Open Journal of Applied Sciences, 2025, 15(3), 619-626
https://www.scirp.org/journal/ojapps
ISSN Online: 2165-3925
ISSN Print: 2165-3917

Study on Flow and Warpage of Windshield Complex Parts Based on Moldflow

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How to cite this paper: Zuo, J.H., Wang, L., Liu, L.L., Li, S. and Peng, M. (2025) Study on Flow and Warpage of Windshield Complex Parts Based on Moldflow. *Open Journal of Applied Sciences*, **15**, 619-626.
https://doi.org/10.4236/ojapps.2025.153040

Received: February 19, 2025
Accepted: March 15, 2025
Published: March 18, 2025

Abstract

It is difficult to form the inner windshield plastic parts, using Moldflow software on the flow analysis of plastic parts, and designing different input plans; the analysis shows that although the four-gate injection pressure has severe fever but the preparation temperature and the number of fusion traces satisfy Functional requirements; and warped analysis results indicate that X-direction, Y, Z, and Z to warpage deformation values are within the tolerance requirements of the plastic parts.

Keywords

Special-Shaped Parts, Moldflow Software, Gate Position, Flow Analysis, Warpage Analysis

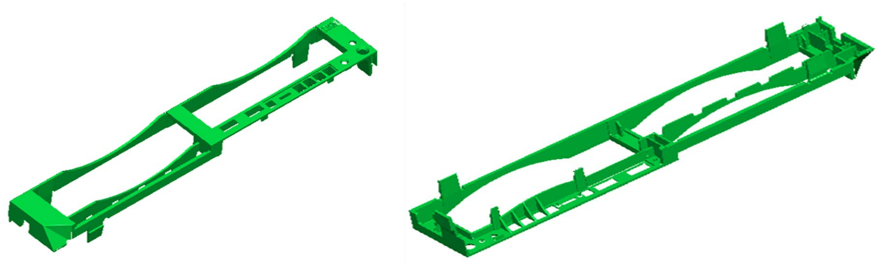
1. Introduction

Plastics are more and more widely used in home appliances, auto parts, aircraft parts, electronic products and other fields, and the injection molding technology of plastic products is a difficult problem for mold design engineers, plastic product engineers, and injection molding technicians, especially the design and molding of heterogeneous parts such as windshields in high-speed trains. Moldflow is a plastic product simulation and analysis software, which can assist mold designers in mold design, plastic product engineers in optimizing product design schemes, and injection molding technicians to debug injection molding machine parameters. The software simulates flash, weld marks and injection pressure in the molding of plastic parts, warpage deformation, etc. [1]-[7]. The mold design engineer can continuously adjust the parameters such as runner, gate shape, gate position and so on on the software; Product designers optimize the design of products through software; The injection molding machine molding technician can continuously correct various parameters of the injection molding machine on the software, which can reduce product waste, shorten the product molding cycle, and improve production efficiency [8]-[10]. In this paper, Moldflow software is used to design the gate selection of a complex heterosexual plastic part.

2. Plastic Part Analysis

This product is an inner buckle plate of the windshield in the train, and the display in the three-dimensional software is more complex (as shown in **Figure 1**). The main dimensions are 1874 × 44 × 16, there are many through holes, and the maximum thickness of the wall thickness of the gusset is uneven, and the maximum thickness is about 4 mm (at the hook of the gusset plate).

The small thickness is 1.5 mm, with a thin-walled characteristic structure, the material selection is PC + ABS, the color is white, the appearance of the product is not high, and the assembly tolerance MT5 is not very high.



(a) Heads (b) Tails

Figure 1. Outline diagram of the inner gusset.

3. Gate Location Analysis of Plastic Parts

3.1. Meshing and Cavity Layout

The structure of the plastic part is a thin-walled part, the surface mesh is divided by hypermesh, the edge length of the grid is set to 1mm, the network aspect ratio is less than 6 after repair, there is no free edge and overlapping overlapping edge, the structure of the plastic part is complex and the thickness is inconsistent, the preliminary consideration is that it is two molds, one mold and one hole.

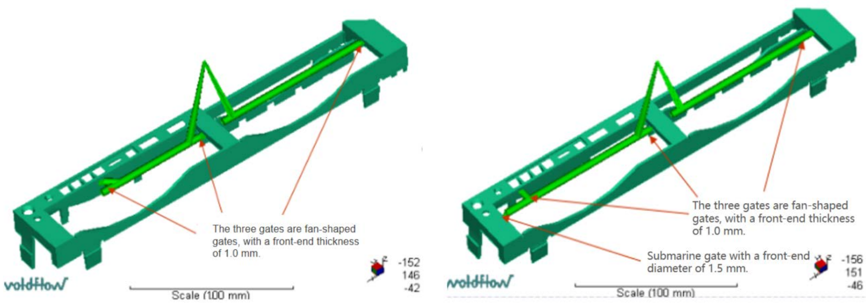
3.2. Gate Type Selection

From the analysis of product properties, there are two schemes, one scheme adopts 3 gates, and the gate type adopts a sector gate, see **Figure 2(a)**; In another scheme 4 gate, one gate takes a latent gate and the other gate takes a fan gate, see **Figure 2(b)**.

3.3. Analysis of Gate Feeding of Plastic Parts

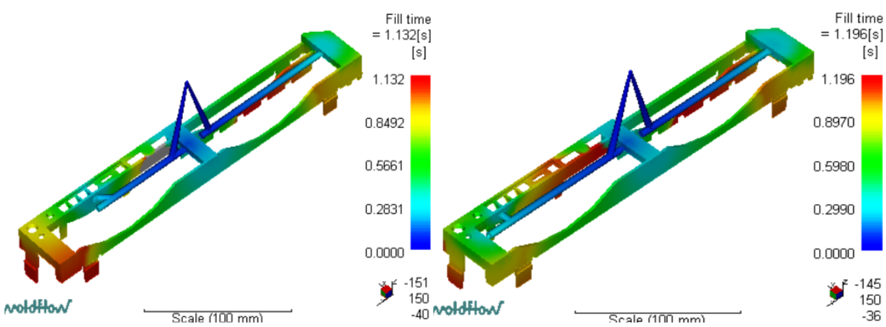
Filling Analysis and Comparison

The three-gate pouring is shown in **Figure 3(a)**, the filling time is 1.13 seconds, and the wall thickness is only 0.5 - 0.6 mm at the place close to the gate position, and the plastic fluid flows to this position with too much resistance and stagnates, which hinders the flow of the plastic fluid, so the short shot phenomenon occurs; Figure 3(b) for 4 gates shows that the filling time is 1.2 seconds, and the stagnation may occur for the same reason at the position of the four gates. Considering the use of a four-gate scheme, the following is a filling and warpage analysis of the four-gate scheme.



(a) Three gate pouring (b) Four gate pouring

Figure 2. Plastic part gate filling analysis.



(a) Three gate pouring (b) Four gate pouring

Figure 3. Filling flow analysis.

4. Flow Analysis of Four-Gate Filling

4.1. Injection Pressure Analysis

Figure 4 shows that 90% of the four-gate injection speed/pressure switching plastic parts are filled through the speed, and the remaining two gray parts need 107 (MPa) pressure to fill at 1.3 s, which requires an injection molding machine with a large cavity, which will cause serious product flash.

4.2. Injection Wavefront Distribution

From the temperature distribution of the injection wavefront in Figure 5, it can be seen that most of the filling temperatures are relatively uniform in the filling process, but the wavefront temperature of the plastic parts in the frame shown in the figure drops sharply, resulting in stagnation, and the fluid plastic parts at 2 and 3 places in the frame can be filled to 1 place in the frame in time to avoid short emission of the plastic parts.

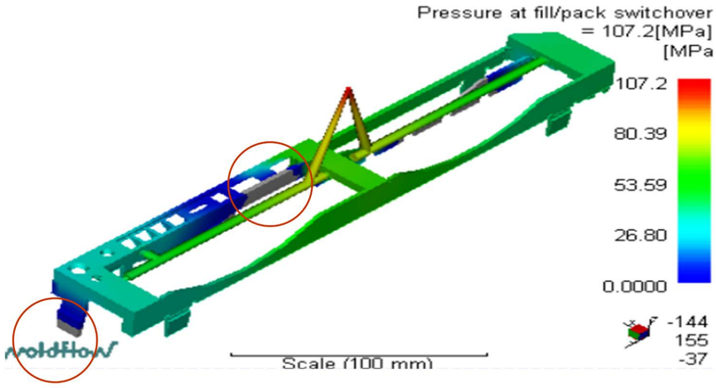


Figure 4. Gate injection speed/pressure switching pressure.

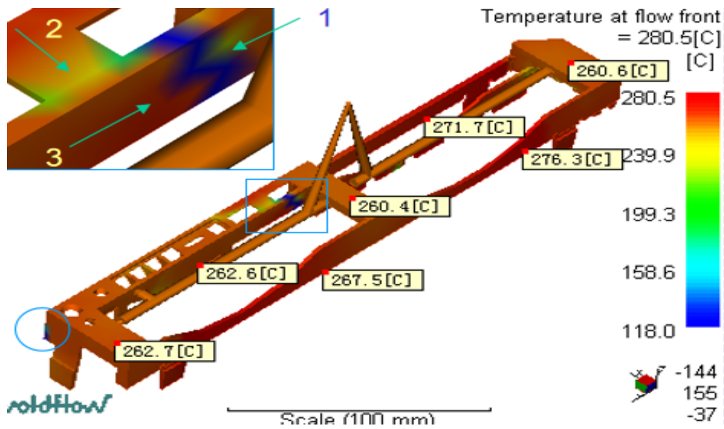


Figure 5. Injection wavefront temperature distribution.

4.3. Weld Mark Analysis

The weld mark in the weld mark frame shown in **Figure 6** obviously affects the appearance of the plastic part, but the welding temperature of the weld mark in the frame is high and does not affect the strength of the plastic part, and the plastic part does not have high requirements for appearance, so the weld mark is acceptable.

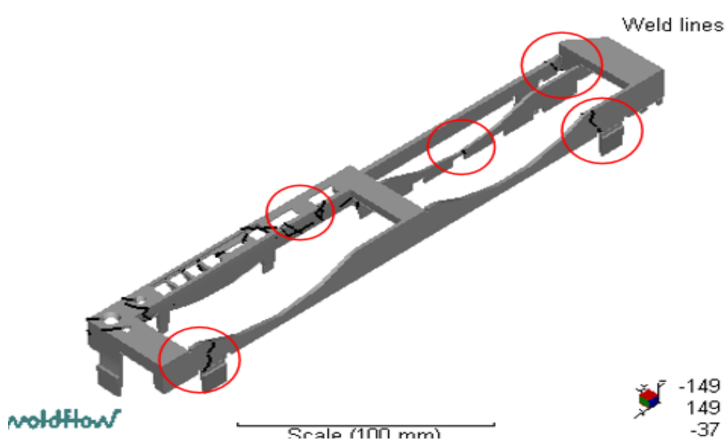


Figure 6. Gate injection weld marks.

5. Four-Gate Cooling Warpage Analysis

5.1. Waterway Layout

The layout of the waterway is shown in **Figure 7**, the upper master mold is designed with two waterways with a diameter of 10 mm, and the lower male mold is designed with four waterways directly of 9.5 mm (the baffle is designed to be directly 12 mm).

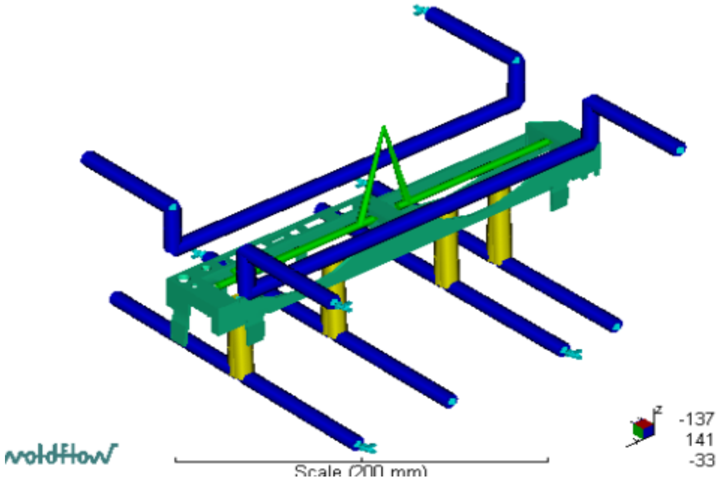


Figure 7. Layout design of plastic parts waterway.

5.2. Cooling Water Variation

The cooling water changes as shown in **Figure 8**, the 8 water channels are not connected in series, the water temperature rise changes slightly, and the water channel design meets the cooling requirements during molding.

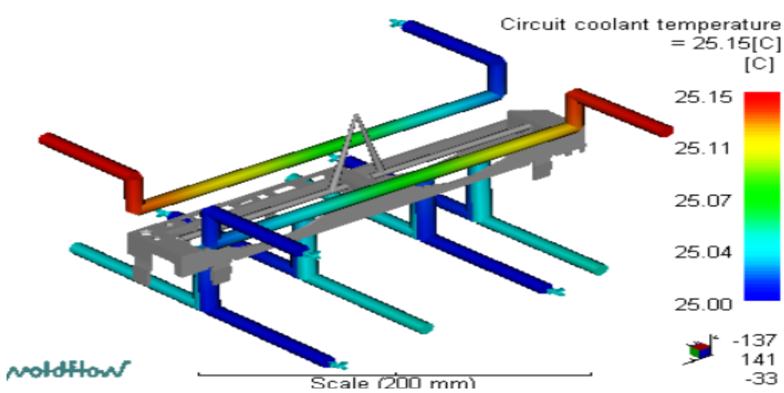
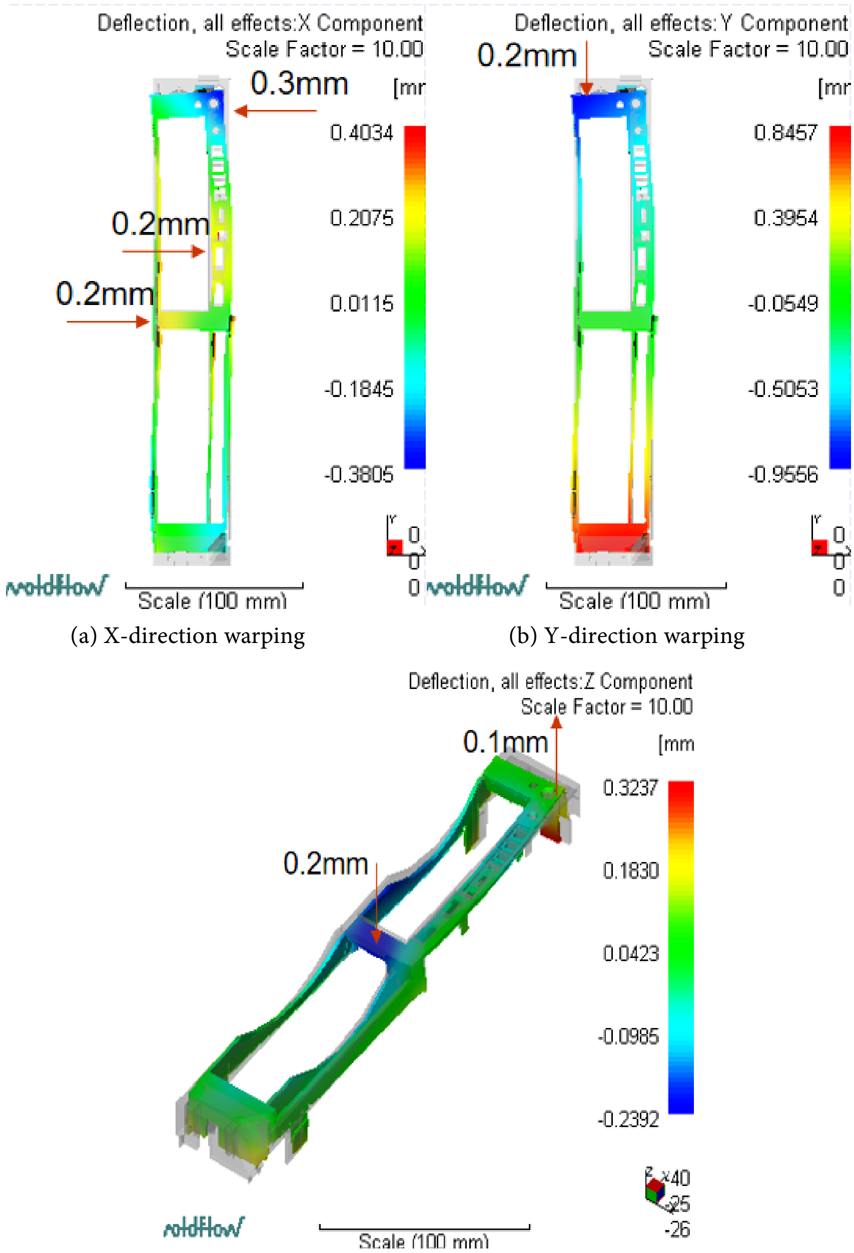


Figure 8. Cooling water variation.

5.3. Warpage Analysis

Figure 9 shows that the total warpage deformation value in the X direction is 0.7839 mm, the end deformation is 0.3 mm, and the gusset deformation is 0.2 mm, the total warpage deformation value in the Y direction is 1.8013 mm, the end deformation is 0.2 mm, and the total warpage deformation value in the Z direction is 0.5629 mm, the end deformation is 0.1 mm, and the intermediate shrinkage deformation is 0.2 mm. The deformation in the three directions is not large, and the product does not have high requirements for appearance, which can meet the assembly tolerance 5MT assembly requirements.



(a) X-direction warping (b) Y-direction warping

(c) Z-direction warping

Figure 9. Warpage analysis.

6. Summary

1) The plastic parts are thin-walled parts with complex structures and different thicknesses, all of which do not have high requirements for appearance, meet the basic assembly function, and consider the cost of designing two molds, one mold

and one hole.

2) The three-gate scheme and the four-gate scheme were designed, and it was found that the three-gate pouring was prone to short injection, which affected the functional requirements of the plastic parts.

3) The analysis of the results of Moldflow for the four-gate feeding of plastic parts shows that this product needs an injection molding machine with a large cavity, the flash is more serious, the wavefront temperature is reasonable, the product does not have high requirements for appearance, and the weld marks are acceptable.

4) After the waterway design of the product, the warpage analysis of the product was carried out. The total warpage deformation value in the X direction is 0.7839 mm, the total warpage deformation value in the Y direction is 1.8013 mm, and the total warpage deformation value in the Z direction is 0.5629 mm, and the deformation amount is within the tolerance requirements of the plastic parts.

5) The designed scheme is suitable for small batch production. Assuming mass production, it is recommended to design a three-plate mold scheme.

Funds

Hunan Provincial Department of Education (23C0810 high-speed train through the rubber inner windshield injection mold design and injection parameter optimization research).

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Zuo, J.H. and Liu, L.L. (2021) Research on the Optimal Gate of the Bottom Cap of AC Contactor Based on Moldflow. *Plastics Industry*, **1**, 85-88.

[2] Dangayach, G.S. and Guglani, L. (2015) Application of Moldflow and Taguchi Technique in Improving the Productivity of Injection Moulded Energy Meter Base. *International Journal of Process Management and Benchmarking*, **5**, 375-385. https://doi.org/10.1504/IJPMB.2015.070820

[3] Li, Q., Zhu, J.F. and Jiang, Y. (2004) Mold Construction and Manufacturing. Tsinghua University Press.

[4] Wang, B. (2015) Application of Moldflow Analysis in Injection Molding Process. *Journal of Plastics Science and Technology*, **43**, 75-78.

[5] Qin, X. and Su, X.P. (2018) Design and Optimization of Injection Mold for PLC Housing Cover Based on Moldflow. *Plastics Science and Technology*, **46**, 115-120.

[6] Zhong, L. and Chen, G. (2015) Chemical Research and Design Institute Co., Ltd., Editorial Department of Plastics Industry, 2013-2014 World Plastics Industry Progress. *Plastics Industry*, **43**, 1-40.

[7] Wang, J.H. and He, B.Q. (2016) CAE Analysis of Gating System Scheme of Scanker Kit Based on Moldflow. *Plastics*, **45**, 79-85.

[8] Zhao, M.J. (2008) Flow Analysis of Injection Molding of Safety Belt Cover Bracket Based on Moldflow. *China Plastics Industry*, **36**, 28-31.

[9] Zeng, X.S. and Lin, Q.Q. (2011) Application of Moldflow in Gate Location Selection. *Mould Technology*, No. 2, 54-58.

[10] Han, Z.G. and Duan, X.Y. (2017) Optimal Design of Gate Position of Instrument Front Shell Based on Mold Flow. *Mold Manufacturing*, **17**, 42-44.