress value at the individual points of the model. Within range of the maximum permitted shear stress (the tension that is formed between the individual layers of the molten polymer when it flows in the mold cavity), it is possible to identify the possible breakdown of the polymer molecules. Which is resulting in the loss of the required mechanical properties plastic molding. It is also important to monitor the shear rate distribution in relation to the gradient velocity and orientation of the polymer molecules. High shear rate tends to drastically deform the molecular chains. Highest shear rate values reach the injected melt at the inlet orifice. However, it must not exceed the limit value that is typical for the individual types of polymer. At low filling velocity, cold connections can occur when the melt is gradually cooled. By setting a higher injection rate, thermal decomposition occurs when molecular chains are deformed.

Table 1. Physical and mechanical properties of the monitored polymers

	Polymer		
	Celanex1600A	Topas5013	Terluran867M
Typ	PBT (Polybutylene terephthalate)	COC (Cyclic olefin copolymer)	ABS (Acrylonitrile butadiene-styrene)
Manufacturer	TICONA	Polyplastics	BASF
Flow index	6.5g/10 min.	56g/10 min.	
Min. melting temperature	240 °C	250 °C	200 °C
Melting temperature	250 °C	275 °C	225 °C
Max. melting temperature	260 °C	300 °C	250 °C
Min. mold temperature	60 °C	95 °C	40 °C
Mold temperature	80 °C	110 °C	60 °C
Max. mold temperature	100 °C	130 °C	80 °C
Discard temperature	164,81 °C	133,85 °C	89,85 °C
Cooling temperature	185 °C	154 °C	110 °C
Poisson constant	0.40	0.38	0.38
Flexibility module	24 000 N/cm^2	20 000 N/cm^2	26 000 N/cm2
Coefficient of linear thermal expansion	0.00011 $°C^{-1}$	0.000082 $°C^{-1}$	0.000094 $°C^{-1}$

Simulation identified, as with one of the materials used, the possibility of surface overflows at Terluran 867M. Although this error can be minimized by shortening the filling phase, we recommend focusing on other types of considered materials. Specifically, the Celanex1600A material, due to its physical and mechanical properties, meets the requirements for the functional and utility features of the manufactured part. In order to prevent hydrolytic degradation of this material during its processing, the manufacturer recommends drying it to a moisture content of less than, or equal to 0.02%. Drying should be carried out in an oven with the possibility of ventilation at 121 °C for 4 hours.

3 CONCLUSIONS

Computer simulation tools can detect errors in the material and its behavior during the production process. Tracking important parameters influencing the injection process facilitates activities leading to higher quality results.

The final properties of the workpiece can be significantly influenced by the designer itself. Designing the optimal wall thickness, adjusting wall stitching, adjusting the ribbing, and so on. The purpose of this activity is to minimize possible deformations that negatively affect the overall properties of the final product.

Computer simulation tools make it possible to imitate a real process using computing. The advantage of using simulations is the ability to achieve a optimal behavior analysis of the base plastic material during the injection process and to optimize the design of the injection molding tool based on the obtained results. Usage of computer support and the determination of an optimal solution is very important in the design of final product. At current stage approximately 70% of the cost of production is defined. Such preparation enables the user and the future processor to accelerate and economically streamline the pre-production process, which is ultimately very beneficial.

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CONTACTS

Assoc. Prof. Eng. Petr Baron, PhD.
Faculty of Manufacturing Technologies with a seat in Prešov,
Technical University of Košice, Slovakia
Sturova 31, 080 001 Presov, Slovakia
+421 556026349