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Enhanced Efficiency in Two-Component Injection Molding Product for Automotive Applications

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***Abstract*. The presented study is focused on an optimization analysis of a complex automotive component consisting of two parts with different materials. The research examines the impact of various runner configurations, cooling parameters, gate positioning, and melt temperature distribution within the mold. The paper emphasizes the advantages and applications of integrating such optimization techniques. Parametric and geometric optimization of the model is done, along with the evaluation of simulated filling processes, as clarified for the paper's objectives. Additionally, a methodical approach is outlined, clearing the process of operational rate selection, material property analysis, control parameter establishment, and preemptive simulations.**

Keywords: CAD modeling, filling analysis, two-component molding, optimization, injection molding, polymer

I. Introduction

A. Multi-component injection molding

The production process of forming multi-component products under high pressure is expressed in the fact that from two or more different polymers one part is obtained. These polymers are most often thermoplastics, but thermoplastic elastomers are also used. The polymers used may differ in color, mechanical properties or other factors.[1][2][3]

Multi-component injection molding is preferred to conventional injection molding for a number of reasons.[3] It significantly improves the functionality of the products and gives much more freedom in terms of design decisions. This process reduces the cost and reduces the weight of the final part.

Disadvantages include the high cost of machinery and equipment, as well as the fact that not all polymers form good adhesion to each other. [1][2]

The development of the methodology is caused by the need of the market for a service for restoration of the working capacity, as well as for modification of mold tools in case of need of corrections.[4]

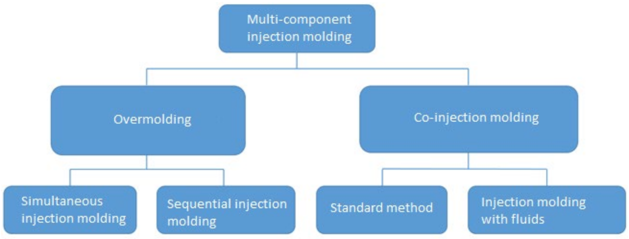

Fig. 1 Classification of multicomponent injection molding processes

A. Overmolding

Overmolding is an increasingly popular process for injecting additional layers of material onto a base in two or more steps. [4][5] This is done by adding a new layer on the same machine in a combined tool on the base of the part already formed in the first step. This technique allows in one step the bonding of two or more polymers which do not require any additional finishing operations successively on top of each other.[6]

Fig. 2 Example of multi-component injection molding by layer-by-layer injection molding

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A molding tool is pre-filled with one material, then it is opened and one part of it is closed with a second half-mold. An additional cavity is formed and reshaped into the shape thus created by the second. The second material is injected directly onto the first to obtain a final product composed of two or more layers created successively on top of each other.[7][8][9]

This method provides additional increased flexibility for the production of multi-component, multi-colored or multifunctional, in terms of materials used, products at the lowest cost. [10]

B. *Co-injection*

The method of sequentially feeding materials through a nozzle is a variation of the multi-component injection molding process. In it, the final product is characterized by a core and a shell. Depending on whether the product is solid or hollow, there are two variants of the method of forming products - standard and injection molding with fluids. It is widespread because it allows to reduce the quantity and quality of the material used.[13][14]

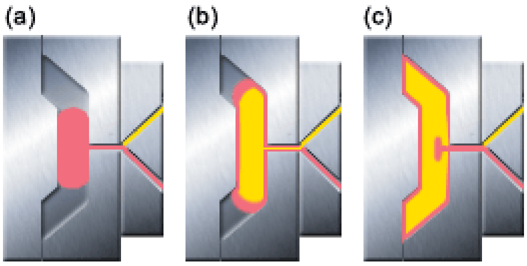

Fig. 3 Example of co-injection molding

C. *Purpose of the research*

The purpose of this paper is to model and analyze different methods of optimization of injection model process. Two layers of two component model are considered.

II. Simulation Analysis and Optimization of the Process in Order to Reduce Displacement of the Model. Material Selection.

The model analyzed in this article is two-component front frame with cluster lens used in some automobiles (fig. 4).

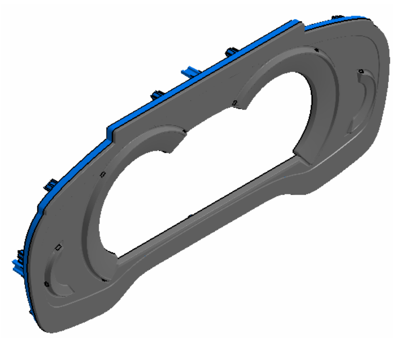

Fig. 4 Front frame

What is specific about these components is that they are directly visible to the end user, which leads to higher requirements.

Engineering analysis are applied using developed virtual prototypes that give results close to expected from physical prototyping and provides data for further design considerations.[11][12]

First part (fig. 5) is a frame which is made of polycarbonate with good hardness characteristics. The material selected for this element is PC with 20% fiber glass reinforced (PC+SANGF20).

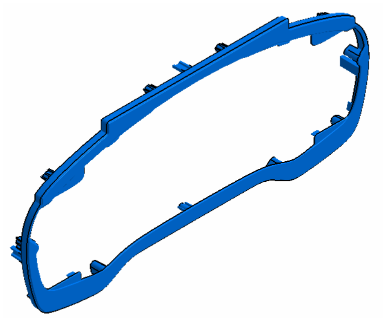

Fig. 5 Frame

The second part to analyze is a lens or the visible part of the assembly which must have good quality with no defects existing. The material for this part is PMMA.

A. *Initial configuration – frame*

In the initial configuration of the simulation, the input data of the process are set to those proposed by the software, which offers default values for the selected model.

Cooling system and gate position are conventional where the part “frame” is filled from two points.

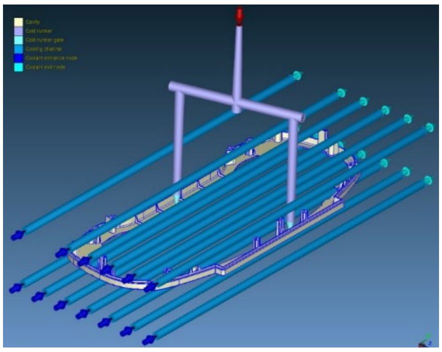

Fig. 6 Cooling and runner systems

When changing working parameters, a process accuracy measurement is required.

Initial working parameters are chosen by default.

TABLE 1 Frame parameters

Parameter	Frame PC+SANGF20
Number of gates	2
Filling time (sec)	1
Packing time (sec)	4
Cooling time (sec)	11
Eject time (sec)	5
Maximum injection pressure (MPa)	120

Maximum packing pressure (MPa)	120
Melt temperature (°C)	320
Mold temperature (°C)	110
Air temperature (°C)	25
Eject temperature (°C)	150
Cooling fluid	Water

With the help of the initial configuration, important information about the behavior of the process can be extracted, problem areas and weak parts of the injection molding can be identified.

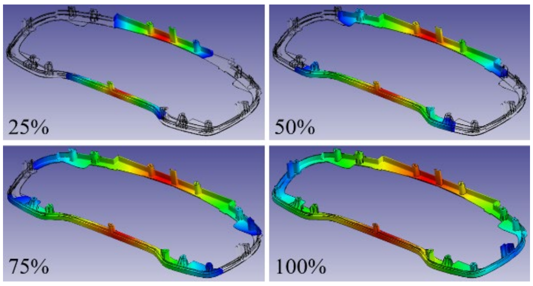

Fig. 7 Filling time

Displacement shown of the first layer is scaled. Through overexposure, it is easier to visually and cognitively identify trends and problem areas. Maximum displacement of the model is 1.2mm.

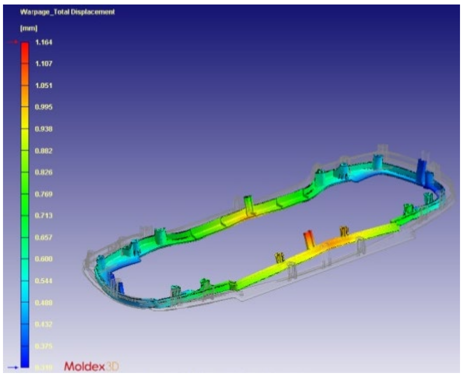

Fig. 8 Total Displacement

B. Runner system optimization – frame

Two variants of running systems are considered and shown in fig. 9.

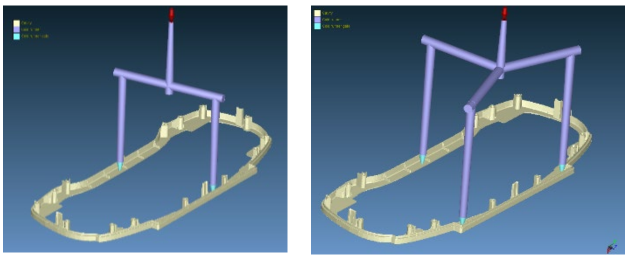

Fig. 9 Runner system comparison

Working parameters remain the same in order not to affect the results. Results from simulations are sorted in table 2.

TABLE 2 Three gates frame parameters

FRAME	Two gates No. 1	Three gates No. 2
Average injection temperature, °C	288.316	290.770
Maximum injection pressure, MPa	42.525	38.305
Average cooling temperature, °C	125.894	128.619
Maximum displacement, mm	1.164	0.989

Changing the number of gates can affect the process in different ways. But from this comes the problem with the welding lines, the more entrances, the more welding lines. They mainly affect the appearance of the product, but due to the fact that the first layer of injection molding is not visible to the end user, this effect can be ignored.

C. Filling time optimization – frame

Filling time optimization consists of simulations with 3 gates but different time to fill the form. First one is with 1 second (No. 2) and second – 0.4sec.

TABLE 3 Frame filling parameters

FRAME	1 sec fill No. 2	0.4 sec fill No. 3
Average injection temperature, °C	290.770	299.099
Maximum injection pressure, MPa	38.305	62.280
Average cooling temperature, °C	128.619	122.067
Maximum displacement, mm	0.989	0.864

Reducing the filling time reduces the cycle time as well as the displacements. Despite higher average injection temperature in simulation No. 3 to No. 2, maximum displacement from nominal dimensions in No. 3 is lower.

D. Injection melt and mold temperature optimization – frame

In the next two comparisons, melt and mold temperatures are listed below:

- Simulation No. 3 – 320°C melt temperature, 110°C mold temperature
- Simulation No. 4 – 300°C melt temperature, 130°C mold temperature

TABLE 4 Temperature parameters

	320°C/110°C No. 3	300°C/130°C No. 4
Average injection temperature, °C	299.099	284.395
Maximum injection pressure, MPa	62.280	85.159
Average cooling temperature, °C	122.067	122.067
Maximum displacement, mm	0.864	0.948

Lowering melt temperature while increasing mold temperature negatively affects maximum displacement of the part. Simulation No. 3 remain for the final optimization.

E. Cooling time optimization – frame

Default cooling time from simulation No. 3 is set 11 sec while cooling time in simulation No. 5 is set 21 sec.

TABLE 5 Cooling parameters frame

FRAME	11 sec cooling No. 3	21 sec cooling No. 5
Average injection temperature, °C	299.099	299.114
Maximum injection pressure, MPa	62.280	62.159
Average cooling temperature, °C	122.067	123.128
Maximum displacement, mm	0.864	0.658

The longer a part cools, the less it deforms after opening the mold but the injection molding cycle increases.

After changing the cooling time, an improvement in the value of the displacement is observed again. It is low enough to move to the optimization of the second layer of the two-component product.

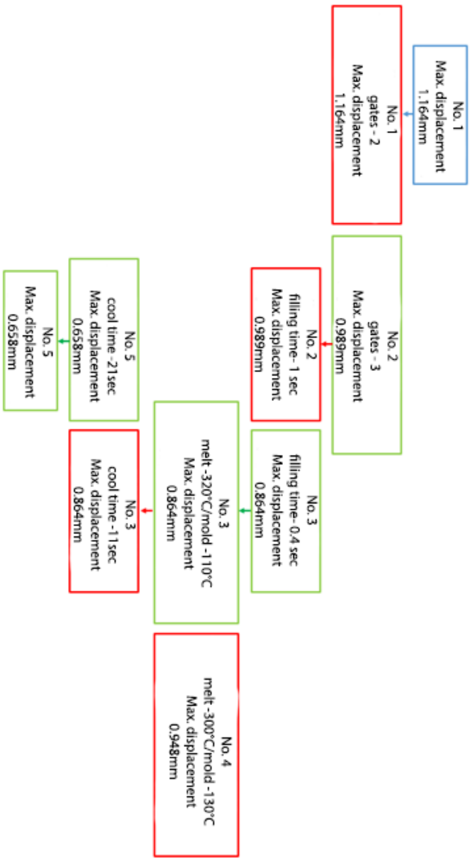

Fig. 10 Optimization stages of frame

F. Initial configuration – lens

In the initial configuration of lens simulation, the input data of the process are set to those proposed by the software, which offers default values for the selected model. Runner and cooling systems are chosen analogously to the frame part.

Cooling system and gate position are conventional where the part "lens" is filled from two points.

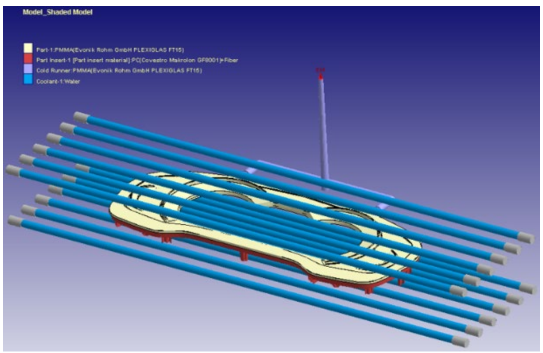

Fig. 11 Cooling and runner systems

Initial working parameters are chosen by default.

TABLE 6 Lens parameters

Parameter	Lens PMMA
Number of gates	2
Filling time (sec)	1
Packing time (sec)	4
Cooling time (sec)	11.5
Eject time (sec)	5
Maximum injection pressure (MPa)	120
Maximum packing pressure (MPa)	120
Melt temperature (°C)	320
Mold temperature (°C)	110
Air temperature (°C)	25
Eject temperature (°C)	150
Cooling fluid	Water

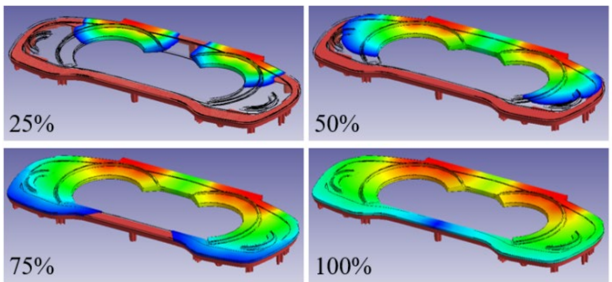

Fig. 12 Filling time

Scaled model of warpage analysis is shown in fig. 13. Tendency of shrinkage is clear.

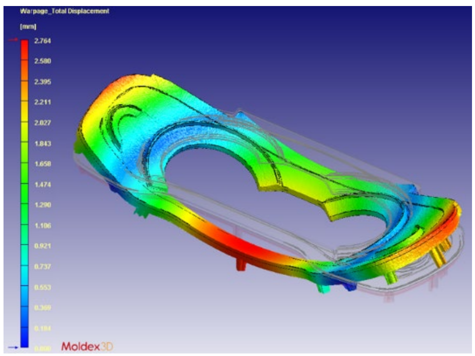

Fig. 13 Total displacement

G. Cooling time optimization – lens

Cooling time from simulation No. 1 is set 11.5 sec as default while cooling time in simulation No. 2 is set 22 sec.

TABLE 7 Lens cooling parameters

LENS	11.5 sec cooling No. 1	22 sec cooling No. 2
Average injection temperature, °C	223.013	220.297
Average cooling temperature, °C	97.430	90.976
Maximum displacement, mm	2.764	4.351

After changing the cooling time, the displacement is almost doubled. This parameter is extremely important, but if it increases too much it could lead to side effects and unnecessary prolongation of the injection cycle. This, in turn, leads to large losses due to reduced productivity.

H. Flow rate optimization – lens

Increasing the flow rate of cooling fluid is expected to cool more intense as well as lowering the warpage of the model.

TABLE 8 Flow rate lens parameters

LENS	120 cm^3/s flow rate No. 1	150 cm^3/s flow rate No. 3
Average injection temperature, °C	223.013	220.295
Average cooling temperature, °C	97.430	90.828
Maximum displacement, mm	2.764	2.290

The higher the coolant flow, the faster the part cools in the given time interval. The optimization of this parameter allows to shorten the cycle and achieve the desired indicators, even for a shorter period of time.

I. Coolant temperature optimization – lens

Coolant temperatures in the next analysis are going to be 72ºC and 90 ºC.

At values that are too low, an undesirably large difference between the temperature of the part and the fluid can occur. This can lead to too rapid cooling and excessive deformation. For this reason, it is desirable to select a suitable value precisely.

TABLE 9 Lens coolant parameters

LENS	72ºC coolant No. 3	90 ºC coolant No. 4
Average injection temperature, °C	220.295	223.621
Average cooling temperature, °C	90.828	103.952
Maximum displacement, mm	2.290	1.767

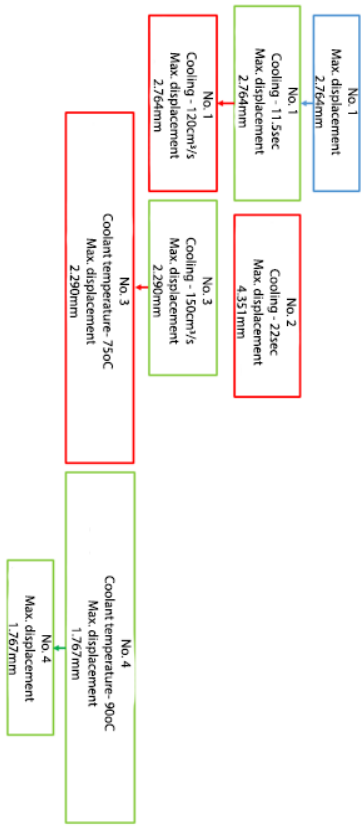

Fig. 14 Optimization stages of lens

Achieved displacement value is low enough so that the next step could be the production of the tool. It is not necessary to wait unnecessarily for the long-term and long-term optimization of the process until the maximum values are reached. It is sufficient for these values to be so low that the part can be included in a normally functioning assembled unit without compromising its functionality.

III. CONCLUSIONS

In the studies above and the results analyzed, it can be concluded that:

- Adverse results in reducing cooling time;
- Higher flow rate leads to a reduction in displacement;
- Higher coolant temperatures reduce displacement;

The achieved displacement value is low enough to start production.

IV. Acknowledgement

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