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Improving Product Design and Injection Molding for Children's Toy Plastic with the Help of CAE Software

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Abstract. CAE is the abbreviation for Computer-Aided Engineering. Taking advantage of the computer's ability to analyze and calculate accurately and quickly, to understand the theoretical model of the system (Theoretical Model), and at the same time combine the computer graphics function (Computer Graphics), helping users obtain rapid analysis results, and use the results to modify design and injection molding parameter optimization.

CAE combines graphics, computer-aided design (Computer-Aided Design/Draft, CAD) and computer-aided manufacturing (CAM). Due to the reliability of CAE results, it is possible to point out potential problems in the injection molding process and design, suggest design modifications and directions to overcome obstacles and feasible solutions, which can avoid blind spots.

CAE at the design stage can be performed on computers to evaluate and optimize design modification options, contribute to reducing time and cost, mold testing, actual mold repair, shortening the actual trial and error cycle, shortening product development time (Product Development Time) and time to market (Time-to-Market), reducing waste and time; time and money in the stages. It can help injection molders predict and understand injection molding parameters that affect product quality, find processing windows and optimize injection molding parameters. It can also indicate the main factors affecting injection molding quality, thereby providing design modification parameters, injection molding parameters and quantitative indicators. It can open the "black box" of injection molding, with a vivid and specific method of displaying machining and design parameters for status sequences and product quality effects, which can help users get quickly accumulated experience in design and injection molding, with relatively large help in employee training.

Key words: CAE, CAD, injection molding, optimization, quantitative indicators

Introduction

Analyzing the process flow in the injection molding process can help detect unreasonable points early in the product design process, code design as well as make useful predictions about the product or optimize injection molding conditions. However, for many reasons, this job is still not important in Vietnam and most of our engineers rely heavily on experience. I'm not saying experience is not important, but when products have increasingly shorter life cycles, higher complexity and increasingly fiercer competition, relying on experience alone is not enough.

If you work in the field of mold design and plastic product manufacturing using injection molding technology, you have certainly encountered the following problems:

- The customer requested a preliminary flow analysis before designing the mold.
- Assume that the product design is not good and you can improve it.
- Doubts about the balance of flow or the optimality of the plastic channel system.
- There are many cooling options, but I don't know which one is more effective.
- The pressed product is defective but I don't know what is the main reason.

With many years of experience providing flow analysis solutions on Moldex3D software for many large businesses, I am confident to bring you analysis solutions that fully meet your requirements. include Analyze and evaluate the technological capabilities of the product (structure, thickness, materials) Analyze and simulate the entire pressing process to find reasonable mold design solutions Analyze product defects based on mold data and pressing technology parameters to improve molds.

Method and Results

Product Shape and Size

Product name: Children's toy product.

Requirements: products require compatibility in terms of accuracy, tolerance and impact. Plastic materials are safe for users.

Aesthetics: limit defects (weld lines, plastic burns, not fully filling the product...) avoid injection port marks and push pin marks on the front and back surfaces of the product.

Product Material, Mass and Volume

Material code EXTRAL. CMU 201 Manufacturer: EXXONMOBIL. Density: D = 1.05 g/cc.

Hot temperature: Max = 270°C, min = 190°C, average = 230°C.

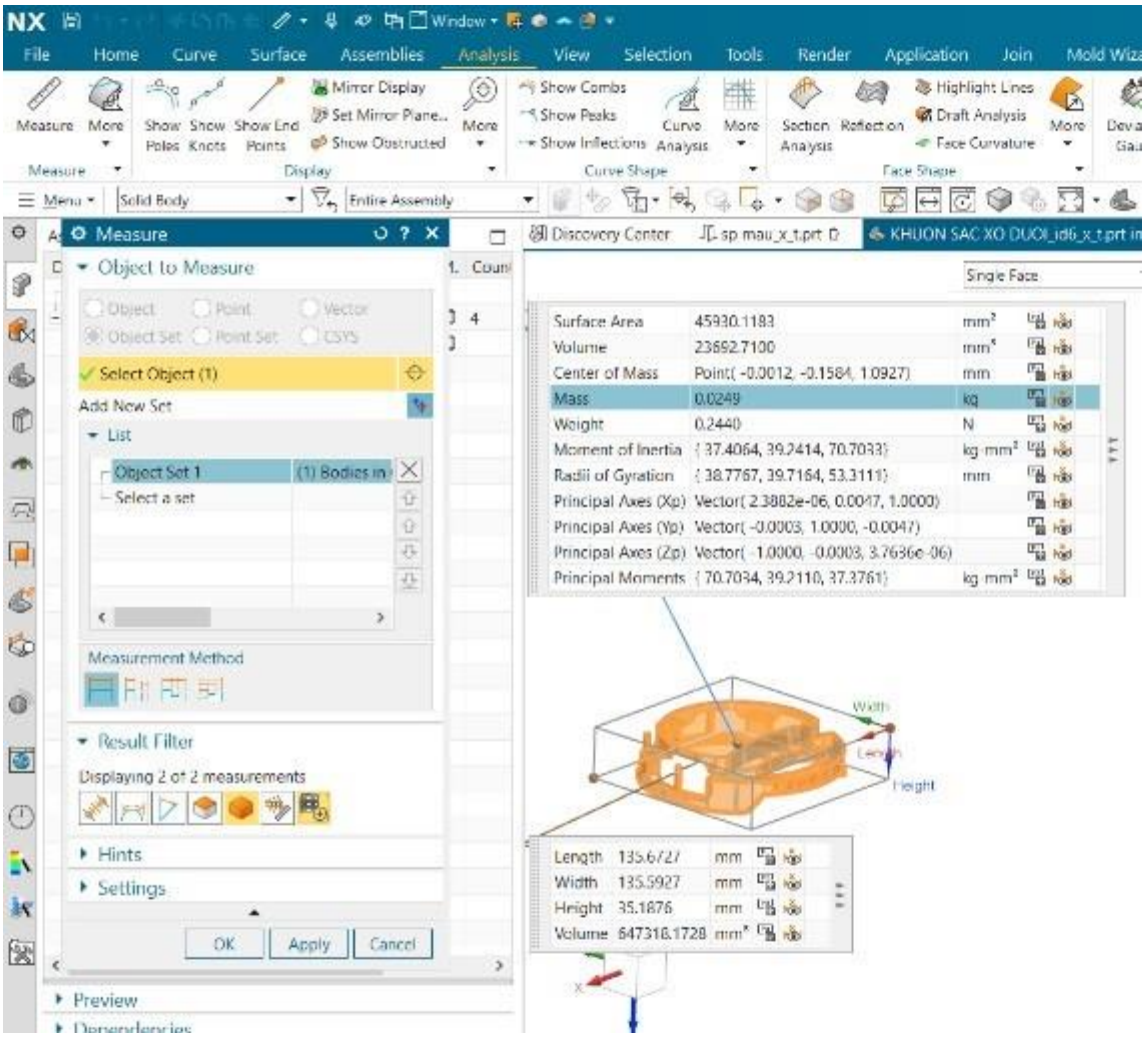

Figure 1. Dimensions of product

Product volume: 647318.1728 mm^3

Product weight is: 24.67g

Product Thickness

The maximun thickness of the product is: 4.056 mm. The minimum thickness of the product is: 0.169 mm.

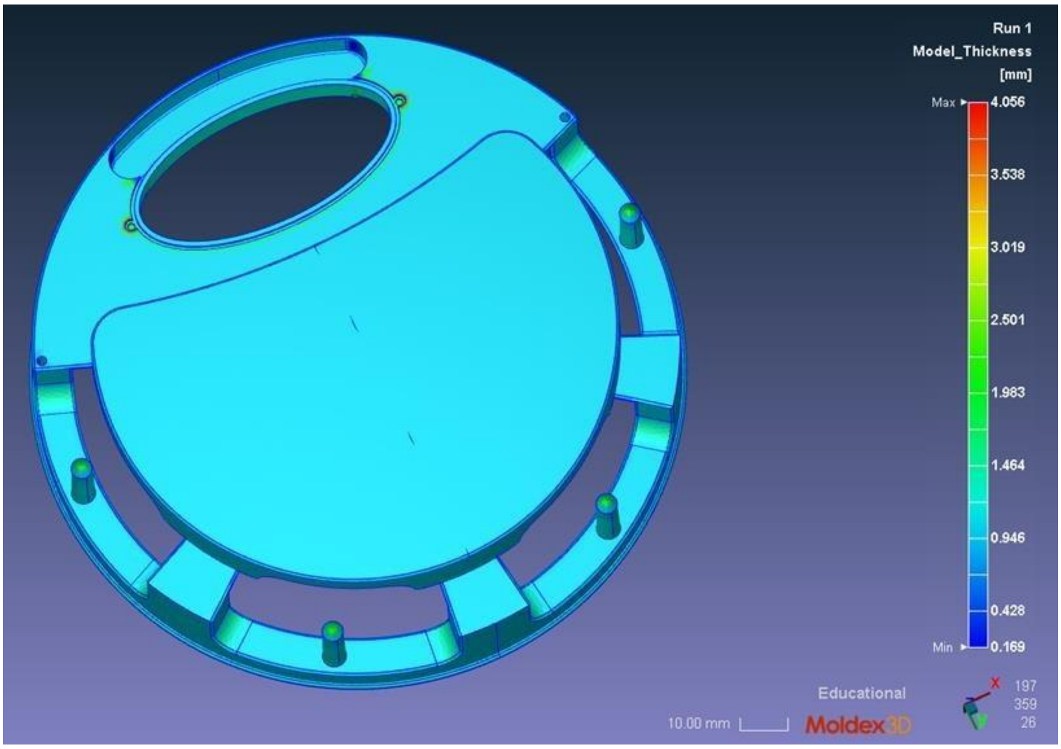

Figure 2. Check product thickness

CAE finds the best plastic injection port location

Injection port location suggested by the software:

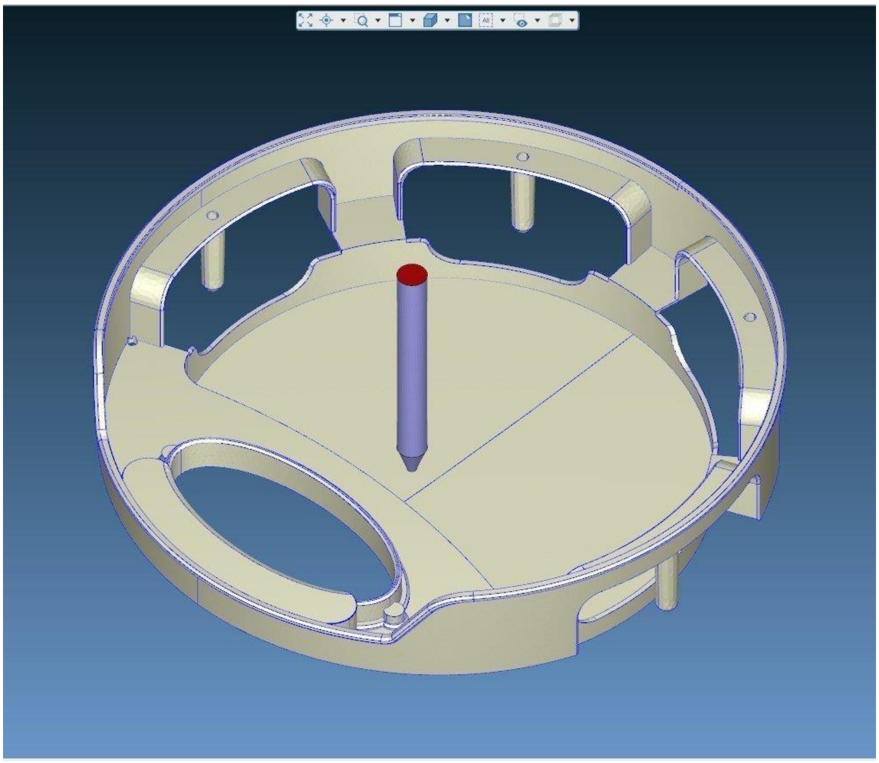

Figure 3. Suggestions of the injection stem selection software

To keep the spray port balanced and ensure uniform filling, we choose the spray port position as shown:

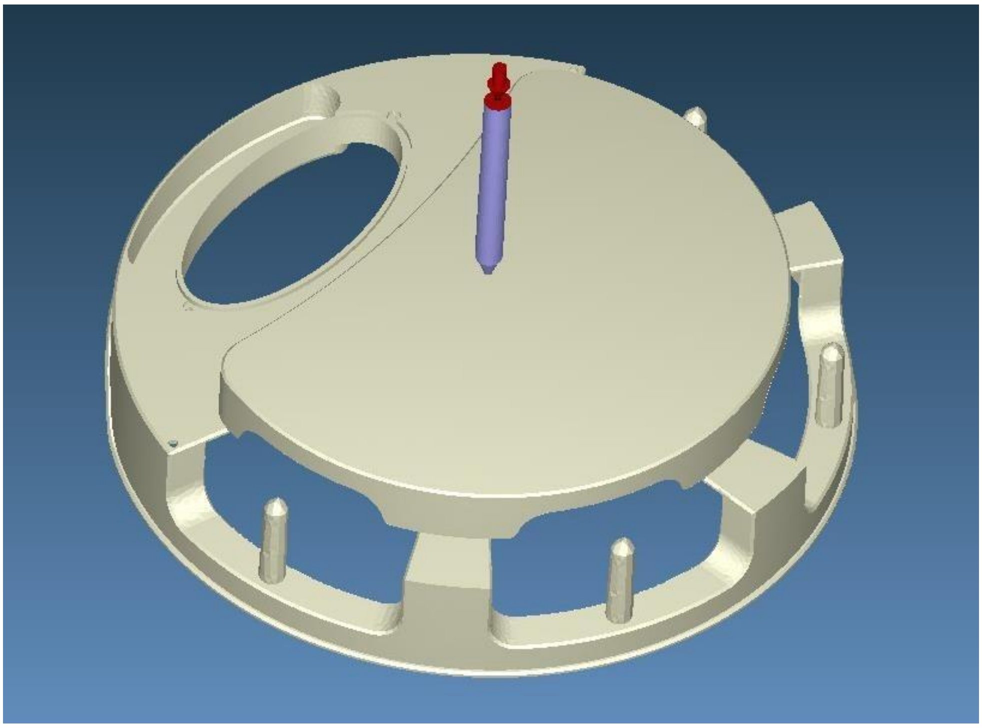

Figure 4. Reselect the nozzle position

Select the spray port location and CAE to check the weld line and the location of air bubble concentration

Weld Line

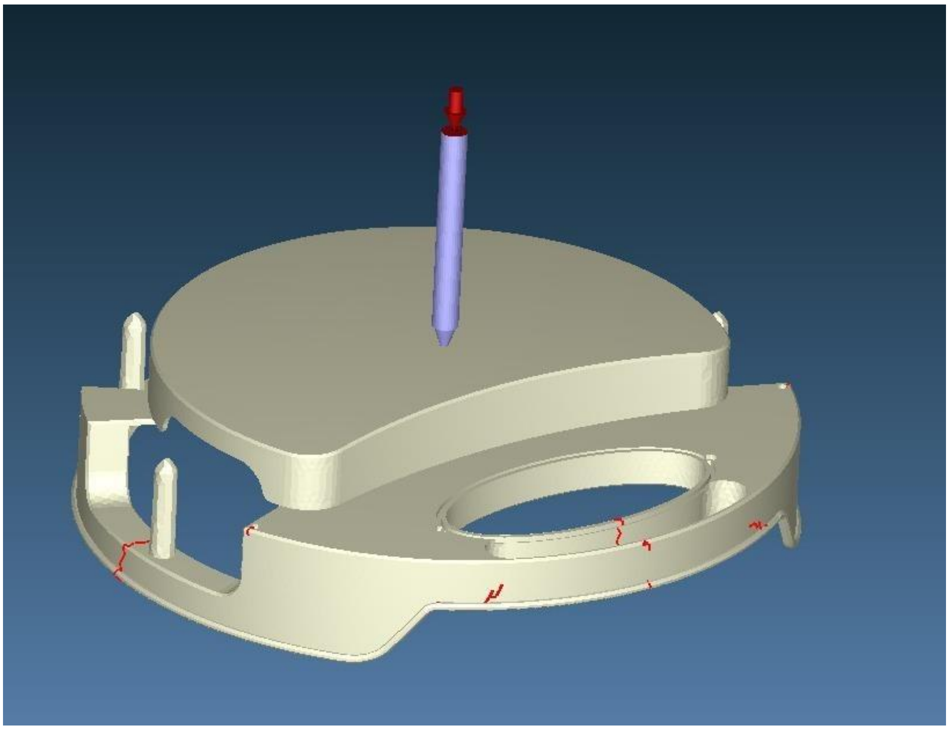

Figure 5. Image of weld line on the front product

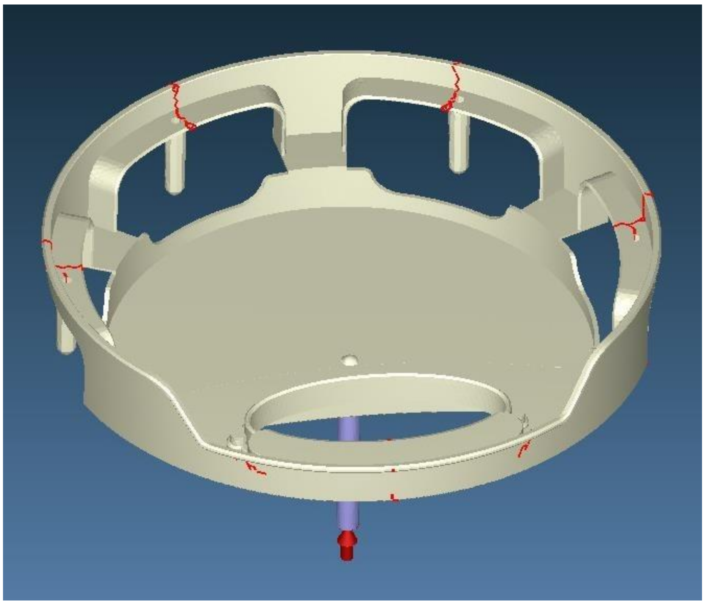

Figure 6. Image of weld line on the back product

The weld line location is mainly on the protruding lugs and hole edges of the product, not having much effect on the surface of the product.

Causes: Where the currents meet; The air has no place to escape; Injection pressure is not enough.

Remedies:

- Increase mold temperature and plastic temperature.
- Increase injection speed and injection pressure.
- Check the mold's air release system or add additional air release slots.
- Use materials with low viscosity.
- Increase the injection port diameter.

Air Bubbles

Simulation results of air bubble position:

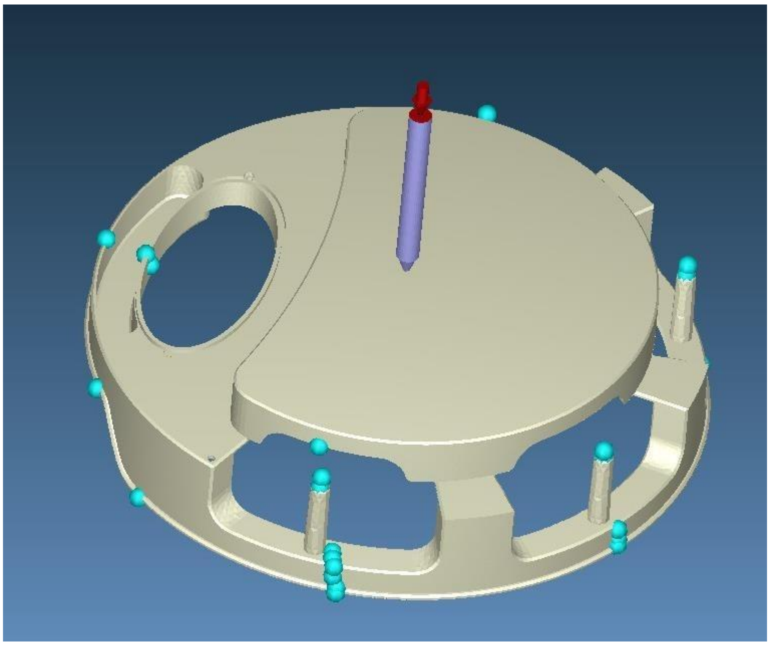

Figure 7. Image of air bubbles on the front product

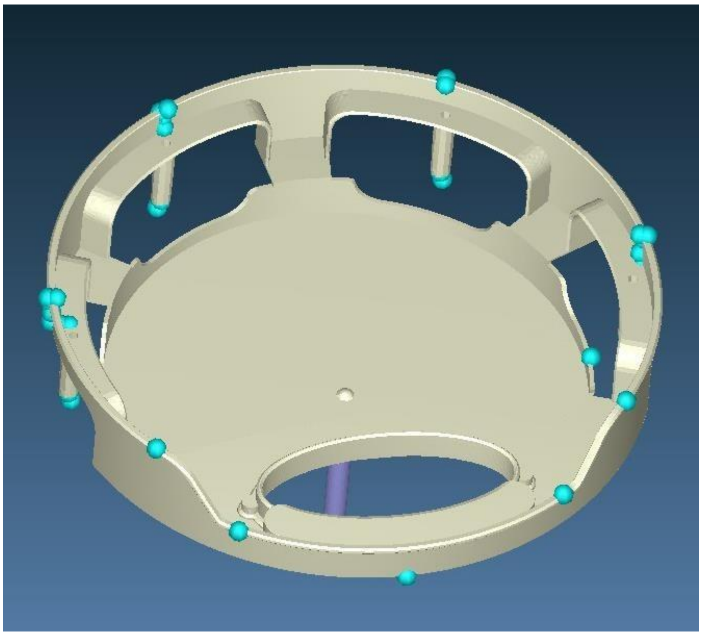

Figure 8. Image of air bubbles on the back product

Air bubbles are relatively abundant in the product, but they are mostly concentrated on the edges, ribs and edges of the product's holes, and very little on the product surface.

Reason - The product has a thin thickness - Raw materials have high moisture content but must not be dried before pressing. - The position of the injection ports creates a concentrated flow, leading to air being concentrated in one place. - Spray stem, plastic channel, and plastic entrance port have degrees. Other remedies - Product design has a more suitable thickness. - Make sure the plastic has been dried before being put into production. - Change injection port position - Reduce the spray speed, because when spraying at high speed, air bubbles cannot escape.

Plastic Channel

Choose a direct nozzle so there will be no channel system. The spray stub contact position with the part wall is as selected.

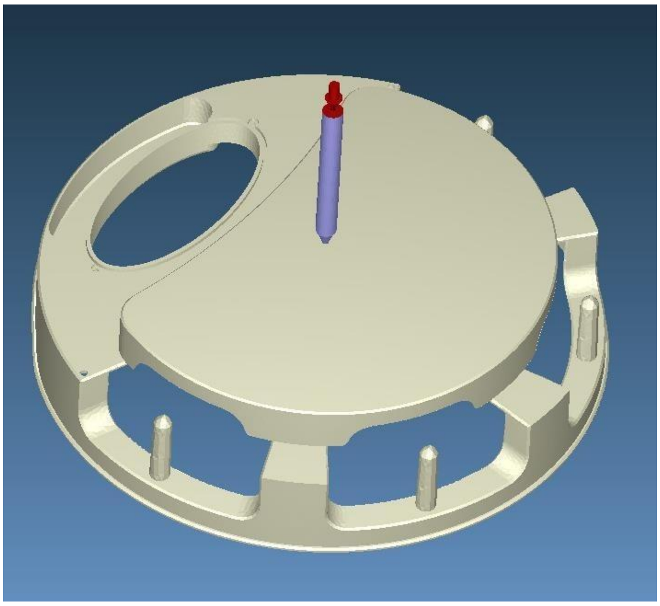

Figure 9. Image of plastic channel

Dimensions: Injection port Ø1.5 mm; Runerr: Ø 4.5 mm; Spray port length: 50 mm.
Simulation results:

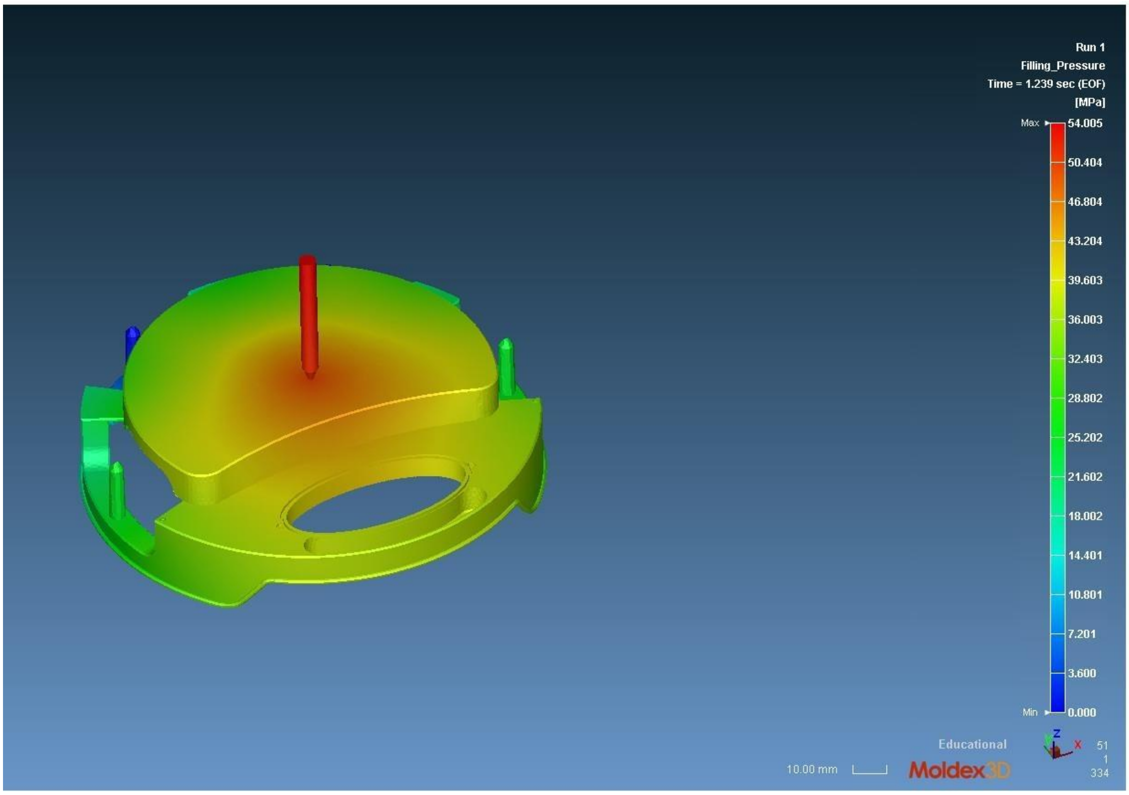

Figure 10. Results of the filling process

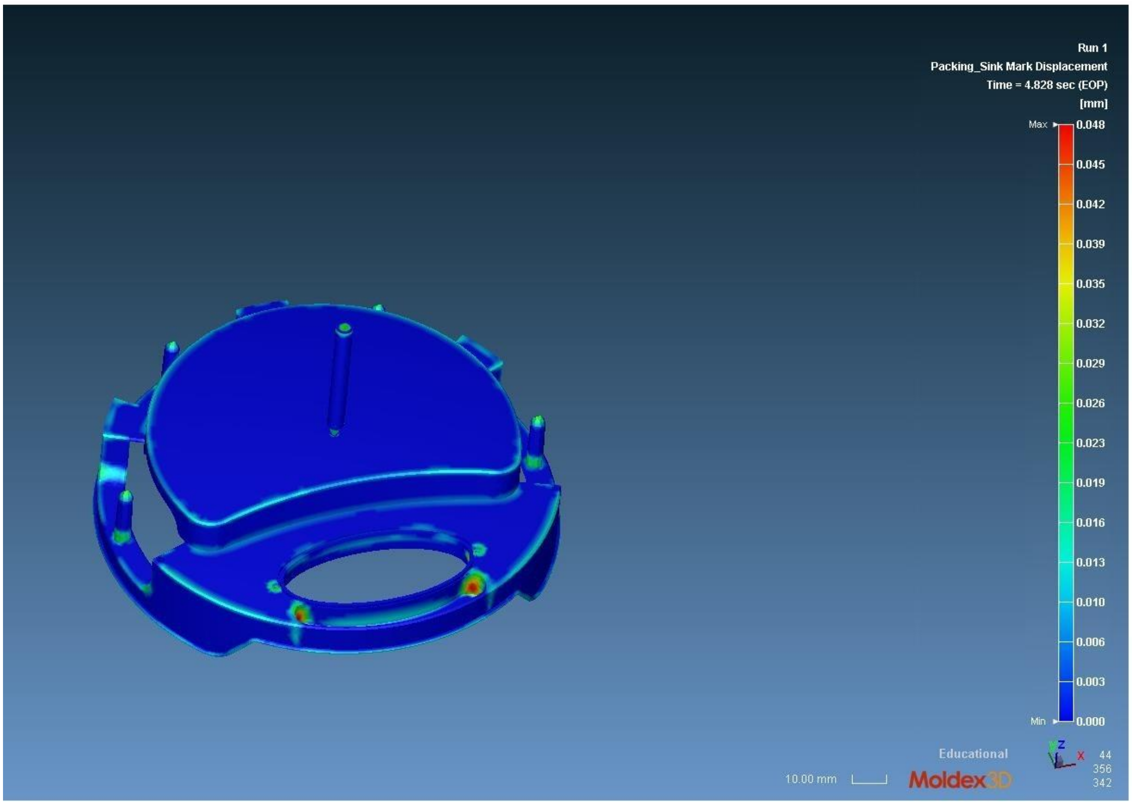

Figure 11. Results of the pressure holding process

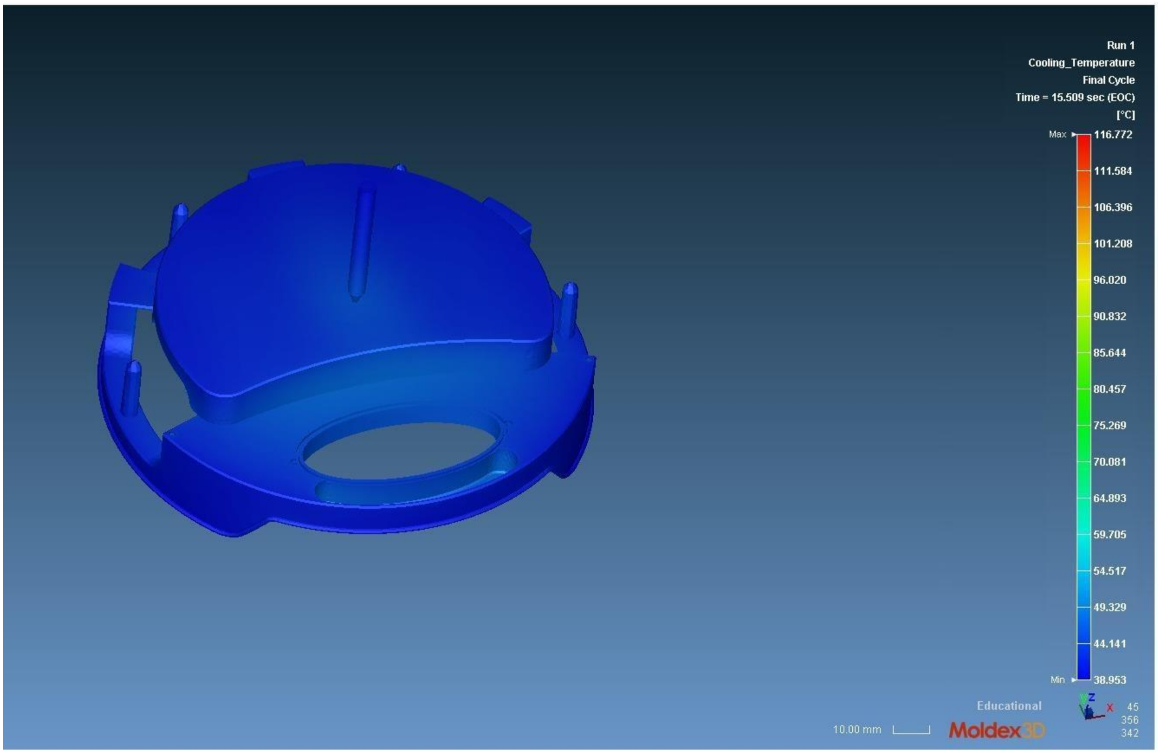

Figure 12. Results of the cooling process

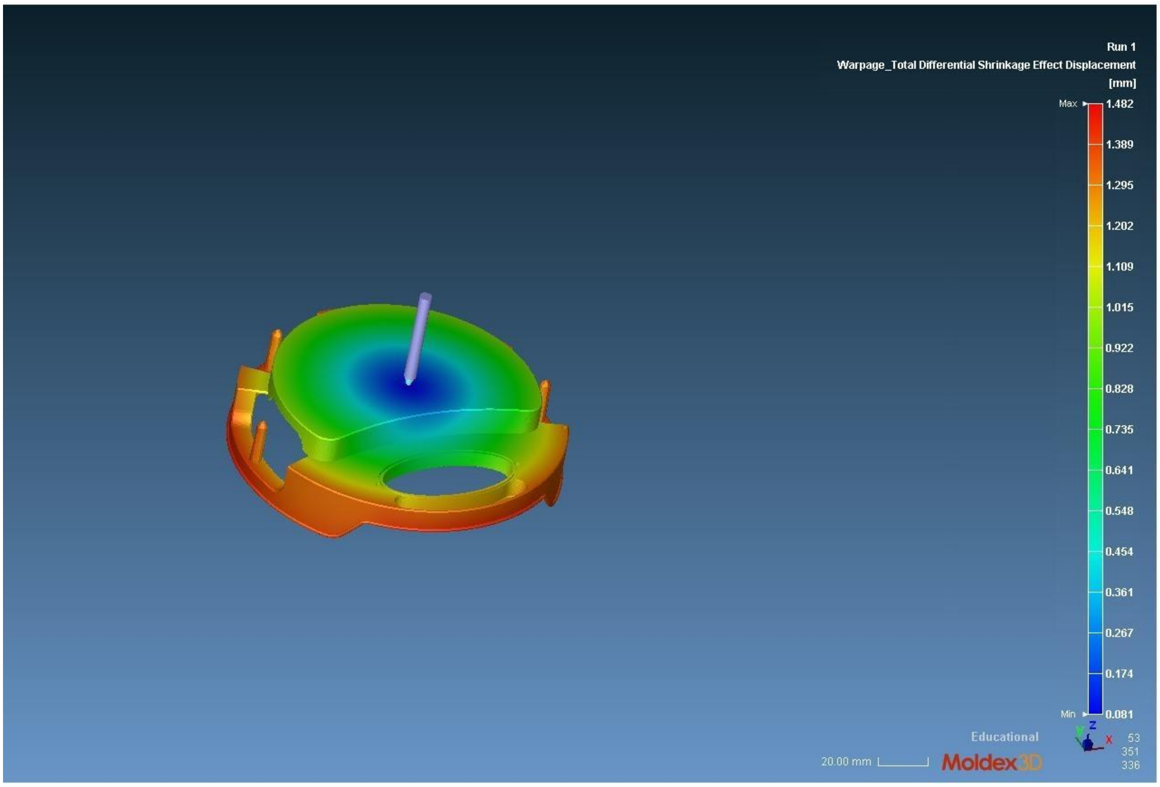

Figure 13. Results of the warping process due to pressure

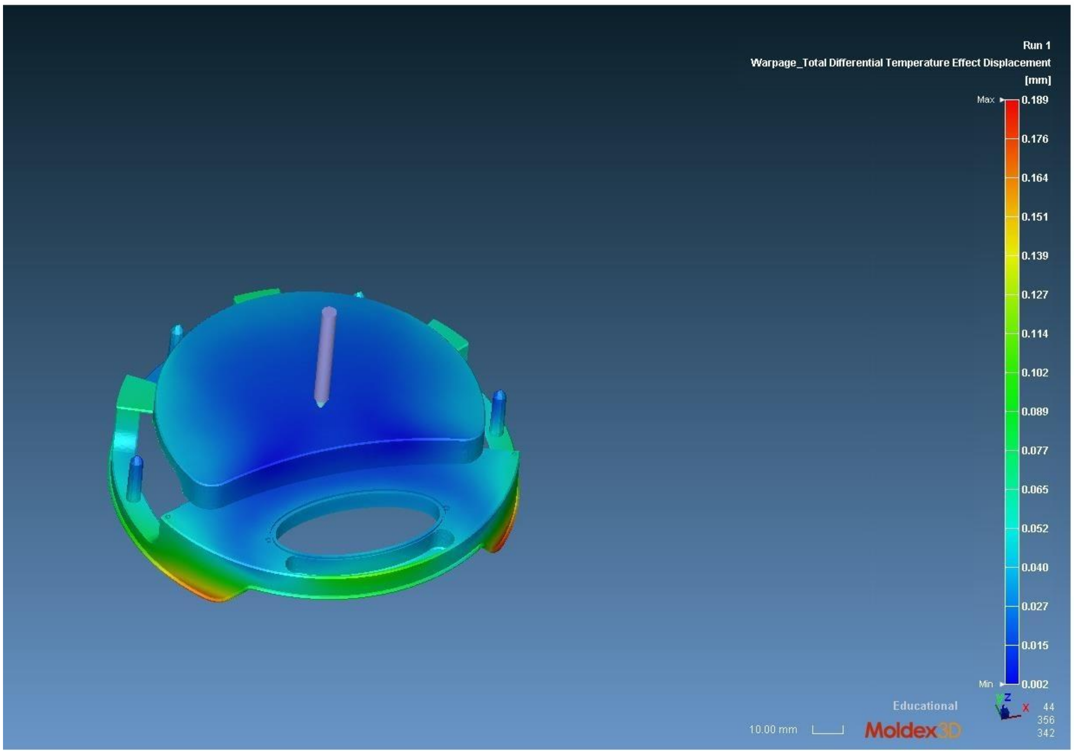

Figure 14. Results of the thermal warping process

Product filling time is 1.239 s; The pressure holding process has the highest pressure of 28,591 Mpa; Cooling time is 22.025 s; Product warping due to temperature is 0.189mm. Warping of the product due to 1.554mm pressure.

Product Improvement

Improved parameters:

Change plastic temperature (230°C => 240°C) Mold temperature from 35°C => 50°C.

Increase phase 1 speed (30% => 50%)

Increase phase 2 speed (78% => 91%)

Increase phase 3 speed (53% => 59%)

The pressure storm process increases 57 => 90 in a period of 2.8 seconds.

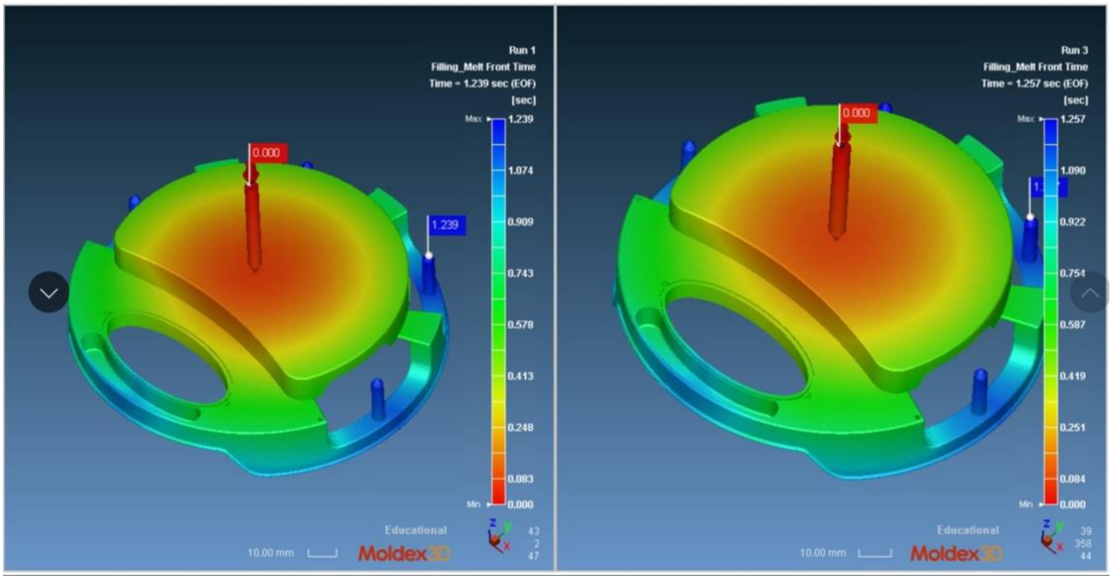

Figure 15. Filling time before and after improvement

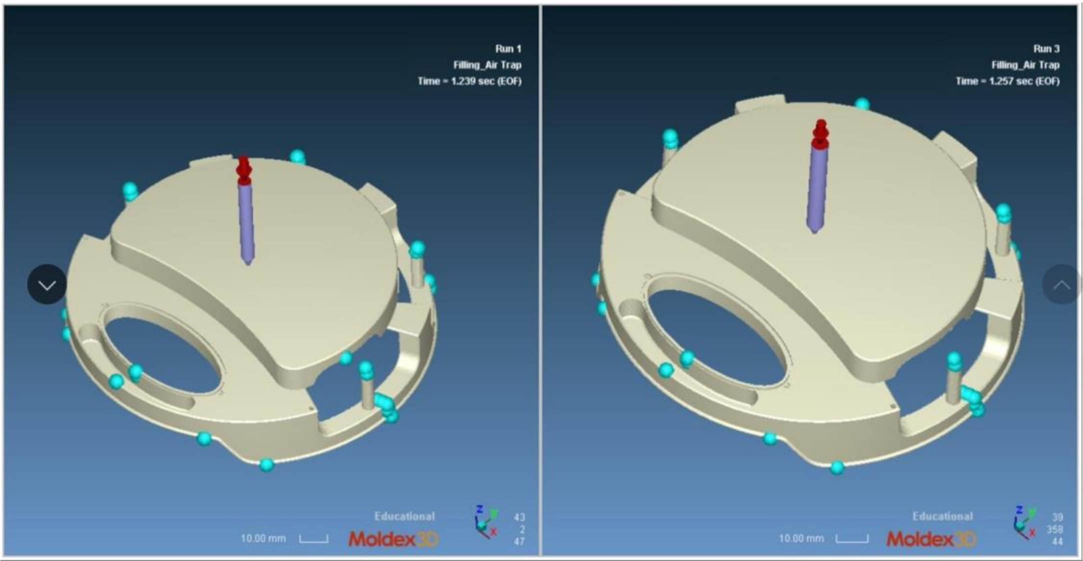

Figure 16. Air bubble error before and after improvement

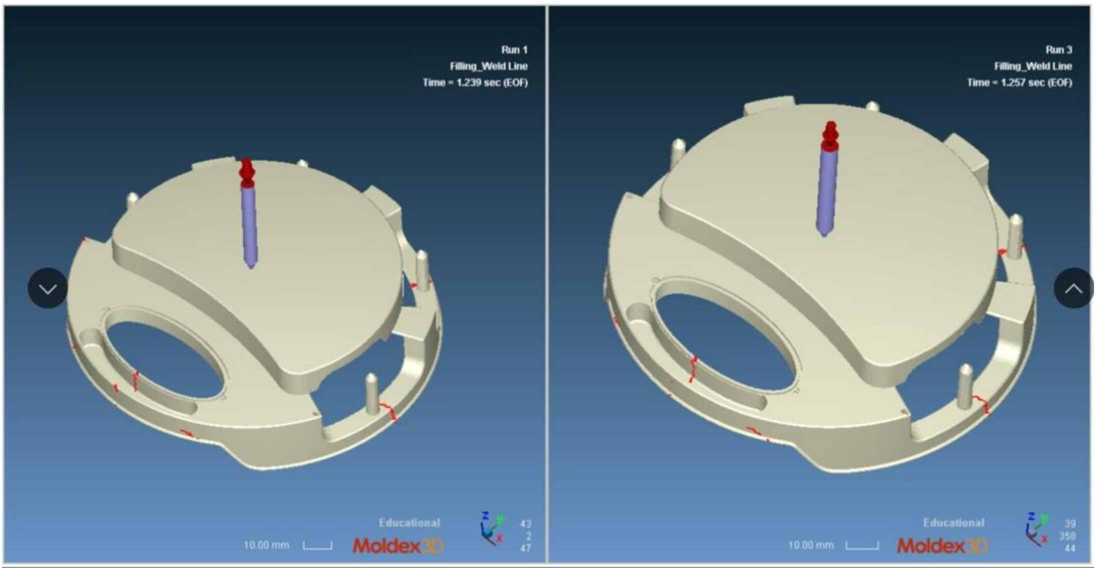

Figure 17. Weld line error before and after improvement.

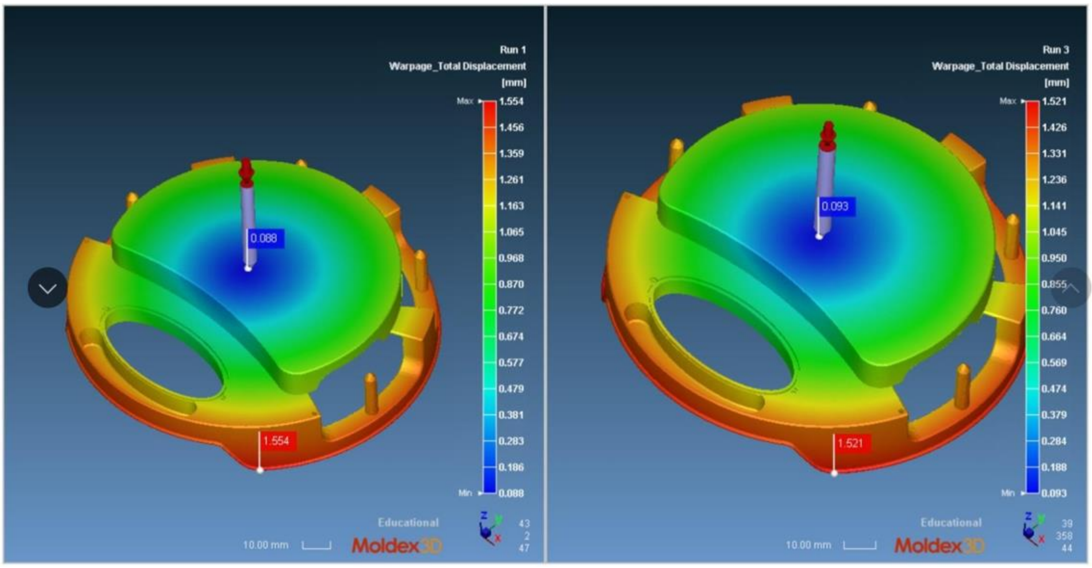

Figure 18. Warping error before and after improvement

Conclusion

Although the mold temperature was increased to 15^{o}C, the amount of air bubbles and weld seams of the product did not change significantly. When improving the warping was reduced by 0.05 mm. The product has large warping but does not affect the requirements and quality of the product.

After improving the gate position, cooling water line, pressure protection, mold temperature, we see that the product has a change in warping, but it is not significant.

After analysis and exchange, work with the customer again. To reduce product warping, it is necessary to change the product design such as increasing product thickness, adding stiffening ribs to the product.

Summary

In positions where the lugs are clogged with air, pin inserts will be inserted to release the air. The location of the major warping does not affect the product's features, discussed with the customer. Weld line locations will have many air vents to open the joint. Because the product is 1mm thick, we will advise customers to increase the product thickness: 2.2mm to 2.5mm.

Flow analysis can predict: the location of the junction of two flows, the location of air bubbles, injection pressure, mold locking force, temperature distribution.

Analyzing the compression stage can know: volume shrinkage, thickness distribution.

Analyzing the cooling process can predict: cooling time, mold surface temperature difference, heat transfer distribution, cooling efficiency.

Warping analysis can predict warping deformation and find the cause of warping.

Can calculate the curing speed of thermosetting resin, calculate resin filling and analyze curing in the mold, junction position, conversion distribution, flow rate distribution, displacement pressure.

Simulates gas/plastic gas-assisted injection molding, gas permeation rate, surface thickness, plastic flow, and can predict cooling and deformation.

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