Open access Journal International Journal of Emerging Trends in Science and Technology

Pre – Destining the Quality of Plastic Parts Produced By Injection Molding Method Using Computer Simulation Techniques

Authors
Madhu Kumar K[1], Kumarswamy R[2], Nataraj M[3], Vasu M[4]
[1]Sir M. Visvesvaraya Institute of Technology, Visvesvaraya Technological University, Bengaluru-562157, Karnataka, india
Email: *Madhukumar_mech@sirmvit.edu*
[2]Sir M. Visvesvaraya Institute of Technology, Visvesvaraya Technological University, Bengaluru-562157, Karnataka, india
Email: *kmrswamy10@gmail.com*
[3]Sir M. Visvesvaraya Institute of Technology, Visvesvaraya Technological University, Bengaluru-562157, Karnataka, india
Email: *natrajmn@gmail.com*
[4]Srinivasa Institute of Technology, Visvesvaraya Technological University, Valachil- 574143, Karnataka, india
Email: *vasu.m.manu@gmail.com*

Abstract
In this paper attempt has been made to eliminate the errors during each step while designing and analysis of the component to minimize the defects during manufacturing of the component. Air filter bottom box component was selected for the study and PPTF (polypropylene talc filled) was considered as a material for this component. Initially component was modeled and modified using wildfire pro-e 3.0 software. Estimation of structural quality of the part was carried out on the basis of injection moulding computer simulation technique. Various computer simulations were carried out for different structural solutions with the support of literatures and also on the basis of instances happens in the industries. For the simulation mold flow insight 5.1 software was used. Using of computer methods to design and optimization of structural conclusions of parts, avoids rejections, rework and minimizes time, hence minimizes the production cost. Results were compared with predictions presented in professional literature. Results obtained during studies will be used during the process of injection mould. This study will help us to understand the use of simulating computer program applications in designing and initiation to production of polymer parts and also helps you to avoid potential manufacturing defects and get innovative products to market faster.
Keywords: *Model study, Basic model conversions, modeling of polymer flow, Mold flow analysis, Product design, Injection molding.*

1. Introduction

The injection moulding process involves the injection of a polymer melt into a mould, where the polymer melt, cools and solidifies to form a plastic product. The process comprises filling, packing, and cooling phases. The typical process cycle time in injection moulding machine varies from several seconds to tens of seconds depending on the part weight, part thickness, material properties and the machine settings specific to a given process. Process control of injection moulding has a direct impact on the final part quality and the economics of the process.

Polymers and its composites processed by injection molding method widespread in many branches of modern industry. Participation of fulfilled materials (composites) in products, which are destined for using not only in everyday life still increase. In that case conducting studies aim at deep came to knowing the phenomena proceeded during wide known as polymer processing, is well grounded. Often happens that error committed by constructor, in mold designing phase, decided about failure during implementation product into production [1]. This paper provides some possible solutions through injection process computer simulation to elimination of those errors. The results are important for the design and manufacturing of mould and manufacturing of component.

2. Objectives of Study

Important objective of this study is to predict and eliminate the possible errors in the final component. Some other objectives are,

- Design of component effectively, based on polymer flow issues.
- Elimination of errors during mesh
- Design of cooling system
- Flow analysis to find out the possible defects and elimination of those defects.

3. Modeling of Component

Component was designed with following dimensions: 240 mm (length), 160 mm (width), 241 mm (height) and thickness of wall is 2.5 mm. Component has a rectangular structure, one round opening at front, sleeves, bosses and ribs at sides as shown in the figure 1.

3.1 Corrections in model

This includes model study and basic model conversion as per simulation results and basic design consideration. After modeling the component flow analysis was done using simulation (Simulation details are discussed later in detail after this chapter) software to check the filling of molten polymer. As per the simulation results polymer was not filled completely for given parameters, hence component was remodeled with some slight changes. And those changes are explained below.

Figure 1 shows the solid (3D) model of component. The component has got round opening and ribs and bosses at the sides.

In the Figure 2 structural details which decide about part quality is presented. At first into simulation studies model from picture 2(a), was used. After accomplishing analysis of received results, it was observed that, at the thicker section material will not solidify uniformly and requires more injection pressure hence increases cycle time, due to this structural changes were brought in model and extra material was removed from the model shown in fig 2(b). This reduces the injection time, injection pressure and uneven solidification at thicker cross sections. Once more simulation was done and made the analysis of results.

In next steps of model modification ribs were applied, to give enough support to the sleeves to avoid deformation defects like bending etc, shown in figures Fig.2(c), and 2(d). Also holes in sleeves were deepened so that extra material in sleeves can be eliminated to achieve uniform wall thickness. Final component achieved the structure of uniform cross section.

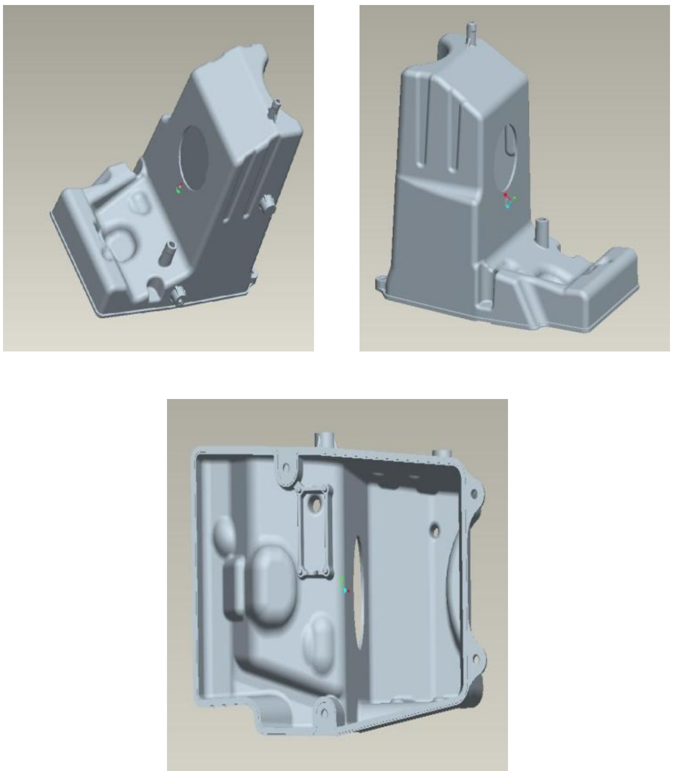

Figure 1. Solid (3D) model of the air filter bottom box (after modification).

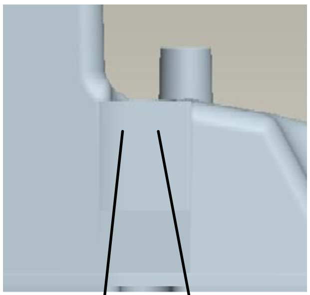

Figure 2(a). Model before modification

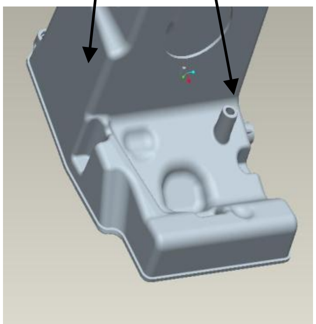

Figure 2(b). Model after removing thicker section

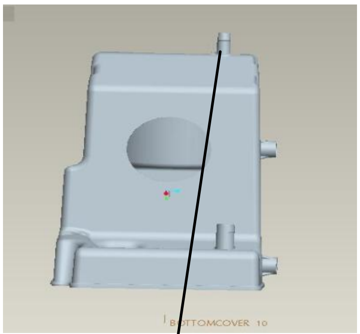

Figure 2(c). Model with no ribs

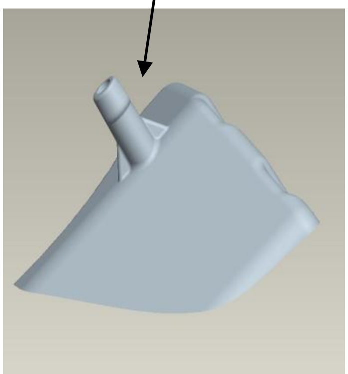

Figure 2(d). Model with ribs

3.2 Simulation

For appropriate conducting of simulation, it is necessary to insert material data which is the integral part of simulation program. Material considered for the component was polypropylene with 20% talc filled. Polypropylene with trade name LUPOL-HI-5205 was used. Weight content of talc is 20%.

3.3 Meshing of the model and problem diagnostic

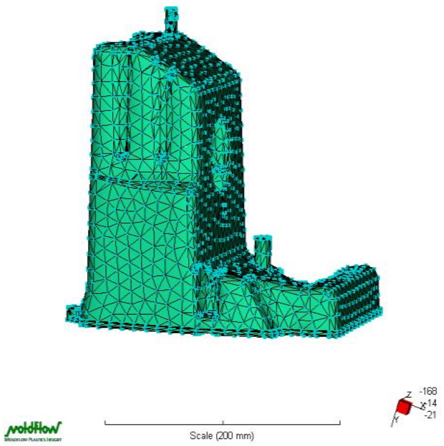

Figure 3. Meshed Model

Component was meshed by using fusion mesh and meshed model is shown in the figure 3. Mesh statistic result obtained and shown in table 1.

Table I: Mesh statistic result

Entity counts	
Surface triangles	12606
Nodes..	6295
Beams	0
Connectivity regions	1
Mesh volume	354.404 cm^3
Mesh area	2801.11 cm^2
Edge details	
Free edges	0
Manifold edges	18909
Non-manifold edges	0
Orientation details	
Elements not oriented	0
Intersection details	
Element intersections	0
Fully overlapping elements	0

Duplicate beams	0
Surface triangle aspect ratio	
Minimum aspect ratio	1.163198
Maximum aspect ratio	58.423441
Average aspect ratio	4.092084
Match ratio	
Match ratio	87.2%
Reciprocal ratio	72.1%

From the above results it concludes that there are no free edges, no overlapping elements but maximum aspect ratio is very small, hence it will affect the final results. In order to overcome this, aspect ratio diagnostic method is used. Poor aspect ratio is shown in figures 4.

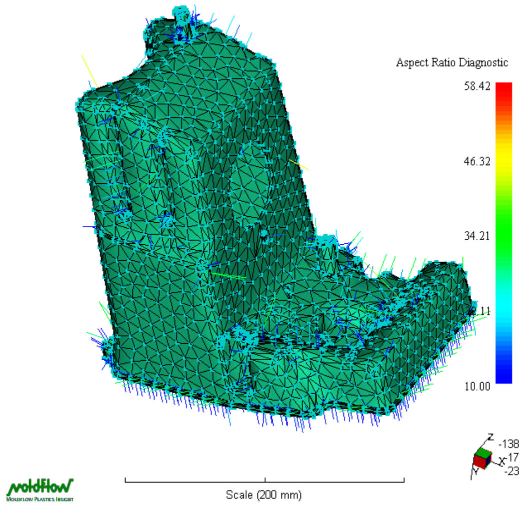

Figure 4. Poor aspect ratio

Set the Minimum aspect ratio to 8 and the Maximum to 15. By doing so, you will place any aspect ratios elements between 8 and 15 into one visible layer, making the problem elements easy to find. After analysis, problematic element will appear in red color as shown in figure 5. And remaining elements will be in light blue. This problem can be eliminated by using aspect ratio diagnostic method in mould flow software. Following result shows the aspect ratios after diagnostic.

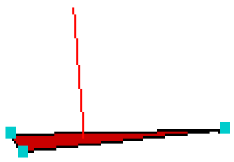

Figure 5. Problematic Element

Table II: Aspect Ratio After Analysis.

Surface triangle aspect ratio	
Minimum aspect ratio	1.163198
Maximum aspect ratio	75.267090
Average aspect ratio	4.092084

From the above result it is noticed that maximum aspect ratio has been increased from 58.423441 to 75.267090. Hence one error is removed from model.

Model after problem diagnostic is shown in the figure 6.

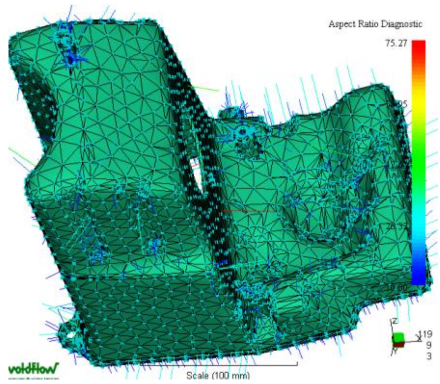

Figure 6. Fixed aspect ratio

3.4 Creating cooling circuit and flow modeling

Figure 7 shows FEM model with cooling circuits and gate arrangement.

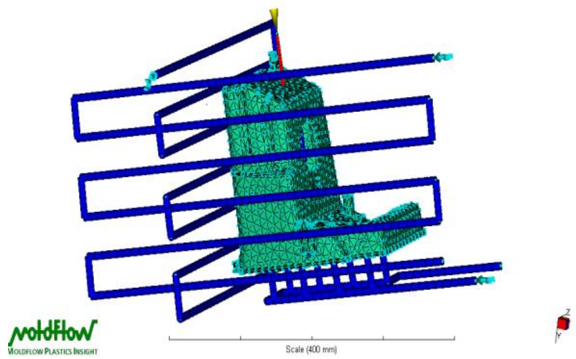

Figure 7.Fem model with cooling circuit

In this step cooling channel was created with channel diameter of 8mm for outside of the component and 10mm diameter for inner channels and 14mm diameter for baffle channels. And hot runner direct sprue system is used for this component in order to minimize the sprue packing, and to improve the flow characteristics. Gate was designed with 5mm (smaller end diameter) and 10mm (larger end diameter) dimension (tapered) shown in the figure 8.

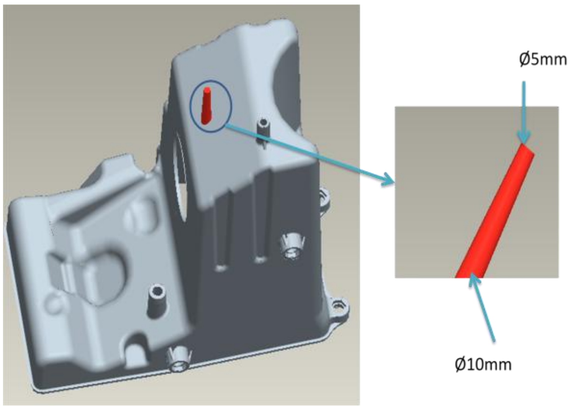

Figure 8. Gate system (hot runner direct sprue type)

3.5 Analysis

This is the most important step to determine the various processing parameters for injection molding includes, determining optimum process parameters and validating the gate design for Fill, Pack, Cool and Warpage. After analysis results obtained are scrutinize and discussed below.

Figures 9 and 10 are Shear Rate Vs Viscosity and Pressure-Volume-Temperature diagrams. Shear rate plot shows that when the shear rate is increased, the material flows easily. Increasing shear rate by gate dimensions and injection rate can help material to flow easily.

PVT graph indicates that below 140° C melt temperature, packing pressure would not have much impact on shrinkage. Figure 8 indicates the clamp tonnage required. From the result it concludes that Maximum clamp tonnage required is 176 tonnes.

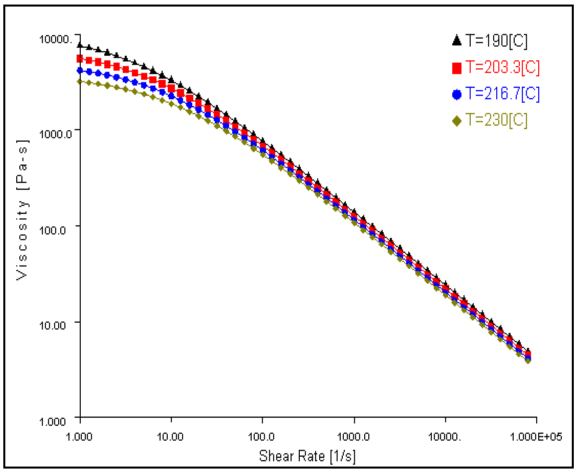

Figure 9. Shear Rate Vs Viscosity

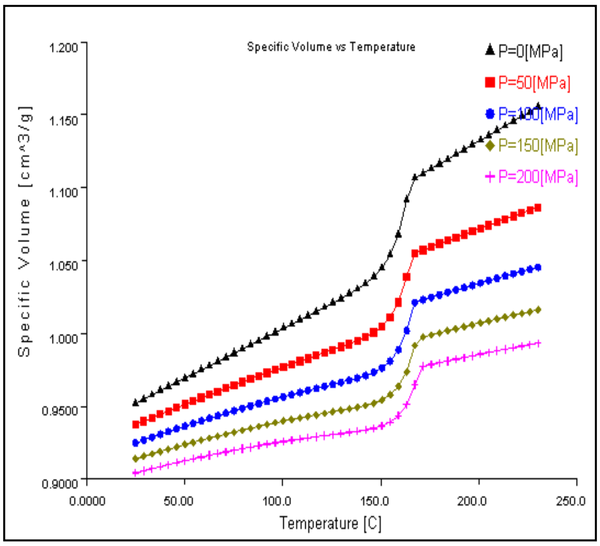

Figure 10. PVT diagram

Figure 11 Shows the fill analysis, Part is filling completely in 12.41 seconds with flow rate of 40 CC/sec and within the specified injection time of 10sec. The flow seems to be balanced and no flow related problems observed in the component. No hesitation effects were observed.

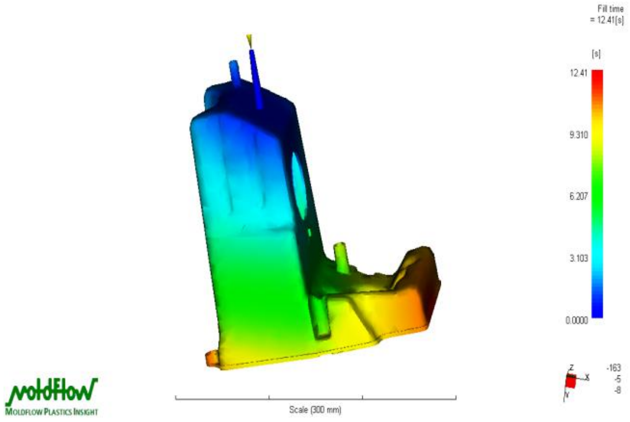

Figure 11. Fill time diagram

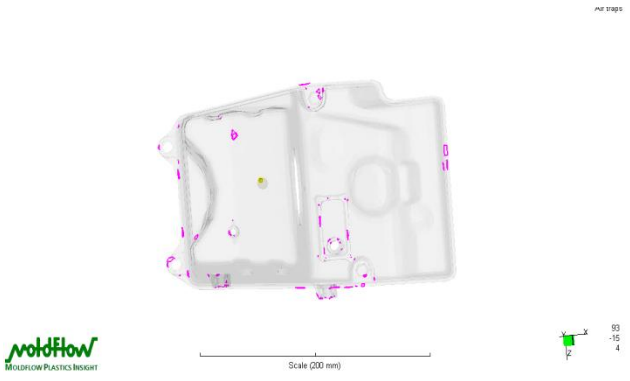

Figure 12. Air traps

There are no air-traps found at the surface but air-traps at the bosses needs to be vented out by providing air-vents, otherwise it will lead to short shot or burn marks onto the component. Air traps are shown in figure 12.

Figure 13 shows temperature flow front for the component. Rise in temperature observed is up to 0.7^{o} C due to shear heating and drop in temperature was observed up to 1^{o} C. Melt temperature is 210^{o}C, Therefore the flow front temperature range is within the acceptable limit.

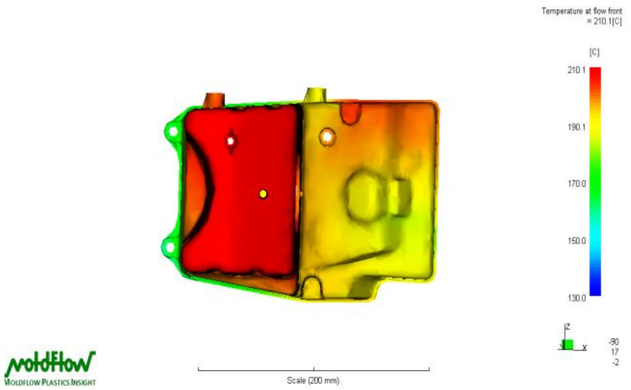

Figure 13. Temperature flow front plot

Figure 14 shows weld lines found during analysis. The temperature when weldlines formed is high (210°C), hence the weld strength will be good and area near the weldline will be structurally strong. Max sink marks depth observed is 4.68 mm which is in the thick walled area. It is also observed that thickness of the bosses are greater than the nominal wall thickness which will lead to very heavy sink marks on outer side of the component.

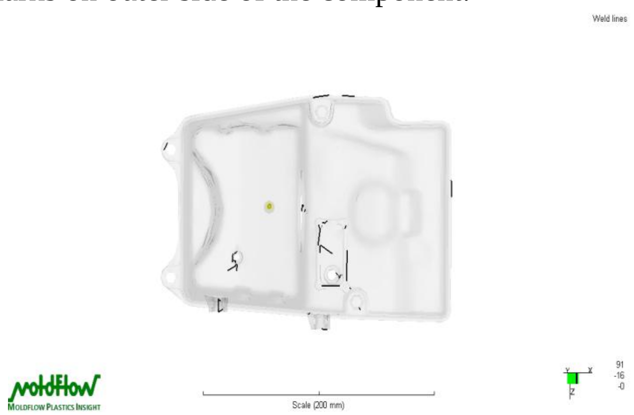

Figure 14.Weld lines

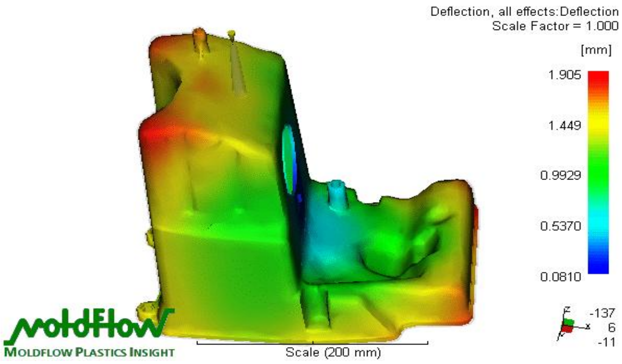

Figure 15. Warpage analysis (deflection)

Deflection pattern is scaled 1 times to understand the shape of the component after deflection. Maximum Deflection due to all Effects is 1.9 mm. Deflection observed in X- direction is (+1.3mm, -1.65mm). Deflection observed in Y- direction is (+1.4mm, -1.075mm). Deflection observed in Z-direction is (+1.23 mm, -0.98 mm). The calculated deflection value may not be the same as actual conditions. However, warpage results can be used to understand the deflection pattern of the component.

4. Results

Results obtained after the analysis are presented in following table.

Table III: Analysis results

Process settings	
Machine parameters	
Maximum machine clamp force	7.0002E+03 tonne
Maximum injection pressure	1.8000E+02 MPa
Maximum machine injection rate	5.0000E+03 cm³/s
Machine hydraulic response time	1.0000E-02 s
Process parameters	
Fill time	12.4s
Flow rate	40 cc/s
Cooling time	20.0s
Packing/holding time	10.0 s
Ambient temperature	25.00 c
Melt temperature	210.00 c
Ideal cavity-side mold temperature	55.00 c
Ideal core-side mold temperature	55.00 c
Volume to be filled	354.4040 cm³
Total part weight	353.7680 ....

5. Conclusions

From Simulation investigations it concludes that specialize computer programs make prediction of specific phenomena appearing for particular process possible. It means that in product designing phase we can predict and optimal the generation process. Optimal results have confirmed the literature prediction and cases met in industrial practice. Totally by using application of professional computer programs to injection molding process make possible to eliminate series of structural errors during designing and helps to minimize the component trial outs during mould proving hence minimizes rejections, rework, time, cost and required quality of parts can be achieved.

References

1. J. Nabialek , J. Koszkul, A. Gnatowski, Expectation of the parts quality on the ground the simulation of the injection moulding process, Archives of Materials Science and Engineering, Volume 32, Issue 2, August 2008, Pages 109-112.
2. R.Y.Chang and W.H.Yang, Three-dimensional computing-aided mold cooling design for injection molding, 740, ANTEC 2001, Dallas (2002).
3. Yi-Hui Peng, David C.Hsu and Venny Yang CoreTech System Co.,Ltd., The warpage simulation with in mold constraint effect in injecttion molding, HsinChu, Taiwan 300, ROC.
4. E. Bociga, T. Jaruga, K. Lubczyñska, A. Gnatowski, Warpage of injection moulded parts as the result of mould temperature difference, Department of Polymer Processing and Production Management, Czestochowa University of Technology, Al. Armii Krajowej 19c, 42-200 Czêstochowa, Poland. E-mail: jaruga@kpts.pcz.czest.pl.
5. Gašper Gantar, Andrej Glojek, Mitja Mori, Blaž Nardin, Mihael Sekavčnik, Resource Efficient Injection Moulding with Low Environmental Impacts, Journal of Mechanical Engineering 59(2013)3, 193-200, DOI:10.5545/sv-jme.2012.661, 2012.
6. E. Bociga, T. Jaruga, Experimental investigation of polymer flow in injection mould, Institute of Polymer Processing and Production Management, Al. Armii Krajowej 19c 42-200 Czêtochowa, Poland, E-mail address: jaruga@kpts.pcz.czest.pl.
7. J. Nabiałek, J. Koszkul, The polymer flow in a mold cavity during the injection molding process. Comparison of an experiment and computer simulations , Department of Polymers Processing and Production Management, Technical University of Czstochowa, Al. Armii Krajowej 19C, 42-200 Czstochowa, Poland.
8. D. Mathivanan, M. Nouby, R. Vidhya, Minimization of sink mark defects in injection molding process Taguchi approach, International Journal of Engineering, Science and Technology,Vol. 2, No. 2, 2010, pp. 13-22.