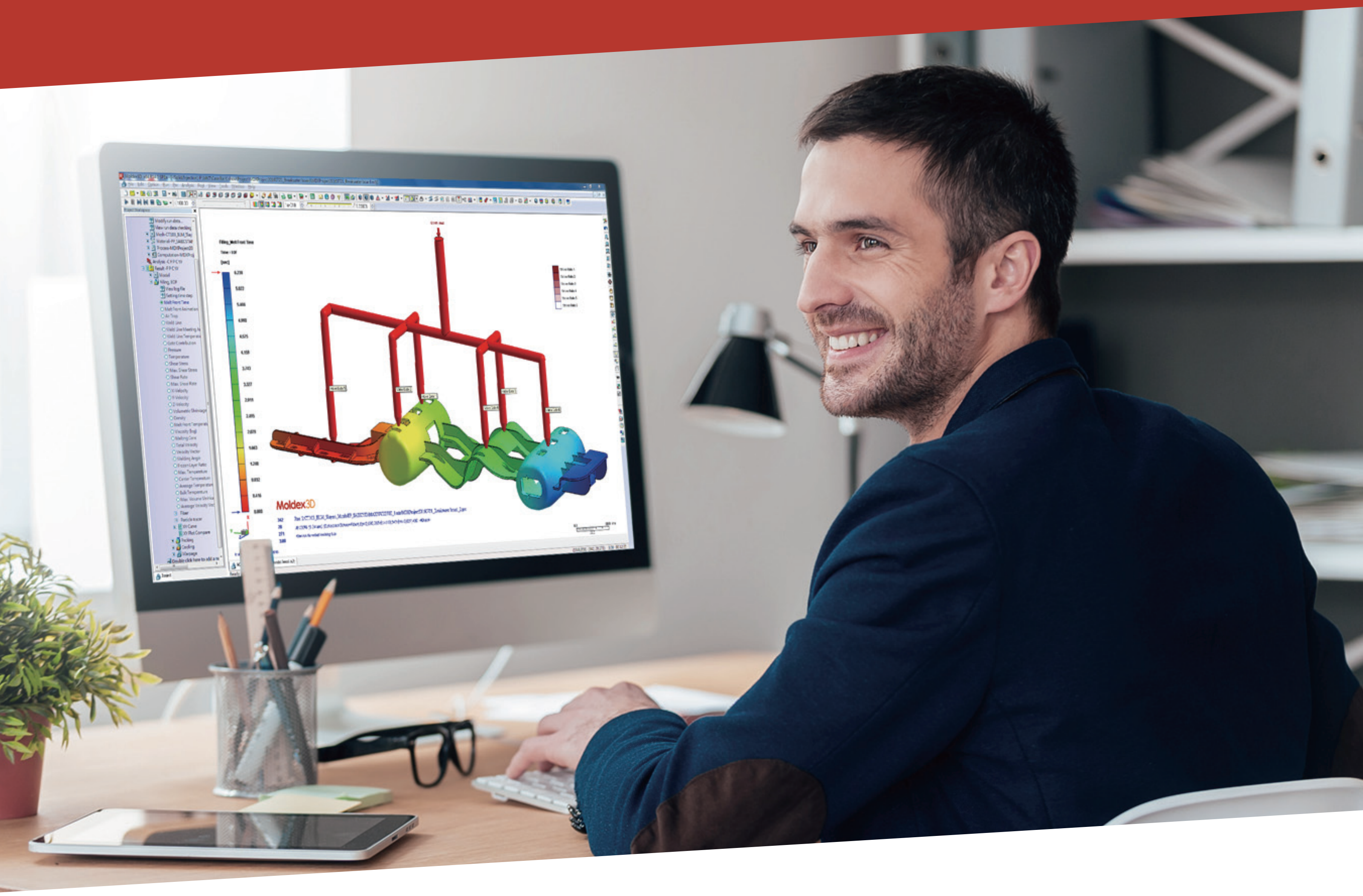
10 Real-World
Injection Molding Simulation Case Studies



Moldex3D

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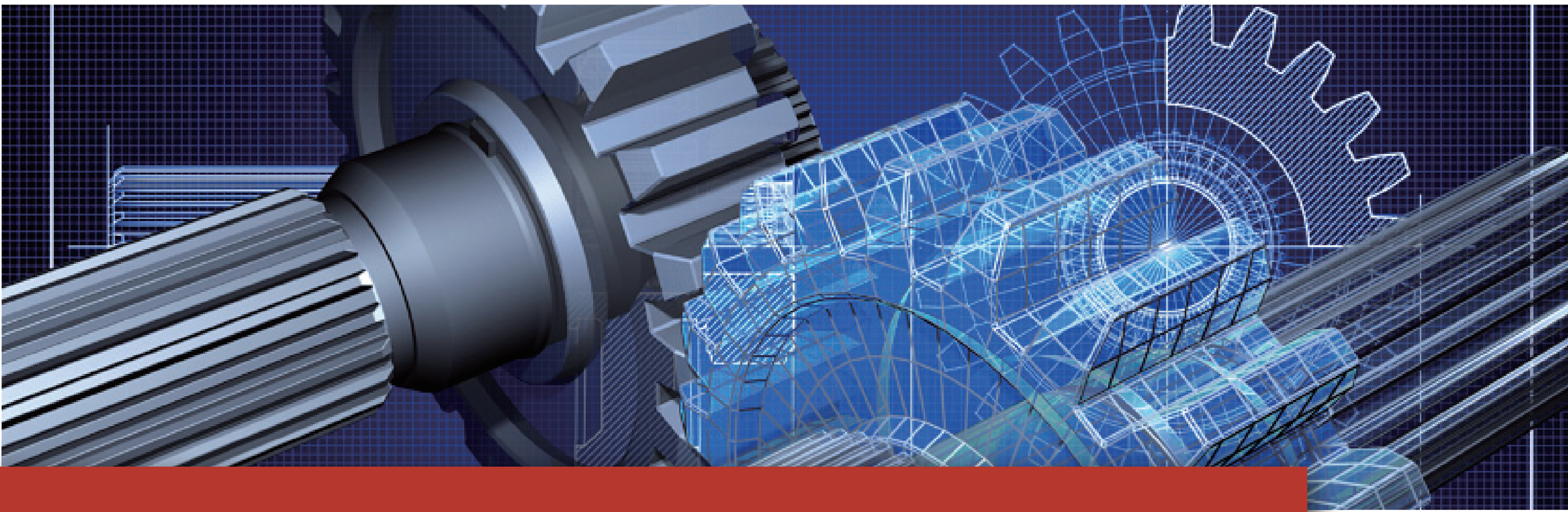
INTRODUCTION

In recent years, we’ve witnessed a change in how companies use injection molding simulation. In the past, most companies simply used simulation software to diagnose problems that already occurred. As the simulation technology became more mature and the awareness of upfront simulation began to increase, we finally see companies extract the value of simulation by incorporating the technology early in the design stage. This helps designers make critical design decisions with confidence and shorten the design-to-manufacturing cycle.

This eBook is a collection of real-world case studies from our clients spanning on a wide range of industry sectors, company sizes and business needs. Here you will see how other companies like yours have met and overcome challenges coming from all levels of manufacturing processes with the aid of simulation.

We hope you find value in these case studies that demonstrate why injection molding simulation plays a pivotal role in the design decision-making process, and how you can apply it in real life scenarios.

Sincerely,
Moldex3D Team



Solving Aesthetic Issues of Electronic Component Insert Molding through Moldex3D

Customer: SKF Technologies India Pvt Ltd.
Country: India
Industry: Electronics
Solution: Moldex3D Advanced

Image Courtesy of SKF Technologies India

SKF has been a leading global technology provider since 1907. Their fundamental strength is the ability to continuously develop new technologies – then use them to create products that offer competitive advantages to our customers. We achieve this by combining hands-on experience in over 40 industries with our knowledge across the SKF technology platforms: bearings and units, seals, mechatronics, services and lubrication systems. Our success is based on this knowledge, our people, and our commitment to SKF Care principles. (Source: http://www.skf.com/)

Executive Summary

Every industry has its unique challenges, but virtually all industries share the goals of increased machine uptime, reduced maintenance, improved safety, energy savings and lower total cost of ownership. With expertise in a wide range of disciplines and decades of experience as a technical partner to both equipment manufacturers and end users in every major industry, SKF is delivering not just products but total integrated solutions that help our customers achieve their goals.

The SKF sensor unit in this case includes electronics that need adequate sealing mainly for preventing liquid ingress and mechanical protection. This can be achieved by potting and over molding. The project involves analyzing the over molding of electronics, connectors and cable with printed circuit board (PCB) material as inserts.

Challenges

- To reduce design iteration and prototyping times.
- Identify the defects and correlate the simulation results with actual product failures for design optimization.
- Reduce product development cycle time.

Solutions

Moldex3D Designer and Project helped to create BLM mesh and run simulation successfully. Moldex3D technical support team helped to explore the tool and fix the problems whenever required in minimum time. As SKF has inserts with small electronic components, cable, connector's etc., achieving good quality mesh was a big challenge. This was achieved using BLM mesh tool as recommended by Moldex3D team.

Benefits

- Optimized the process parameters.
- Identified defects and suggested improvement with respect to design modification and process settings.
- The simulation results helped to investigate the reason for product failure.

Case Study

In the first phase, the objective was to carry out low pressure over molding simulation for single cavity molding. With current process setting identification of design and process defect was one of the main requirements. The observation must be made to find correlation with the existing manufactured part. Phase 2 objective was to realize a rheology over molding study to check the feasibility of molding 2 parts of the same product and define the best position of the injection point, best runner and gate design and dimension of cooling circuit. At the same time, the defect identified in the 1st phase must also be fixed.

The technical centre of SKF used Moldex3D Advanced solution to simulate the molding scenario of the original design. The meshing issue of the small electronic component and cavity was solved by BLM meshing. Through Moldex3D simulation results, they found filling issues in some regions on the part due to the gate location. There was also flow hesitation in thin wall areas. In addition, SKF was able to identify the internal residual stresses on the electronics during molding process. Finally they were able to optimize the process parameters to get the best cycle time and operate at the lowest possible pressure.

There was a design change in the gate type and location of the 2-cavity mold design. The runner system dimension and design was also changed respectively taking into account the defect observed in the first phase. This resulted in smooth material flow without hesitation effect and filling was better compared to the existing design (Fig. 1). The process was optimized to achieve the best cycle time with reduced cost and operated at low pressure. These were done by performing various runs and then compare the graph to finalize the best solution. Simultaneously, the temperature, pressure and thermal residual stresses around the electronic component were also controlled.

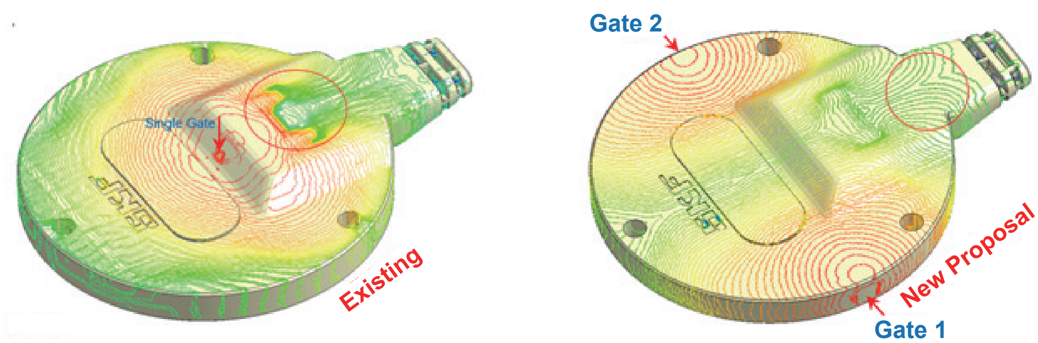


Fig. 1 We can observe the flow is not uniform in the original design (left) and there is flow hesitation in some areas like connector area. In new proposal (right) with 2 gates, we can observe the flow is uniform and the flow hesitation has almost been eliminated.

The simulation was generated for the existing design with the help of Moldex3D. All the observation was noted and the action plan was created with respect to process changes and design changes. The results obtained from simulation for the existing design were close to the real scenario. This was verified with the process data sheet from the production. The identified defects in the existing design were also observed in the existing product as shown in Fig. 2. After the design changes, Moldex3D was used to simulate both the original design and the optimized design. The design was optimized taking into account all the identified problems from the existing design. Additionally, the cycle time was optimized to reduce production time and cost. When compared with the actual mold trial results, SKF's technical centre found that Moldex3D simulation analysis results had strong correlation with the real scenario.

Fig. 2 High correlation between simulated and actual manufactured part is shown. A sink mark is identified on the simulated model (left) and the same result is visible in the prototyped part (right).

Results

Through Moldex3D analysis, SKF could clearly understand the filling behavior and predict probable defects due to process parameters and design deviations prior to prototyping and production. This saved a large, valuable amount of product development cycle time due to early investigation using Moldex3D tool. The accuracy of Moldex3D simulation analysis was verified with the actual manufacturing process sheet and visual inspection. The result helped their technical centre to optimize the process parameters, identify and fix defects in product and also correlate the cause of product failures at end application with the identified defects.

Using Novel CAE Tools to Verify Warpage and Refractive Index of Optical Parts

THE OHIO STATE UNIVERSITY

Customer: The Ohio State University
Country: U.S.A
Industry: Educational/Academy
Solution: Moldex3D Advanced, Optics Module

Image Courtesy of The Ohio State University

For 144 years, The Ohio State University's campus in Columbus has been the stage for academic achievement and a laboratory for innovation. It is also one of America's largest and most comprehensive. As Ohio's best and one of the nation's top-20 public universities, Ohio State is further recognized by a top-rated academic medical center and a premier cancer hospital and research center. (Source: https://www.osu.edu/)

Executive Summary

Microinjection molding is a mass-production method to fabricate affordable optical components. However, it often results in part deformation and uneven refractive index distribution. Finite Element Method (FEM) was employed to understand the influences of injection molding on the optical performance of freeform Alvarez lenses. The optical wavefront patterns were evaluated using an interferometer-based wavefront measurement system. This setup utilized an optical matching liquid to reduce or eliminate the lenses' surface power such that the wavefront pattern with large deviation can be measured by a regular wavefront setup. Moldex3D was also applied to help understand how the potential issues, surface deformation and refractive index variation, can influence the wavefront change.

Challenges

- Quality issues for optical applications: thermally-induced shrinkage, non-uniform refractive index, and birefringence
- How to use FEM to model the molding process
- How to analyze process' influences on optical performance of injection molded freeform optics
- How to fundamentally verify simulated optical performance

Solutions

Moldex3D provides two most critical, accurate simulated parameters: part warpage and refractive index for freeform optics. It provides true 3D results with consideration of filling, packing, and cooling stages too.

Benefits

- Improve understanding of the quality control of microinjection molded freeform optics
- Visualize and obtain the value of geometry deformation and refractive index variation
- Learn how the surface deformation and refractive index variation affect the wavefront change

Case Study

The objectives of this study are to compute geometry deformation and refractive index variation from FEM model of the freeform optical element, to measure the wavefront pattern which indicates the optical performance of the microinjection molded lens, and to compare the simulation with the measurement results that will give better understanding for optimization of the optical performance via CAE approaches.

Moldex3D simulation was performed using a 3D FEM model, created using HyperMesh beforehand, in order to obtain the results of part deformation and refractive index distribution (Fig. 1). The material used in the simulation was PMMA Plexiglas V825. The software can detect and show the surface deformation of this freeform optics and the uneven distribution of the part refractive index (Fig. 2). Then, these results were verified and compared with the measured ones by which the aberrations could be calculated.

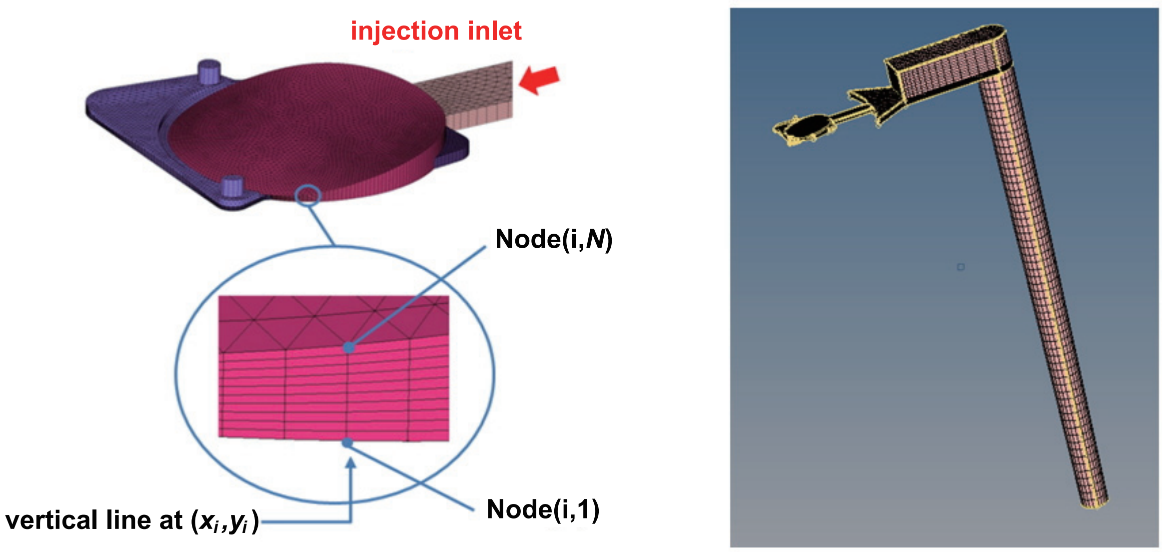


Fig. 1 The 3D meshed model is made of 10-layer prism elements (left) with a runner system shown on the right.

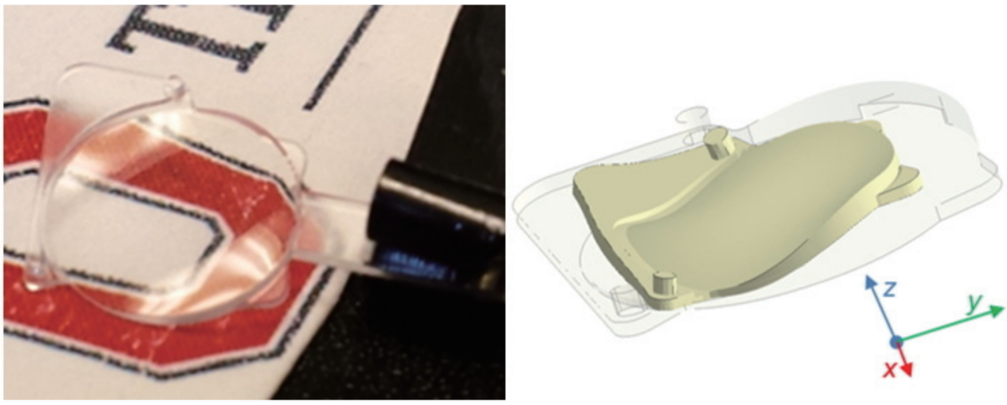


Fig. 2 The microinjection molded Alvarez lens (left) and the visualization of its surface deformation (right).

There was no change made to the original design since the main purpose of this study is to verify the simulation results by the measured ones (Fig. 3 & Fig. 4). Any changes to optimize the injection molding process are planned to be part of the future tests of this study.

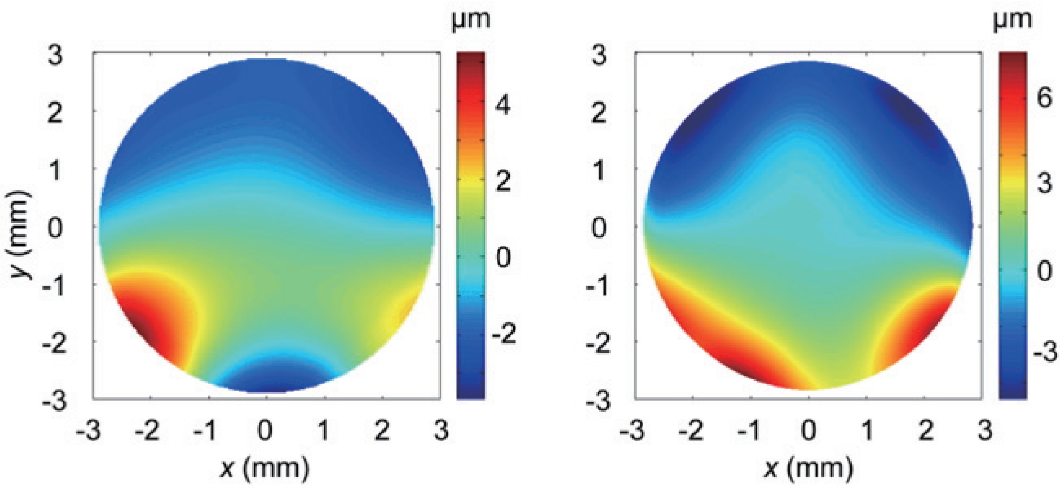


Fig. 3 The simulated (left) and measured (right) surface deformation of the microinjection molded Alvarez lens.

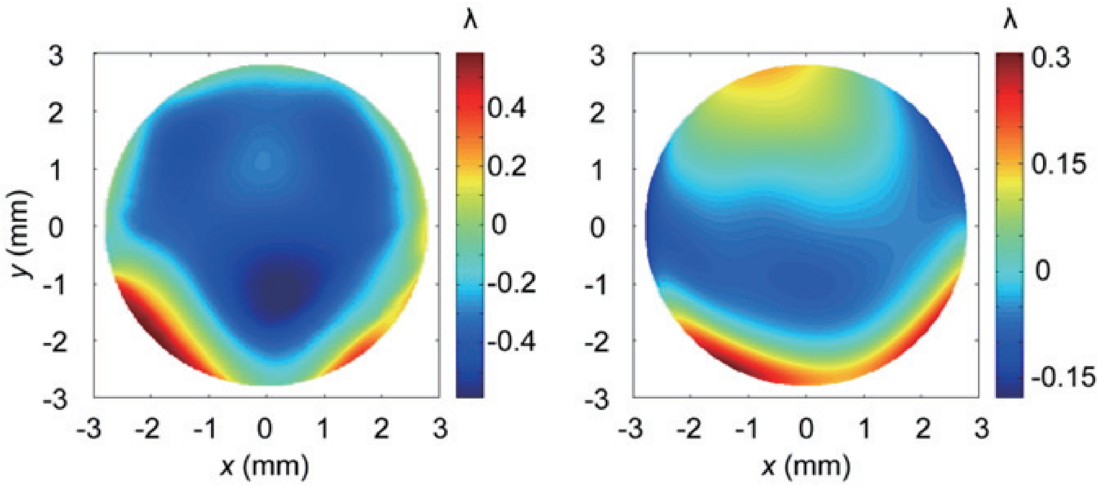


Fig. 4 The simulated (left) and measured (right) refractive index distribution of the microinjection molded Alvarez lens.

Furthermore, the wavefront patterns of this freeform lens were also verified. The verification compared the nominal wavefront pattern of an undeformed Alvarez lens which had uniform refractive index with the measured wavefront pattern of the microinjection molded Alvarez lens. The measurement setup utilized a transmission interferometry setup. The lens was immersed in an optical liquid with controlled refractive index. If the controlled refractive index of the optical liquid matches to the nominal surface refractive index of the lens material, the measured wavefront pattern indicates the refractive index variation inside the lens. On the other hand, if the controlled refractive index is not equal to the nominal refractive index of the lens material, the measured wavefront pattern is primarily determined by the surface power.

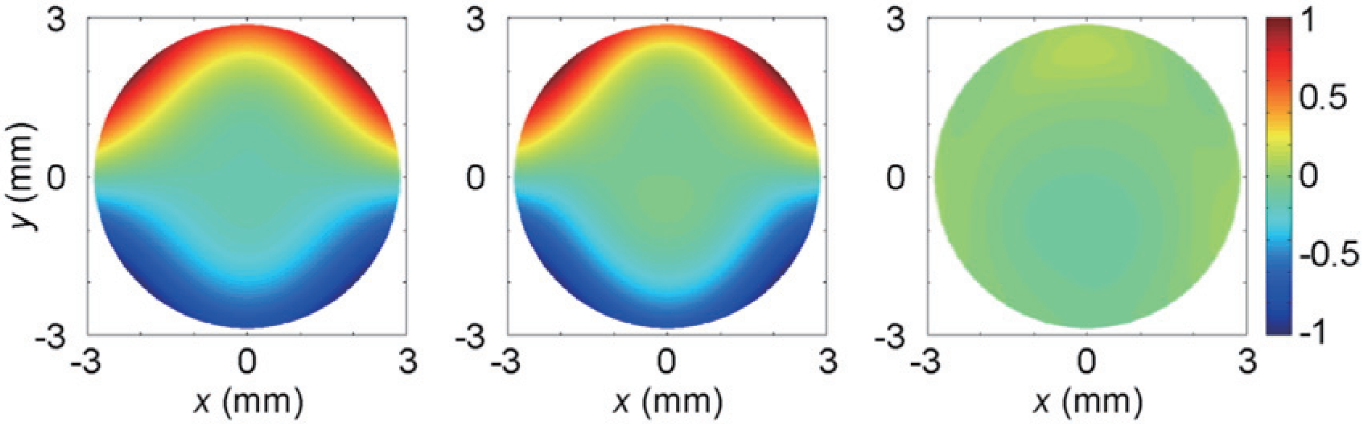


Fig. 5 The nominal wavefront (left) and the measured wavefront (middle) are compared to show their difference (right).

The results show that the nominal wavefront deviation is 15.89 λ, while the measured one is 15.8 λ. The maximum local difference of these two wavefront patterns is less than 5%, and the major differences come from the center and corner areas. Indeed, the cause of this difference is the combined effect of both surface deformation and refractive index variation occurring in the actual microinjection molded part, once predicted by Moldex3D software beforehand as well.

Results

Through Moldex3D analysis, both part warpage and refractive index of the microinjection molded freeform optics could be accurately obtained and visualized. This helps to give better understanding of how the potential issues, such as surface deformation and refractive index variation, can influence the wavefront change. The difference between nominal wavefront pattern of undeformed Alvarez lens with uniform refractive index and the measured one of microinjection molded Alvarez lens, which had deformed shape and non-uniform refractive index, was found out to be primarily determined by the combined effects of those two issues. In addition, true 3D results of filling, packing, and cooling stages are also provided from the simulation. Importantly, the use of this software also helps to significantly reduce the product development cycle time. Last but not least, Moldex3D provides an opportunity to conduct several future tests for this study, such as stress and birefringence analyses, insert molding for integrated optics, and optimization for the injection molding process using the DOE feature that will reduce the wavefront difference.

GARMIN Reduced Thousands of Dollars Cost by Improving Watch Product Warpage through Moldex3D

GARMIN

Customer: Garmin Corporation
Country: Taiwan
Industry: Electronics
Solution: Moldex3D Professional

Image Courtesy of Garmin Corporation

As a leading worldwide provider of navigation, GARMIN is committed to making superior products for automotive, aviation, marine, outdoor and fitness markets that are an essential part of the customers' lives. (Source: http://www.garmin.com/)

Executive Summary

Waterproof is a key function in Garmin's product design. The molding scenario has to be accurately set in order to control product deformation, air traps and product size. If the product size is not properly controlled, the watch will tend to leak under high pressure environment because of deformation. Thus, Garmin Corporation decided to utilize Moldex3D to find the optimal product design to improve waterproof.

Challenges

- Part warpage
- Poor waterproof due to warpage

Solutions

Utilizing Moldex3D Professional Package to obtain the optimum process settings in order to successfully improve the product's warpage problems.

Benefits

- Reduced 2 or 3 mold revision times
- Saved NTD$200,000 ~ NTD$300,000 worth of mold revision costs
- Reduced 40,000pcs of the product capacity lost
- Improved warpage by 75%
- Improved the waterproof yield rate by 15%

Case Study

The objective of this case is to determine the gate location of a GPS watch in order to reduce the warpage problems in the middle of the part. The warpage of the original design is about 0.4mm. Garmin utilized Moldex3D to simulate the molding scenario of the original design. Through Moldex3D simulation results, Garmin found out that using traditional injection molding method, high warpage would occur in the middle of the part. This molding defect would have a direct negative impact on the product's functionality and physical appearance. Thus, in order to solve this problem and produce high-quality products, Garmin decided to change the gate design. Therefore, they proposed two new designs of revising the gate location (Fig. 1).

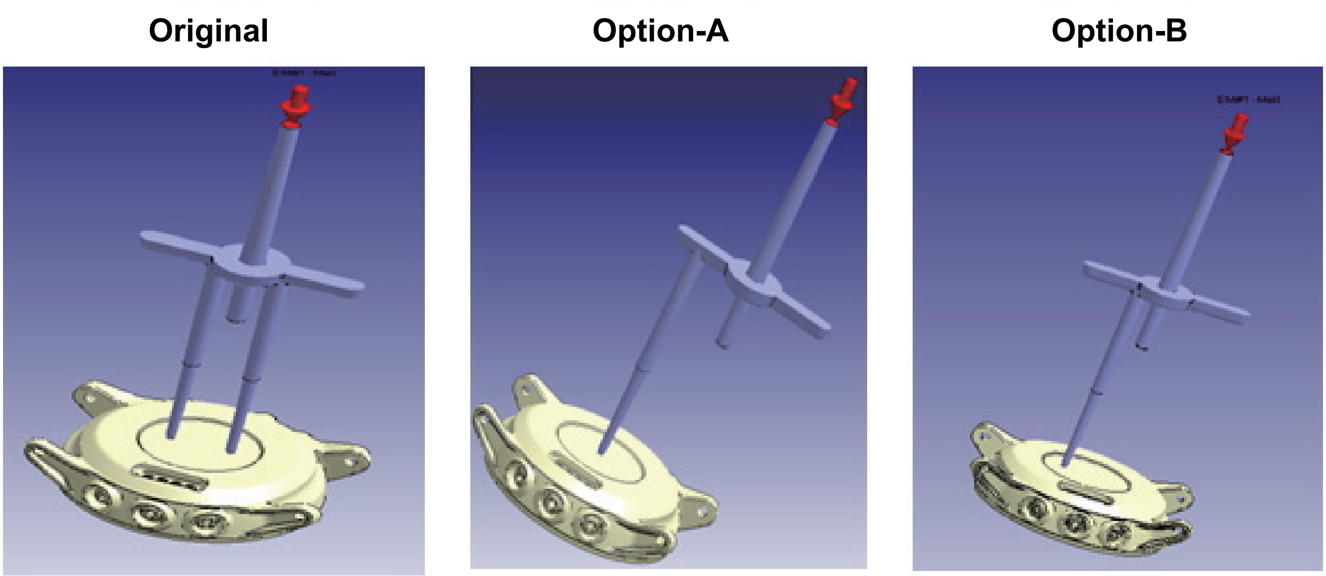


Fig. 1 The gate design revisions, Option A & B compared to the original design

After the design changes, Garmin used Moldex3D to simulate the original design and the revised designs. The analysis results of the original product design showed (Fig. 2) the Z-axis warpage would reduce from 0.36mm (original) to 0.06mm (Option-B). And the actual mold trial results showed the warpage would reduce from 0.4mm (original) to 0.1mm (Option-B). Furthermore, Garmin found that Moldex3D simulation analysis results were strongly correlated with the results of the actual mold trials (Fig. 3).

Warpage of Z-axis

Original: 0.36mm Option-A: 0.25mm Option-B: 0.06mm

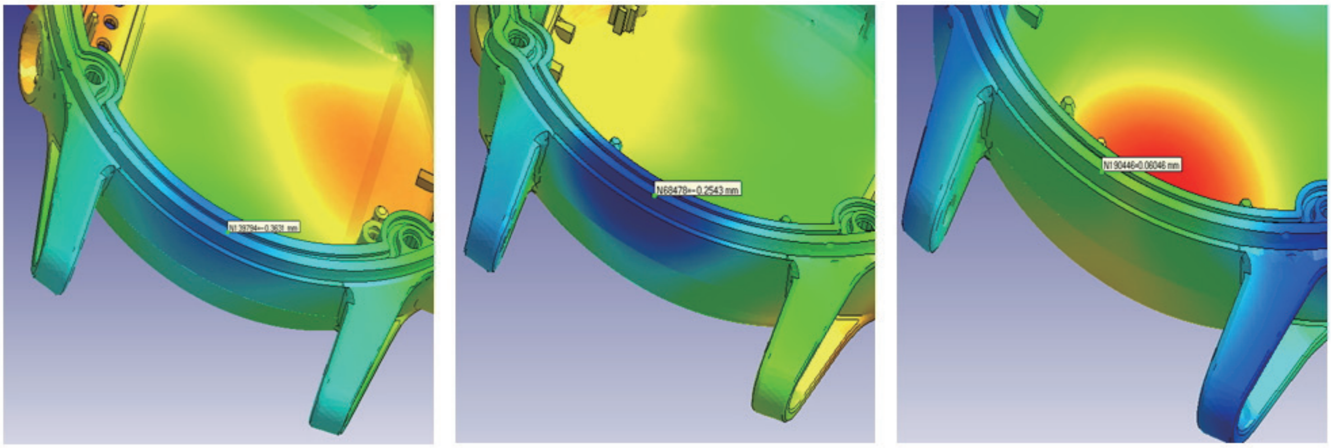


Fig. 2 The Z-axis warpage simulation results of 3 designs

Warpage of Z-axis

Original: 0.4mm Option-B: 0.1mm

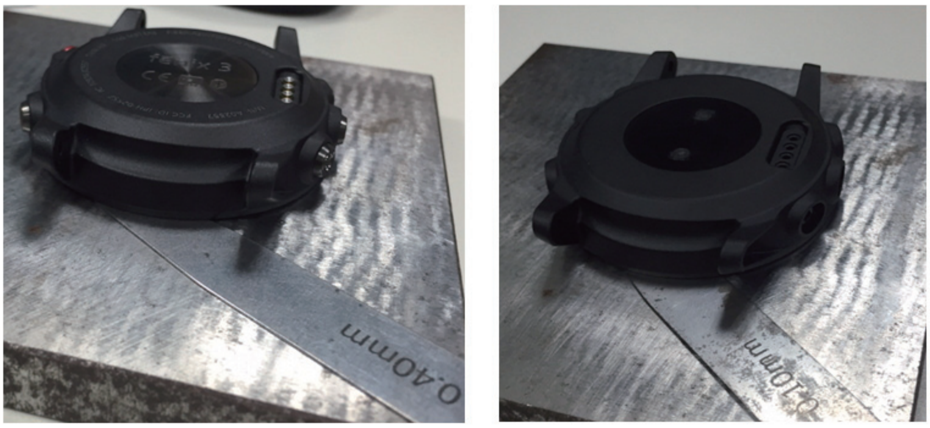
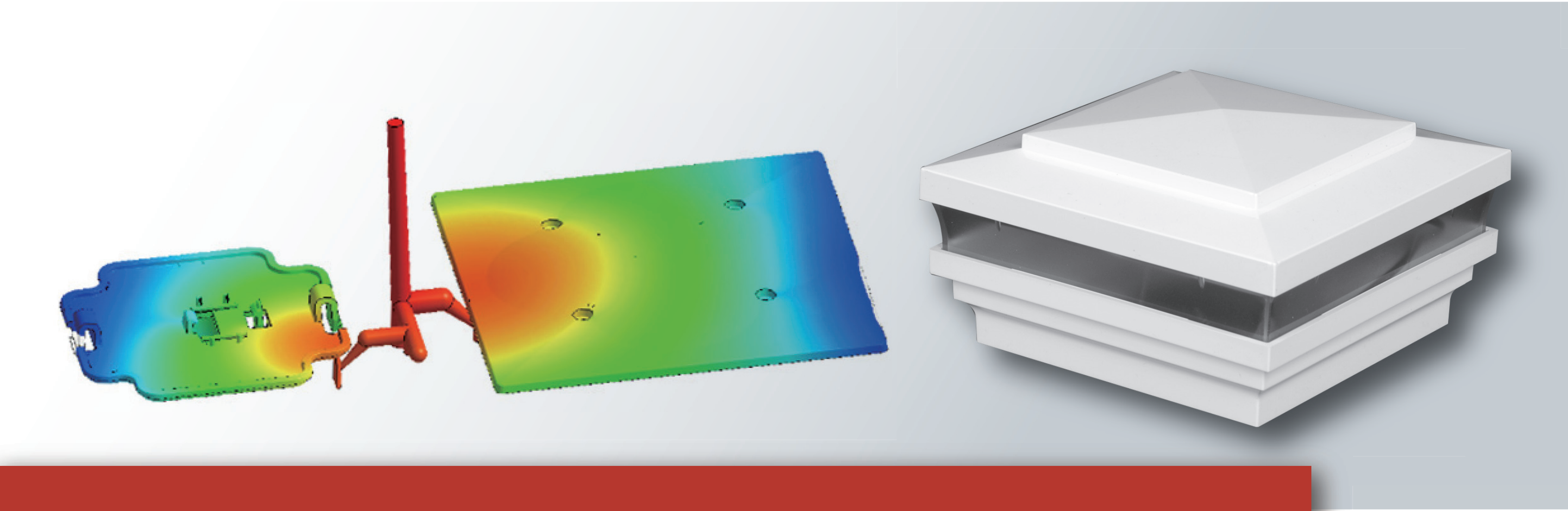


Fig. 3 The Z-axis warpage mold trials of the original and the optimized design

Results

Through Moldex3D, Garmin was able to evaluate how molding scenario affected concentricity and flatness of a watch under different gate locations and numbers. Thus, Garmin could successfully improve the flatness as well as assembly yield rate and waterproof rate. Moldex3D's 3D mesh technology also made the simulation results more consistent with the actual results in manufacture. Ultimately, Garmin was able to decide the optimal design within limited development time, avoid repetitive mold trials, and reduce costs.



Earning Total Savings of $11,500 on Mold Work for LED Products with Moldex3D

Customer: LMT Mercer Group, Inc.
Country: USA
Industry: Consumer Products
Solution: Moldex3D eDesign

Image Courtesy of LMT Mercer Group, Inc.

LMT Mercer Group, Inc., the leading manufacturer of vinyl fence, deck, and railing accessories in the US and Canada, operates three manufacturing plants in New Jersey and Ohio. LMT operates more than 30 state-of-the-art injection molding machines equipped with servo-robotics and nitrogen gas-assist capabilities. It has used Moldex3D for their product development process optimization since 2013. (Source: http://lmtproducts.com)

Executive Summary

Two lighting parts, made from the same material, were both produced in the same mold to reduce the costs. However, their sizes were quite different, so unbalanced filling occurred. Through Moldex3D, the other issues, such as sudden spike in clamping tonnage and overworked cooling channels could also be detected. Therefore, optimization on runner/gate and cooling systems were made that resulted in the eliminations of unbalanced filling and sudden tonnage spike, the reductions of both clamping force and cooling time, and the improvements of both cooling efficiency and part flatness. In addition, substantial time and cost savings could be achieved too.

Challenges

- To complete the filling process at the same time for both parts
- To ensure the runner/gate configuration and cooling channel sizes and locations that would not cause excessive warpage on the parts

Solutions

Moldex3D provides the analyses for filling, packing, cooling, and warpage in which the effects of any design changes and modifications in runner/gate and cooling systems on the improvements on filling time, cycle time, cooling efficiency, and part flatness can be observed beforehand.

Benefits

- Succeeded in reducing the clamping tonnage required at the end of packing from 225 ton to 175 ton which reduces costs of the part too due to smaller press size required
- Succeeded in having both parts to be fully filled at 1.28 s; the initial runner and gate design resulted in full filing times of 1.07 s and 1.28 s for the smaller and larger parts, respectively
- Obtained optimized cooling channel design which reduced cycle time through reduced maximum cooling time by 11.99% and made the cooling efficiency difference only 13.759% from 25.452%
- Improved flatness of the smaller part by 2.56% and of the larger part by 6.18%
- Earned total savings of $11,500 for mold work and sampling charges

Case Study

The objectives are to reduce the cost of parts by both reducing the press size required through optimized runner/gate and reducing the cycle time, to keep part flatness within acceptable quality limits, and to accomplish all these goals before the making of the mold so that the tooling and sampling costs could be reduced.

Moldex3D eDesign was utilized to mesh the model which contains two different cavities in one mold; the smaller part was for LED board holder, whereas the larger one was for light reflector. Moldex3D became a powerful tool to detect and identify unbalanced filling through melt front time, sudden spike in tonnage of the clamping force, maximum cooling time, overworked cooling lines, and the Y-displacement for both parts.

The changes include runner layout and cooling system as illustrated and explained in Fig. 1 and Fig. 2.

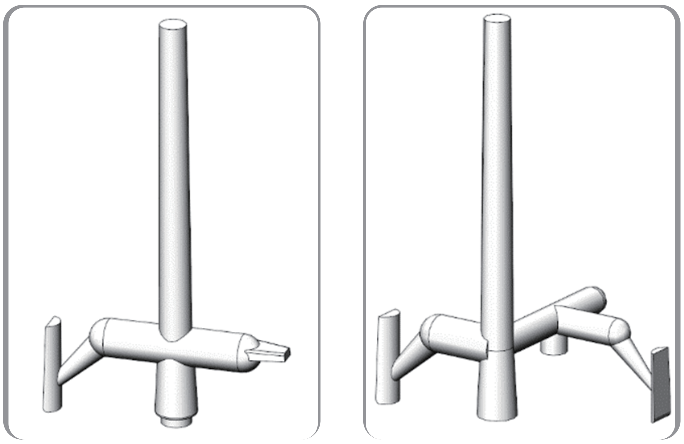


Fig 1. The original design has the edge gate for the smaller part and jump gate for the larger part (left), while the revised design keeps the jump gate for the larger part but uses the extended jump gate for the smaller part (right).

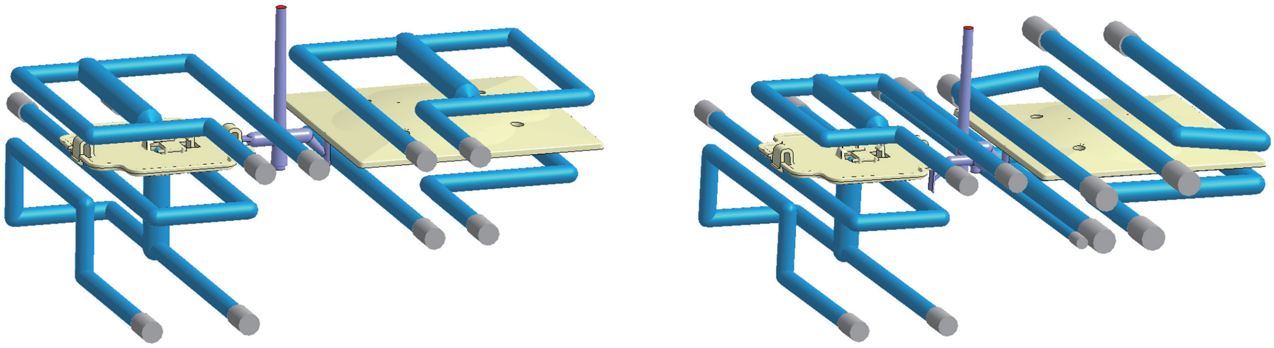


Fig 2. Different from the original design (left), the revised design (right) splits the connected loop cooling channel for the larger part's top and bottom sides and add a cooling channel for the larger part's bottom side.

As shown by Moldex3D's simulation results, the smaller part has been fully filled too early compared to the larger part. The revised design makes the flow path for the smaller part longer from its runner and gate design, so its filling time can catch up with the longer filling time of the larger part (Fig. 3).

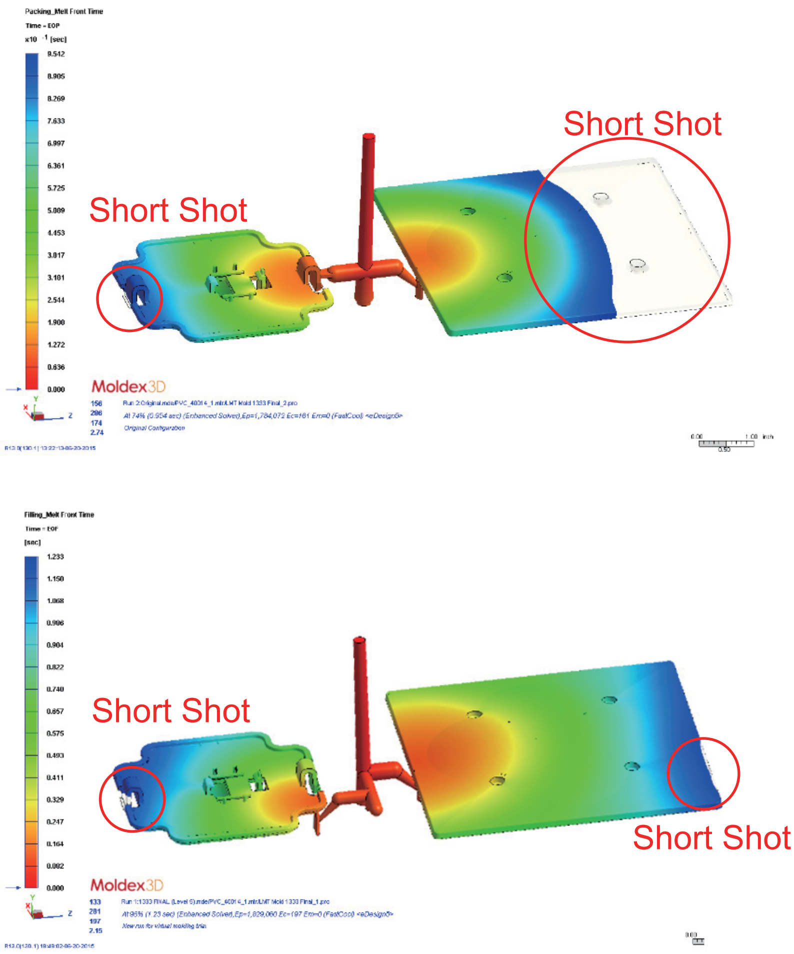


Fig. 3 The comparison between the melt front time of the original design at 74% filling (top) and the revised design at 96% filling (bottom) shows that the unbalanced filling for both cavities has been solved.

The next result is the cooling time in which the maximum cooling time can be reduced from 21.009 s to 18.489 s via optimized cooling system design. In other words, the cycle time could be reduced as well. The last result is the Y-displacement which represents the part flatness. The original design results in maximum displacements of 0.1981 mm and 0.6985 mm for smaller and larger parts, respectively. Meanwhile, the revised design can reduce the maximum displacements for both smaller and larger parts to 0.1930 mm and 0.6561 mm, successively.

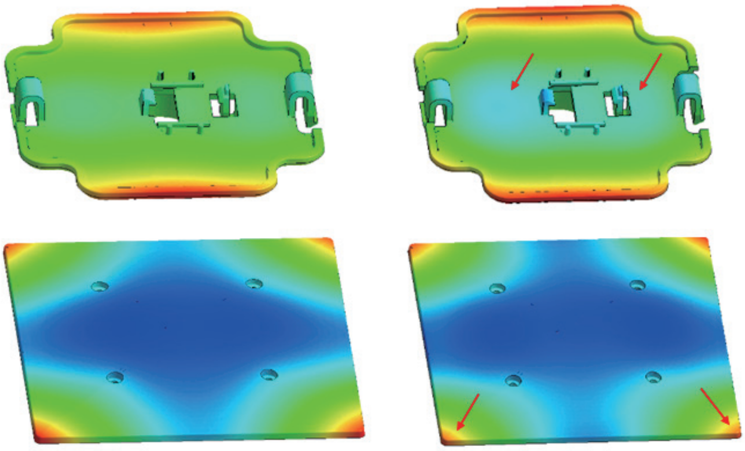


Fig. 4 The distributions of the Y-displacement for both of the smaller and the larger part show that the original design (left) has larger displacement than the revised one (right).

The design revision was verified by the actual injection molded parts. During initial mold sampling, the process conditions from Moldex3D were given to the process engineer. The process engineer made short-shot parts just before the end of the filling. The injection molded short-shot parts has identical short shot locations to the ones in simulation results as shown in Fig. 5.

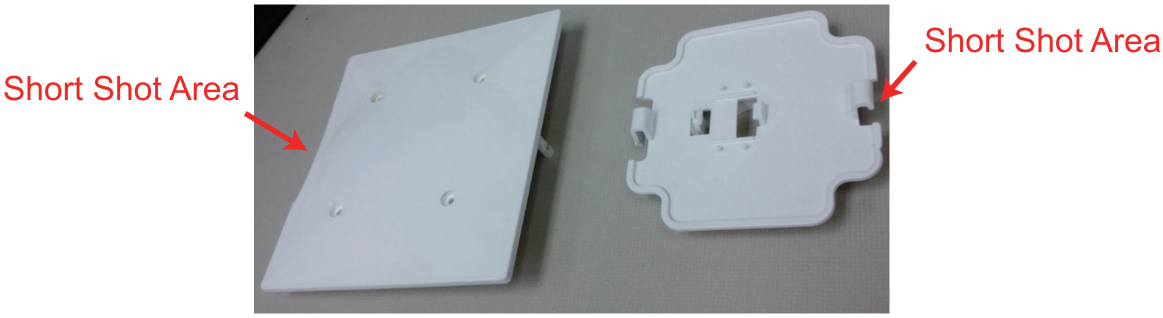
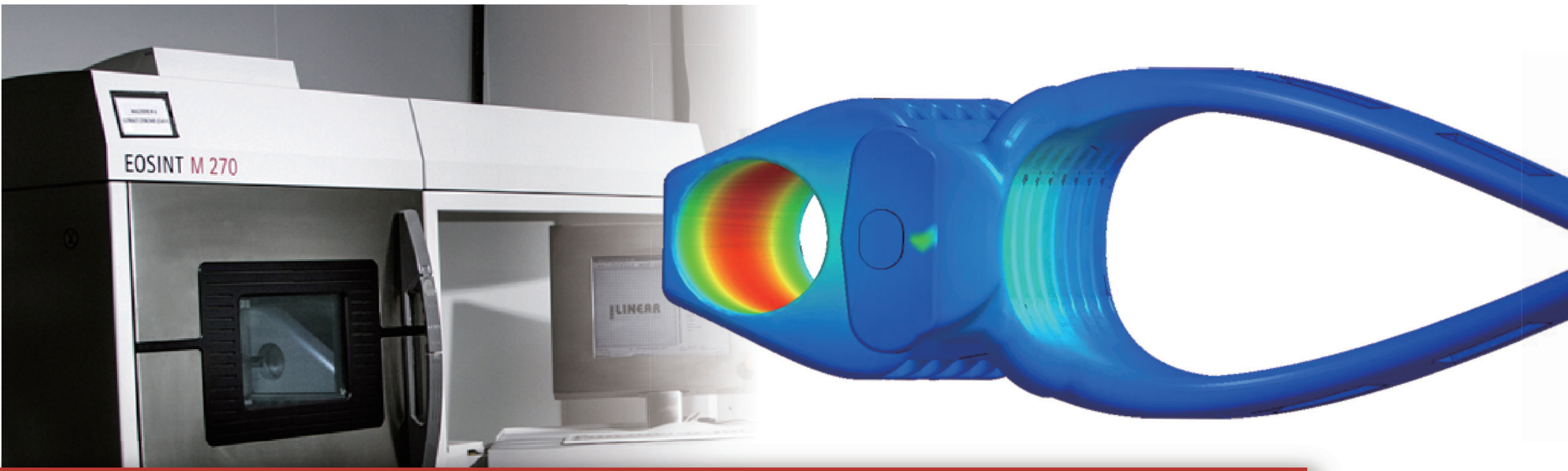


Fig. 5 The actual injection molded parts for the revised design for larger part (left) and smaller part (right) have identical short shot locations with the simulation result in Fig. 3.

Results

This project was a success in which the objectives of both reducing the part cost and improving the quality of the finished products had been accomplished. The design revision was made by modifying the runner/gate design and optimizing the cooling channel layout before the mold steel was cut and shaped. With the ease of use that Moldex3D offers, various designs were tested quickly to find the best results without having to make expensive changes to the tooling after the fact. By improving the mold and part designs with the assistance of Moldex3D, time to market and tool sampling had been streamlined. Thus, substantial time and cost savings could be achieved as well. Besides, the validation comparing the simulation result with actual injection molded parts showed that both filling results were very identical.



Linear AMS Utilizes Moldex3D Conformal Cooling Analysis to Reduce 69% Cooling Time

LINEAR AMS
A Moog Company

Customer: Linear AMS
Country: USA
Industry: Mold Making
Solution: Moldex3D eDesign

Image Courtesy of Linear AMS

Linear Mold& Engineering was founded in 2003. By pushing the limits to develop new uses, testing new materials, and creating new production processes for their customers, Linear helped establish an emerging market for delivering precision tooling, molding and industrial parts. In 2015, global engineering industry leader Moog, Inc. purchased controlling interest in Linear, rebranding the company to Linear AMS highlighting their additive manufacturing solutions capabilities, but maintaining operations as a separate company. (Source: http://www.linearams.com/)

Executive Summary

In plastic injection molding, the cooling process is the longest portion, often prolonging the total cycle time. In the supply and demand world, the ability to produce parts faster and more efficiently is always the top priority for the manufacturers. However, conventionally drilled cooling lines in molding tools have many limitations in shortening the cycle time. In order to solve this present issue, Linear AMS decided to propose a new conformal cooling system and utilized Moldex3D to validate the design. In the end, they successfully reduced the cooling cycle and had more confidence while helping their customers solve cooling issues.

Challenges

- Limitations of conventional cooling design resulted in unacceptable, long cooling times
- Designing an effective conformal cooling system to reduce cooling time

Solutions

Utilizing Moldex3D eDesign to design the optimum conformal cooling layout in order to successfully reduce the cooling portion of the cycle time

Benefits

- Reduced cooling time by 69%
- Developed a competitive advantage in the market

Case Study

This case features a rifle stock arm brace part. Linear AMS' long term objective is to design a conformal cooling system to assist customers to reduce cycle times. This project's specific objectives primarily focused on reducing the cooling portion of the cycle time.

First of all, they needed to produce a higher volume of parts, but they were not able to add additional molds and presses into the process. The fill/pack process had been successful prior to Moldex3D's involvement, so warpage was not an issue. When they utilized Moldex3D to analyze the conventional cooling process (Fig. 1), they found serious heat accumulation in the middle area as well as the shaft (Fig. 2).

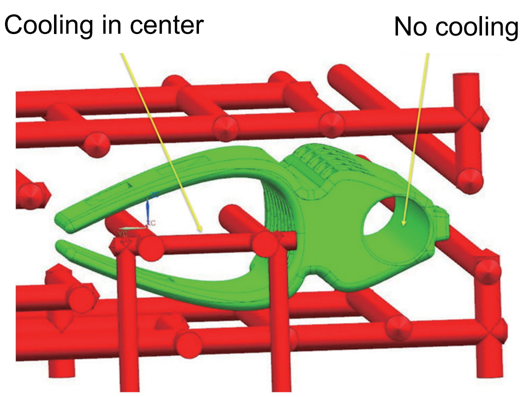


Fig. 1 Original Cooling Channel Design

Fig. 2 The cooling analysis of the original cooling channel design.
The result indicates heat accumulation in the middle area as well as the shaft.

In order to improve the cooling time, they altered the cooling system that can better conform to the shape of the part (Fig. 3). The cooling in the middle area as well as the shaft was completed and in addition to those areas, new cooling was applied to the outer sides as well. After the design changes, Linear AMS used Moldex3D eDesign to simulate the revised cooling design. The analysis results of the modified cooling channel design showed a much more uniform temperature distribution (Fig. 4) compared to the original design.

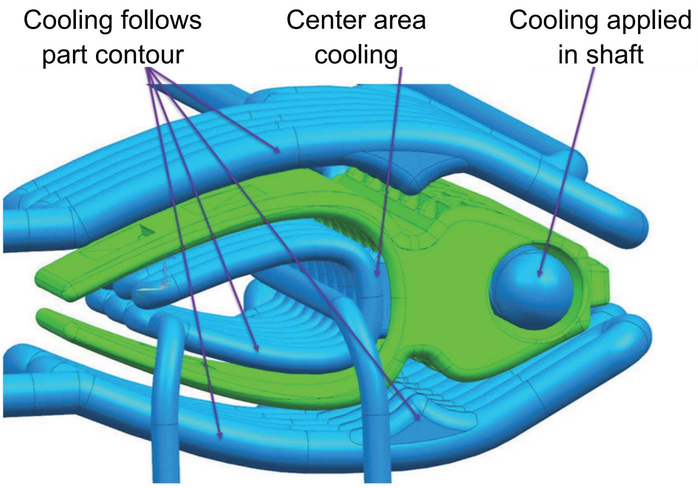


Fig. 3 The revised cooling channel design

Fig. 4 The analysis results of the revised cooling channel design. The temperature distribution is much more uniform

As a result, Moldex3D has successfully reduced the cycle time from 112 seconds to 35 seconds. This allowed the customer to produce a higher volume of parts without making additional molds and using additional presses.

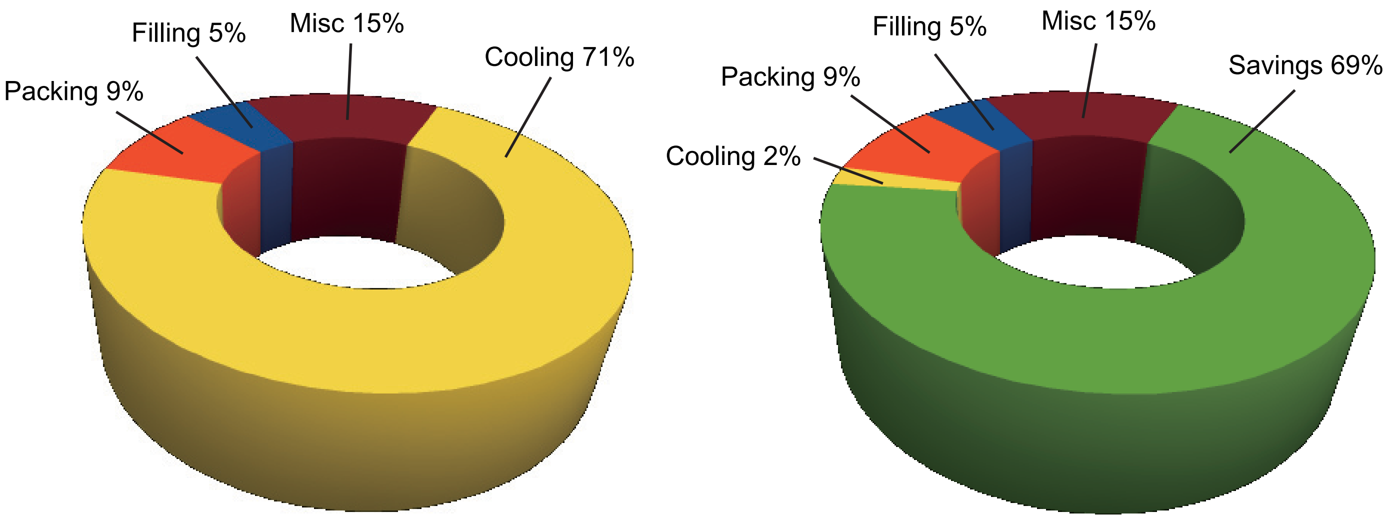


Fig. 5 The breakdown of savings in this case: the reduction in the cooling cycle has translated to 69% in the manufacture cost.

Results

The benefit of using Moldex3D is making it possible to present the time savings prediction to the customer. From their experience with Moldex3D, Linear AMS has found that the cooling predictions are surprisingly accurate and they now can confidently tell their customers how they can better help them reduce their cycle times (Fig. 6).

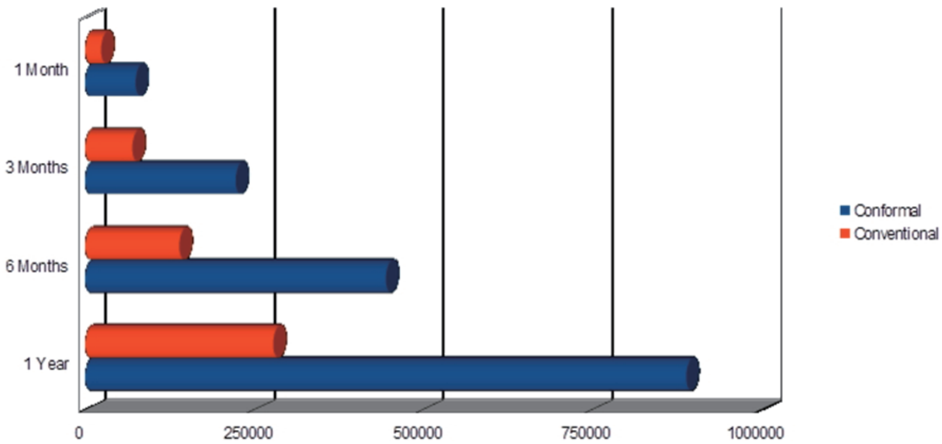


Fig. 6 The difference a savings of 77 seconds per shot can make over the course of a year

TomTom Solved Deformation Issue of Navigation System Parts through Moldex3D

Customer: TomTom Asia
Country: Taiwan
Industry: Electronics
Solution: Moldex3D eDesign, Fiber Module

Image Courtesy of TomTom Asia

TomTom is the world's leading supplier of in-car location and navigation products and services focused on providing the world's best navigation experience. TomTom's products include portable navigation devices, smart phone apps, GPS sports watches, in-dash infotainment systems, fleet management solutions, and maps and real-time services, including the award winning TomTom HD Traffic. (Source: http://www.tomtom.com)

Executive Summary

The product in this case is a front cover of the cradle of a truck GPS navigation system. Deformation is a significant issue that has to be controlled in order to conform to the aesthetic and assembly requirements. In the original design, the maximum deformed magnitude could reach 2.3mm whereas the qualified value should have been less than 0.3mm. TomTom used Moldex3D to design several trial methods and predict each warpage results. As a result, they were able to obtain the most effective design and meet the specification.

Challenges

- The mold trials display a serious deformation issue
- The gap exceeds the required spec. (≥0.3mm)

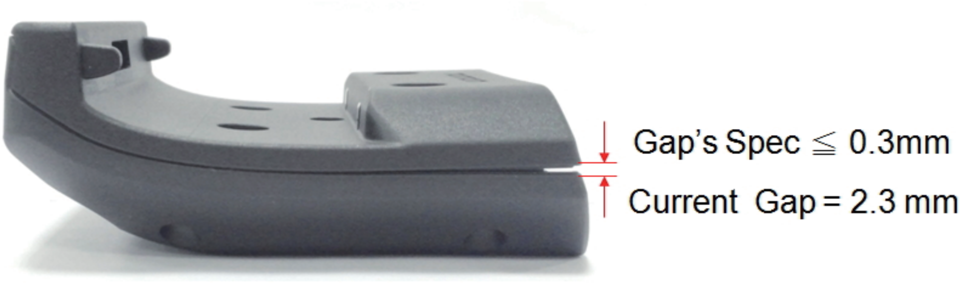


Fig. 1 The deformed situation of a real product showed 2.3mm which was over the spec. requirement.

Solutions

TomTom utilized Moldex3D eDesign to simulate the temperature, pressure drop and mechanical perspectives of several improved designs and was able to find out the most optimized design.

Benefits

- The assembly gap has been significantly reduced from 2.3mm to 0.25mm
- Reduced mold-trial frequency by 3 times
- Raised the yield rate from 55% to 92%
- Reduced the cost by USD$20,000 and development time by 6 weeks

Case Study

The product in this case is the front cover of a cradle, and its main function is to lend support to the navigation device. The objective of this case is to reduce serious warpage after molding. TomTom utilized Moldex3D eDesign to simulate the molding scenario of the original design and observed obvious issues. In the original design, the front cover is locked with the mating part and there is a 2.3mm gap which exceeds the spec. of 0.3mm. Fig.2 shows the CAD model and its simulation result, in which serious warpage at the edge of the part can be observed. The dotted line in Fig. 2 shows the deformed tendency. It will affect the assembly and cause shape defects that would have a direct negative impact on the dimensional functionality and its physical appearance. Thus, in order to solve this problem and produce high-quality products with fine aesthetic attributes, TomTom considered applying several alternative revised designs.

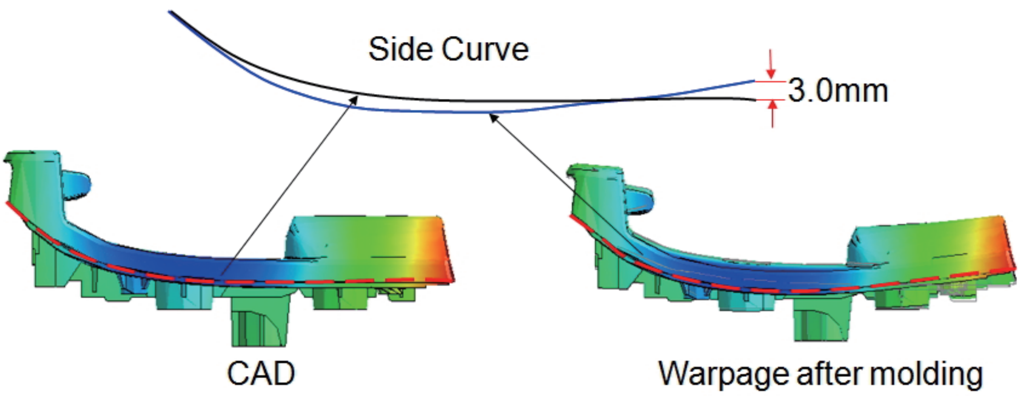


Fig. 2 The CAD model of the original design (left) and its simulation result (right)

Fig. 3 shows a large pressure drop and it is a critical factor that dominates deflection. Thus, the following study mainly focuses on how to reduce this pressure drop. Apart from the pressure drop, uneven heat distribution is another factor of deformation and will also be considered in the revised design.

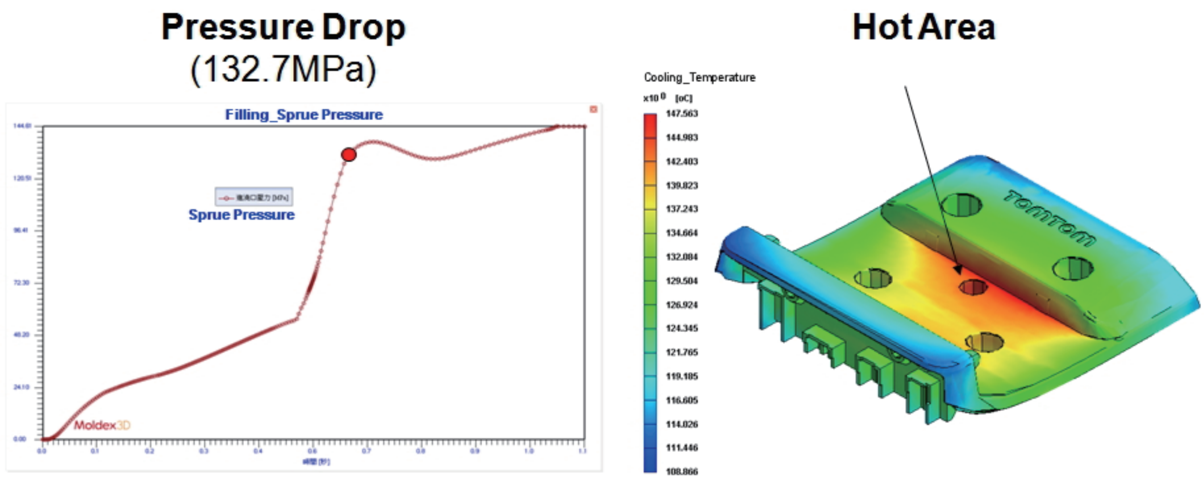


Fig. 3 (Left) Original design of simulated sprue pressure results ;
(Right) Heat accumulation in the center region

TomTom considered three influential factors including thermal, mechanical and pressure drop to reduce warpage. Table 1 shows the 6 design changes proposed by TomTom and the contributing factors they considered.

Considered Factors of Warpage	Revised Design	Design Changes	Targets
Thermal factors	Type A	Add cooling channels in the hot area	To increase the cooling efficiency and diminish mold temperature differentials
Mechanical factors	Type B	Add ribs in the weak area	To strengthen the weak region to maintain the shape accuracy
Pressure drop factors	Type C	Change the gate locations and numbers	To improve flow balance and reduce the pressure drop for a more uniform pressure distribution
	Type D	Increase the wall section by 0.3 mm	To enhance the packing efficiency and melt pressure of the penetration in order to achieve uniform volumetric shrinkage
	Type E	Reduce the length of the runner	To shorten the flow path to increase the packing efficiency and achieve uniform volumetric shrinkage
	Type F	Change the cold runners to hot runners	To reduce the length of runner (This mechanism is the same as type E).

Table 1 The 6 design changes

Table 2 is the summary of the pressure drop, warpage of the original and each revised design. As shown in the results, Type C, D, E and F have a higher contribution on warpage reduction. Thus, TomTom combined these 4 design changes as the optimized design. Fig. 4 shows the comparison of the optimized design with the lowest pressure, 31.25 MPa, and the minimum deviation with the CAD model.

Type	Pressure Drop (MPa)	Side Curve Warpage (%) Compared to CAD
Original	138.33	31
Type A	138.28	30
Type B	137.31	28.2
Type C	88.26	15.71
Type D	86.58	14.32
Type E	73.21	17.26
Type F	52.17	8.59

Table 2 Summary of pressure drop and warpage condition

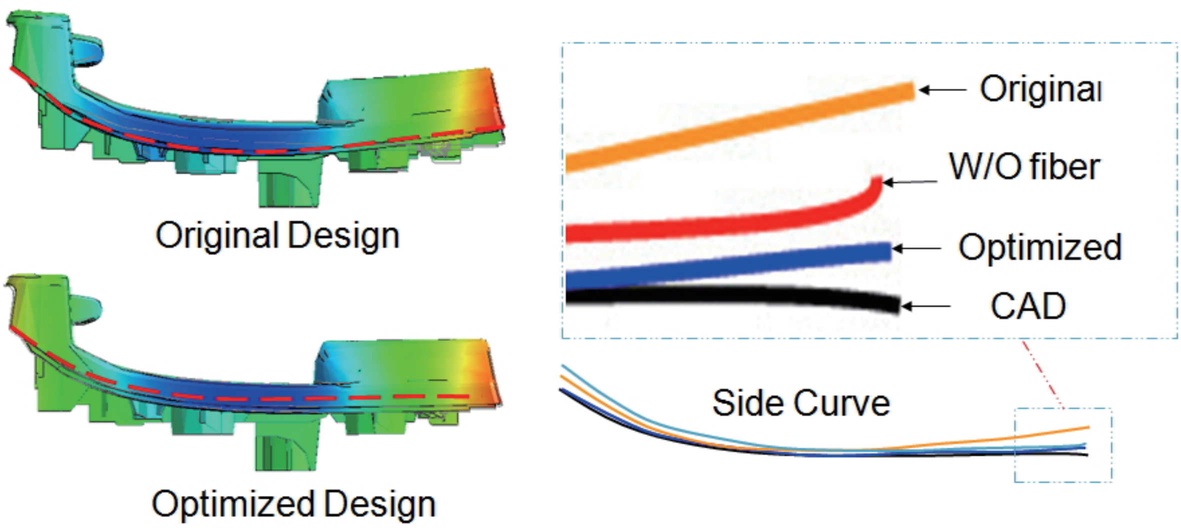


Fig. 4 Optimized profile of deflection diagram

After the design modification, TomTom used Moldex3D eDesign to simulate both the original design and the optimized design. The analysis results of the original product design showed obvious warpage. In the optimized design, there is a qualified magnitude and significant improvement on warpage. Next, TomTom compared the simulation results with the actual mold trial results and found a high correlation between both results. The original gap is 2.3mm and the gap in the optimized design has been reduced to 0.25mm, which is a great improvement (Fig. 5).

Fig. 5 The photo of actual molded part in original and optimized gap

Results

Through Moldex3D's analysis, TomTom clearly understood the deformed tendency and was able to predict the potential manufacturing difficulties prior to actual production. In the end, TomTom was able to successfully solve manufacturing issues and optimize the product and mold designs.

FARPLAS Using Moldex3D to Overcome Difficult Molding Issues in Multi-shot Injection Molding

FARPLAS

Customer: FARPLAS A.S.
Country: Turkey
Industry: Automotive
Solution: Moldex3D eDesign, MCM Module

Image Courtesy of FARPLAS

FARPLAS is a world leading auto manufacturer that operates as a full-system supplier and determines to sustain the best outcomes at the lowest costs. With more than 40 years of experience, the spirit of an investor, global understanding, and customer oriented approach, it has excelled in every field it operates. (Source: http://www.farplas.com.tr)

Executive Summary

This study examines the filling analyses of PP+GF30 and ethylene propylene diene monomer (EPDM), consecutively. It is particularly difficult to work with this multi-shot injection molding. Glass fiber must be oriented along the flow direction, influencing the part deformation. If the distorted piece cannot be fitted accurately while being inserted to the other compartment, EPDM filling cannot be performed. Another problem is the inability to fill a fine-layered EPDM onto PP+GF30 in a full balanced manner. Several analyses on a gasoline tank casing mold have been performed in Moldex3D. The results help to foresee the potential issues and save time for proper modifications accordingly.

Challenges

- Undesirable deformation after PP+GF30 filling
- Correct gate locations and cross-section of the passage for EPDM filling
- Sufficient EPDM filling amount to compensate the quantity and the interval of the hot runner as well

Solutions

Moldex3D can help to obtain correct design modifications, which result in smaller warpage in the first filling (PP+GF30) and good filling behavior without short shot in the second filling (EPDM); its high mesh level option also leads to closer results (nearly 100% accurate) between simulation and experiment.

Benefits

Product Quality Improvement:

- Reduce total displacement of PP+GF30 filling
- Achieve short-shot-free EPDM filling
- Obtain close-to-100% accuracy between simulation and experimental results of warpage and filling behavior
- Save the required time to finish the design modifications as well as production cycle time and development costs

Case Study

The objective is to solve the problems in multi-shot injection molding of PP+GF30 and EPDM in which the warpage resulted from the first filling (PP+GF30) should be minimized to a certain level to avoid any mismatch when the part is inserted to the other compartment for the second filling, and the cavity of the second filling (EPDM) should be properly designed to ensure a complete filling.

In this case, Moldex3D was first utilized before commencing the mold design of the first filling in order to initially obtain the right design with acceptable part deformation. Then, the analysis of the second filling was carried out, while the first mold design was underway. Finally, the mold design of the second filling referred to the modified one after the short-shot problem had been overcome through the simulation analysis. Moldex3D detected the two critical issues for this case: warpage problems from the first filling and incomplete filling from the second filling. The design modifications for the cavity of the first filling comprised the addition of ribs at certain regions to support part rigidity and the removal of some particular regions to promote more uniform wall thickness. (Fig. 1) As the supporting ribs were added, the warpage from the first filling was reduced. (Fig. 2)

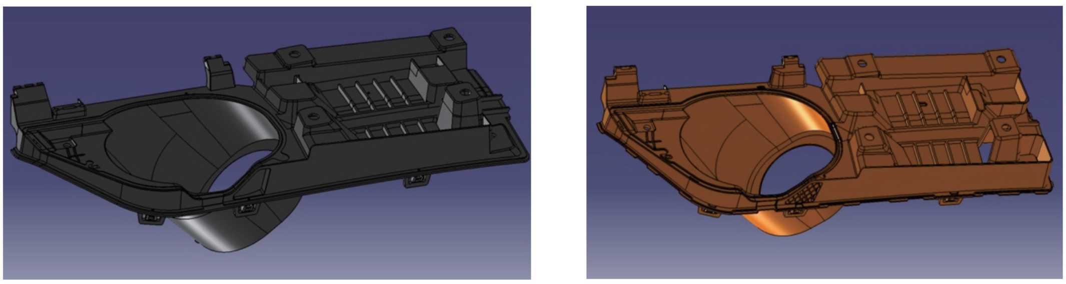


Fig. 1 Compared to the original design for the cavity of the first filling (left), the final design (right) has more ribs, and some of its sections have been core out.

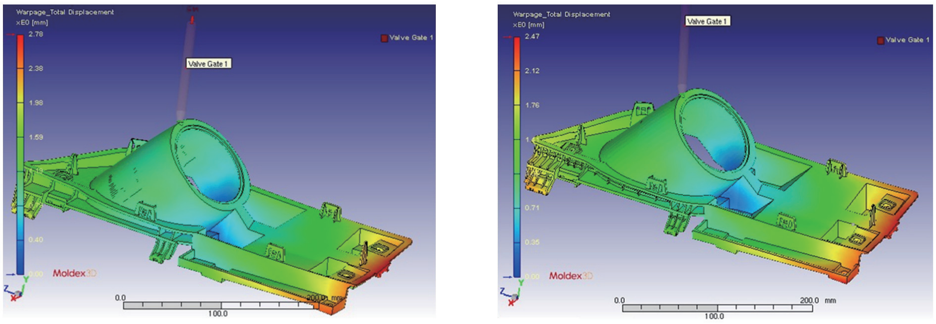


Fig. 2 The original design without supporting ribs (left) results in larger warpage total displacement (max: 2.78 mm) than the modified design with supporting ribs (right) (max: 2.47 mm).

The design modifications for the cavity of the second filling comprised the geometry (Fig. 3) and the thickness (Fig. 4). Due to these changes, the EPDM filling behavior had been improved so that the filling could be completed without any short shot. (Fig. 5)

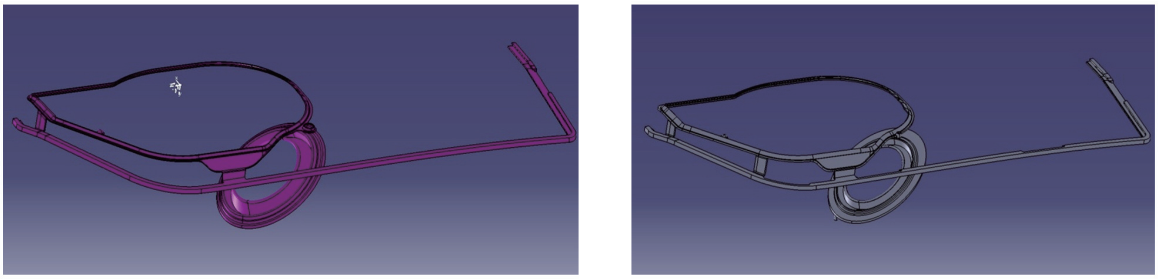


Fig. 3 The geometry of the original design for the cavity of the second filling (left) has been modified for its final design (right).

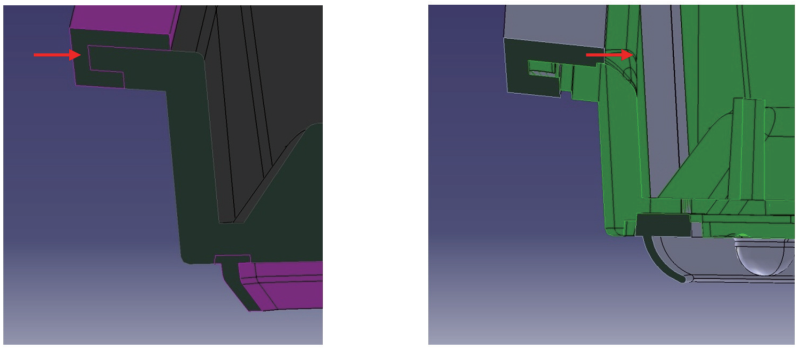


Fig. 4 The thickness of the EPDM passage in the final design (right) have been increased, compared to the original design (left).

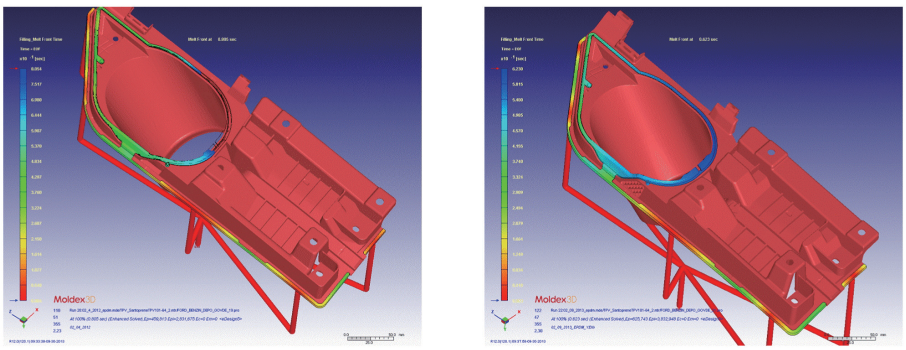


Fig. 5 The short shot problem for the original design (left) has been solved in the final design (right).

The design revisions were verified by comparing their filling results with the results from their original designs in which the improvements could be observed; the warpage had been minimized and the short shot had been solved. Furthermore, the simulation results were also compared to the experimental results in which both simulation and experiment were in a good agreement; the similarity was nearly 100% accurate when the mesh level for the simulation analysis was changed from 3 to 5. One of the examples is the following short shot issue from EPDM filling (Fig. 6 & Fig. 7):

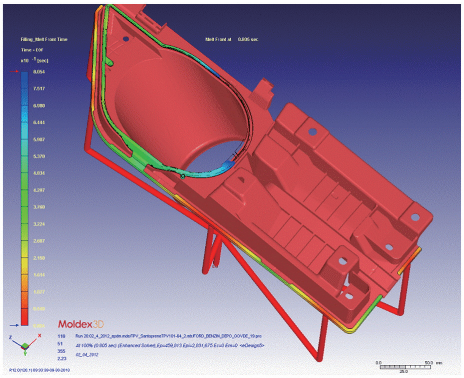
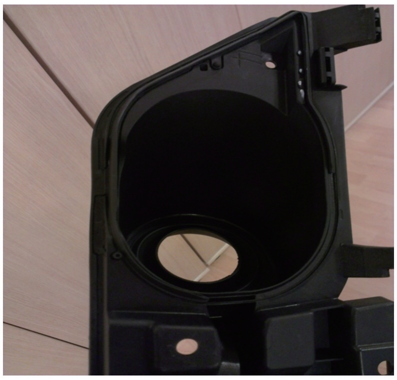



Fig. 6 The short shot location of the original design in the simulation (left) is similar to the one in the experiment (right).

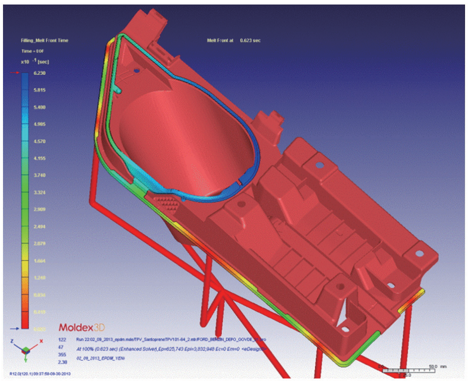



Fig. 7 Both simulation (left) and experiment (right) result in short-short-free filling in the final design.

Results

Through Moldex3D analyses, both warpage of the first filling (PP+GF30) and filling behavior of the second filling (EPDM) could be understood well. By providing the mesh level of 5 for the simulation model, the simulation results could be nearly 100% accurate compared to the experimental results. These benefits could help to predict the potential manufacturing difficulties prior to the actual production, so any necessary modifications could be made beforehand, which in turn had savedalot of time for design improvements and development. As a result, FARPLAS A.S. could successfully solve the critical manufacturing issues in this multi-shot injection molding.

World's Leading Automotive Part Supplier Utilizes Moldex3D Analyses to Make Confident Decisions on Product Design Optimization

Customer: Faurecia Interior Systems India Pvt. Ltd., Pune
Country: India
Industry: Automotive
Solution: Moldex3D eDesign

Image Courtesy of Faurecia Interior Systems India Pvt. Ltd., Pune

With 320 sites including 30 R&D centers in 34 countries around the world, Faurecia is now a global leader in its four areas of business: automotive seating, interior systems, automotive exteriors and emissions control technologies. Faurecia is the world's number one supplier of seat frames and mechanisms, emissions control technologies and vehicle interiors. The Group is also the world's third-largest supplier of complete seat systems and is Europe's leading name in automotive exteriors. Faurecia has one R&D center and two production plants in Pune. (Source: http://www.faurecia.com/)

Executive Summary

This case features an important automotive interior part: a center console fascia. Since it is a visible part, a high level of aesthetic quality and appeal is required. Visible defects such as sink marks, weld lines and flow marks should be controlled in less visible areas of the part and kept at a minimum. Also, part warpage should be reduced in order to keep the dimensional precision within the gap and flush tolerance to ensure a proper part assembly. However, it's a difficult challenge to fully control the warpage and eliminate the defects merely based on the previously accumulated molding knowledge and experience. Thus, Faurecia resorted to the help of Moldex3D simulation solution to make confident decisions on part and mold design optimization. Through Moldex3D detailed analyses, they were able to look at a full spectrum of molding aspects, including the detailed analyses on filling, packing, cooling and warpage and examine possible solutions to resolve the critical product defects and manufacturing difficulties. Ultimately, Faurecia was able to achieve their goal and complete their project successfully.

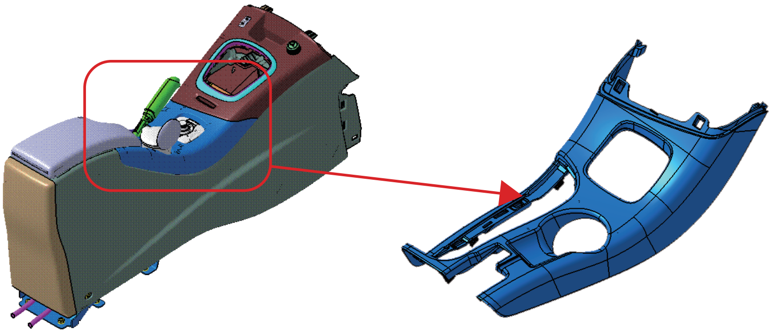


Figure 1: This case features an important automotive interior part: a center console fascia.

Challenges

- Avoiding visual defects such as sink marks, weld lines, and flow marks on the visible areas of the part
- Reducing warpage within the gap and flush tolerance for part assembly
- Controlling proper temperature and pressure to avoid over-packing and short filling

Solution

The goal of this project was to overcome the hurdles and challenges during the design and development phase instead of at the later tool launch or the mold trial stage. In this case, the whole Moldex3D eDesign analyses including filling, packing, cooling and warpage were utilized for a detailed study and design optimization.

Benefits

- Successfully avoiding weld lines in visible areas
- Drastically reducing part deflection to keep the gap and flush well maintained within the acceptable tolerance for part assembly
- Significantly reducing tool tuning cost by 68%
- Successfully reducing what was traditionally a high scrap rate down to an unprecedented negligible number

Cast Study

In this case, Faurecia utilized Moldex3D eDesign full package to get in-depth insights into what might happen in the real molding with the original design. Through Moldex3D simulation results, Faurecia found out that with the original design, weld lines would occur in the visible areas of the part and warpage was severe enough to jeopardize the part precision and it might cause a failed part assembly later. Also, due to the drastic pressure and temperature drop, over-packing was observed near the gate area, and short filling was found in the thin rib region. In order to solve the abovementioned issues and produce a fine part of high aesthetic appeal, Faurecia proposed a different feeding system design along with a change in the part thickness to tackle the problems.

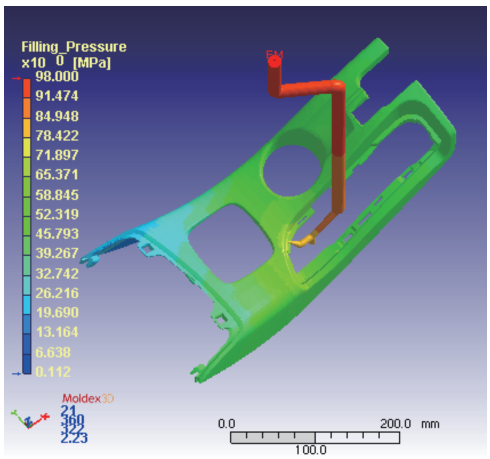


Figure 2: The original feeding system design: with one hot drop and one inverse sub-gate.

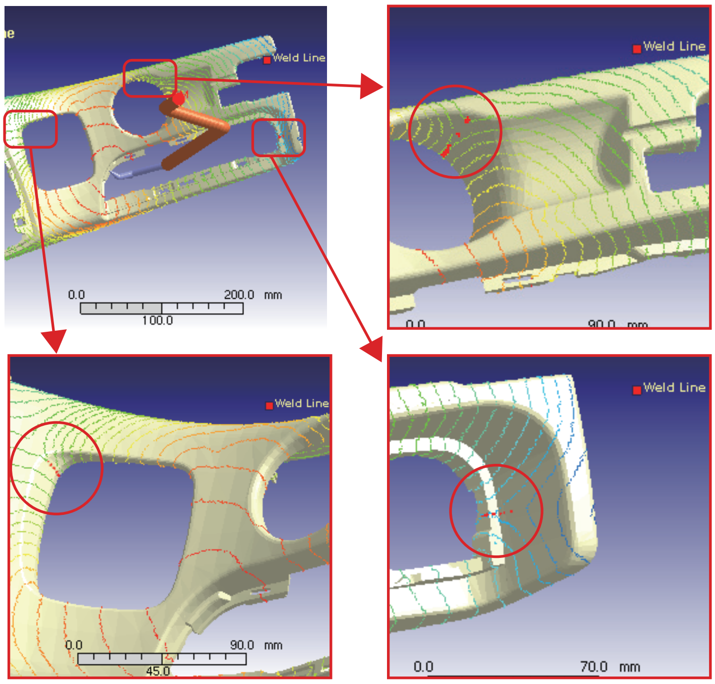


Figure 3: According to Moldex3D's filling analysis, the weld-lines were observed in the visible areas of the part in the original design.

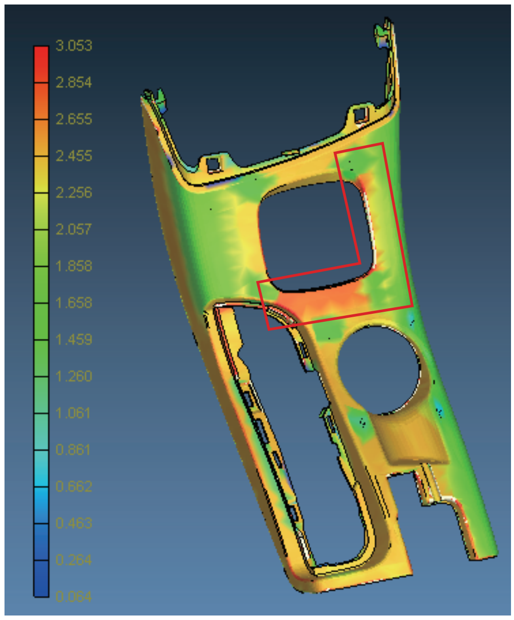


Figure 4: The circled area indicated a change in the part thickness in th e revised design.

First of all, given the fact that the main goal of this project was to avoid/minimize all types visible defects like weld lines, sink marks, flow marks etc., Faurecia suggested a thickness reduction in the fillets (Figure 4) to avoid corner effects and other significant warpage in the Y & Z directions. In addition to making a change in the part thickness, Faurecia revised the feeding system design. That is, to better control the pressure and temperature drop in the cavity, Faurecia added one hot nozzle instead of injecting with only one single nozzle, then they added one more branch of cold runner with submarine gates to make the flow more uniform. Injection ribs were also added in the part for submarine gates to be placed (Figure 5). With the help of Moldex3D simulation results, the revised design proved to be very effective in improving visible defects and showed positive results.

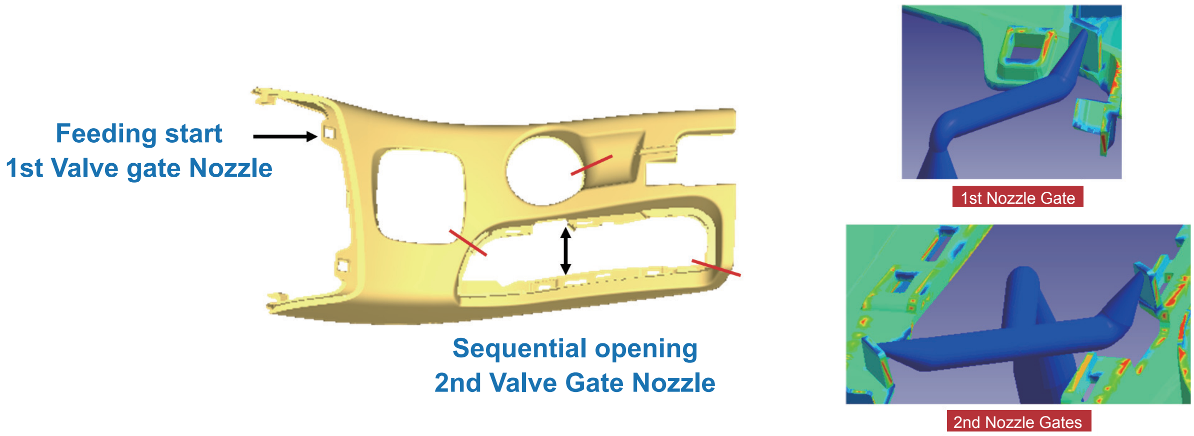


Figure 5: One more hot nozzle and one more branch of cold runner were added in the revised feeding system design.

The following Moldex3D's analysis results show a significant improvement in the weld line locations in the revised design. The weld lines were successfully moved to the corners, the less visible areas of the part (Figure 6).

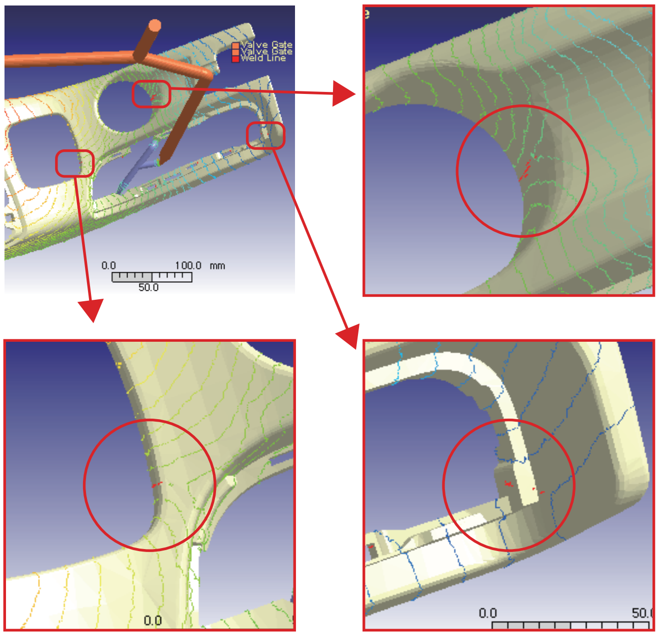


Figure 6: Two weld lines were moved to the corners and one weld line (upper right) was visible, but would be covered by another part in the assembly.

Then, Faurecia conducted a correlation study between the simulation results and the actual injection trials in order to observe the accuracy of simulation and see how their suggestions were working. Moldex3D's filling and the filling defect predications matched perfectly with the actual injection trials (Figure 7 & 8).

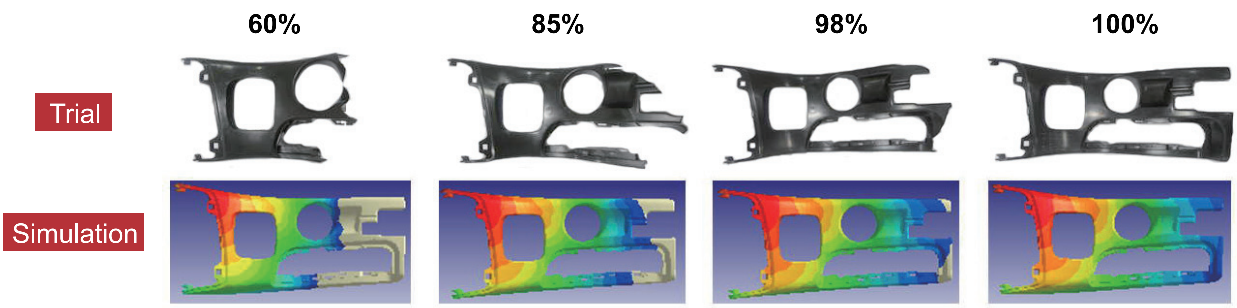
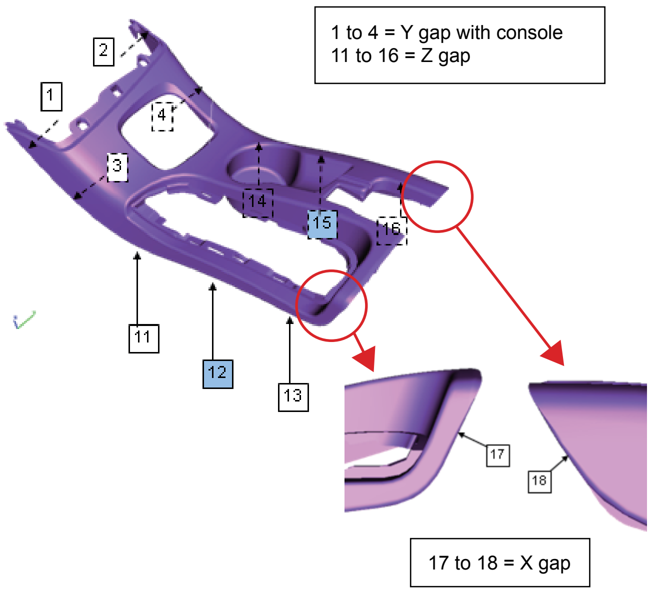


Figure 7: Moldex3D filling prediction matched perfectly with the actual injection trial.

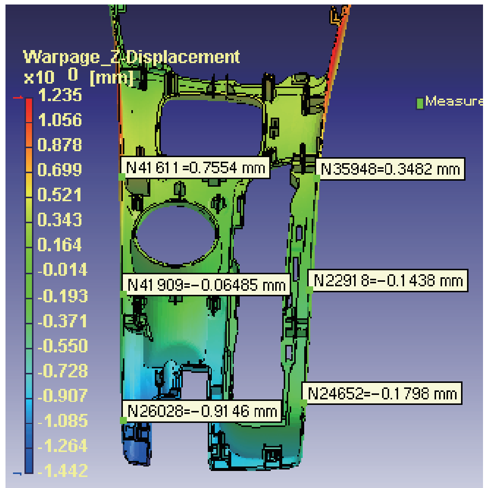
Figure 8: The weld line occurred in the actual injection trial (left) and some changes in gloss on the surface in the flow hesitation area were observed (right).

According to the actual injection trial, Moldex3D's warpage prediction was proven to be highly reliable. With the revised design, the part deflection in the Y and Z directions were drastically reduced. Thus, the warpage was greatly reduced to fit within the gap and flush tolerance to ensure a successful console assembly.

Trial Part CMM - Points Layout



Simulation - Deflection Z - points 11 to 16



	P11	P12	P13	P14	P15	P16
CMM	0.01	-0.47	-0.63	-0.68	-0.51	-0.23
Simulation Vz	0.35	-0.14	-0.18	-0.91	-0.16	+0.76
Deviation	0.34	0.34	0.45	0.23	0.45	0.99

Figure 9: The CMM is done on painted part with complete console assembly to check the gap and flush.

Figure 10: The satisfactory warpage comparison between the simulation and the actual CMM trial proved to be close to the reality.

Results

Through the accurate simulation results by Moldex3D, Faurecia was able make good use of the simulation data to optimize the filling and packing profiles and successfully avoid the occurrence of weld lines in the visible areas of the part. Also, the Y and Z deflections were drastically reduced, making the gap and flush well maintained for a successful console assembly.

In addition, with the involvement of Moldex3D's simulation results into the design and development phase, the tool tuning cost, which normally contributed to at least 4% of the total tool cost, was able to significantly reduce down by 68%. Moreover, generally speaking, the scrap rate of the similar type of components was very high due to the strict aspect requirements; however, for this part the scrap rate was greatly reduced to an unprecedented negligible number. Each design change was simulated and validated by Moldex3D analysis, thus, Faurecia was able to make confident decisions in every stage of the product development and optimization phase. That is, by optimizing the part and feeding system designs, Faurecia was able to achieve these phenomenal results: prolonging the tool life, lowering part rejection and successfully completing the project.

Accurate Simulation Results on MuCell ® Technology Enables Adoption of Moldex3D Solution

proplast
PLASTICS INNOVATION POLE

Customer: Proplast
Country: Italy
Industry: Research & Education
Solution: Moldex3D Advanced, Foam Injection Molding Module

Image Courtesy of Proplast

Proplast was founded in Alessandria (Italy) in 1998 with the mission of supporting enterprises in the plastics sector with a special focus on applied research, technological innovation, recruitment of industry talents, and training of human resources. In May 2008, Proplast opened its new 3500 sqm premises which tripled the amount of space dedicated to technical services for plastics sector entreprises. Proplast started its activities with the support of four founding members (Bayer, Basell, Guala and Mossi & Ghisolfi), and has hugely grown with the significant support of other companies, associations, and universiteis involved in the whole plastics chain over the years. (Source: http://www.proplast.it/)

This project was developed by Proplast in cooperation with Engel Italia, Trexel and Onni-stamp.

Executive Summary

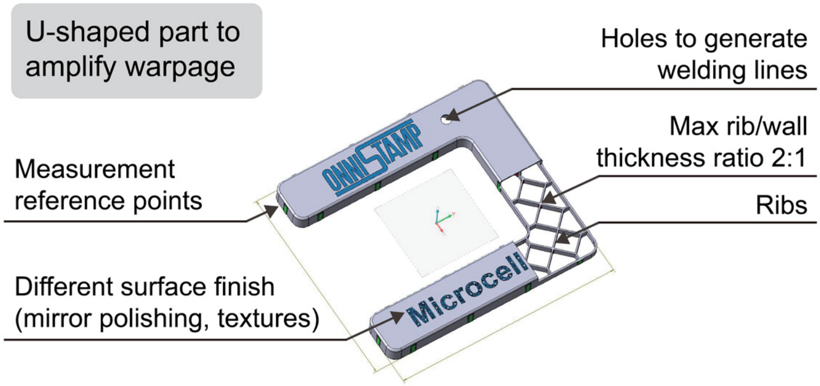
Proplast's goal in this project was to support their customers at every stage of the MuCell® technology implementation. The support went from part design and mold design to MuCell® molding trials and mold piloting. Being that this is a challenging and complex process to approach, Proplast resorted to the aid of Moldex3D solution for MuCell® technology to help engineers navigate through the whole process, optimize part and mold design, and successfully complete the project achieving positive results at the end.

Challenges

The greatest challenge in this case study was to accurately predict MuCell®, and make optimizations accordingly. In this case, four particular areas were identified to further study the effects of MuCell® technology:

- Sink marks
- Warpage
- Cells size prediction and validation
- Cells density prediction and validation

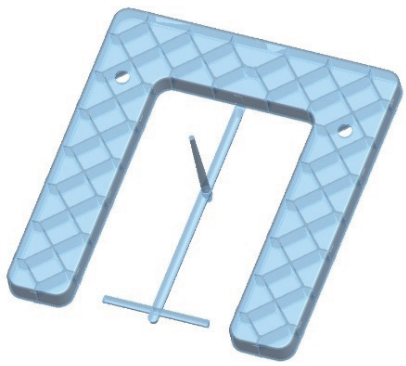
Every step of the process was supported by using the simulation software, Moldex3D.



Specific features were added to the part design to further help evaluate, measure, and compare results

Solutions

Moldex3D simulation capabilities offer an opportunity to simulate both conventional molding and MuCell® injection molding. Basing upon software simulations, Proplast was able to compare results of each process and better understand operating differences between the two. Futhermore, Proplast's goal of conducting an in-depth analysis on the microcelluar molding process, including cell dimension, cell denisty and cell distribution was fulfilled through the use of Moldex3D simulation technology.



Part Design

Benefits

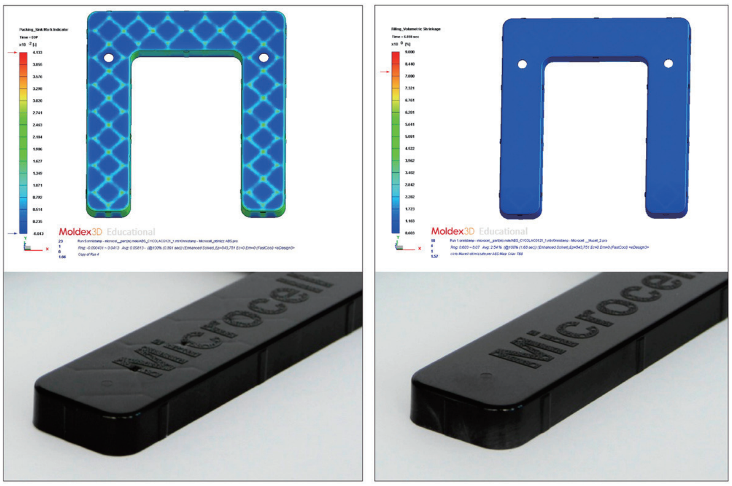
Moldex3D provided an all-around simulation analysis on every aspect of the MuCell® process. With the valuable data from the Moldex3D simulation, Proplast was able to gain insights into the MuCell® process, optimize part and mold design, and most importantly offer constructive recommendations to guide their customers throughout the MuCell® implementation. Moldex3D's Foam Injection Molding simulation includes analysis on:

- Process settings
- Cycle time
- Pressure
- Clamping force
- Expansion / weight reduction
- Volumetric shrinkage / sink marks
- Warpage / residual stress distribution
- Local cell size
- Cell distribution and density

Case Study

Virtual foam injection molding is a great help in the whole process to predict MuCell® technology in order to understand the real benefits MuCell® technology can bring. Moldex3D simulation enabled access to the following important aspects of the MuCell® technology:

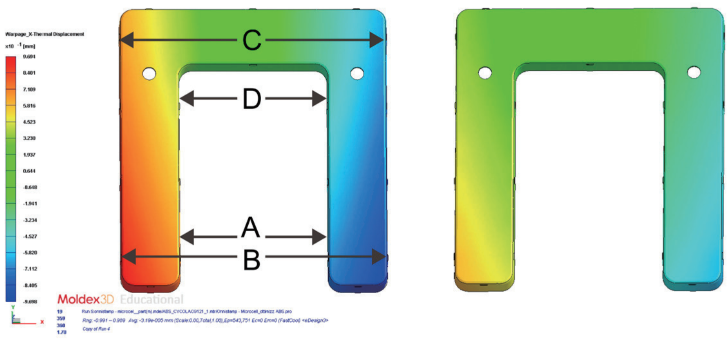
1. Sink marks:



Compact molding (left): Visible sink marks vs. MuCell® (right): No sink marks

The experiemental mold trial results proved that the simulation showed great accuracy of the sink mark prediction on both the compact and MuCell® process. Also, from this example, it demonstrated clearly that the MuCell® technology prevents sink marks very effectively.

2. Warpage:



Compact molding (left): Warpage is more severe than MuCell® (right)

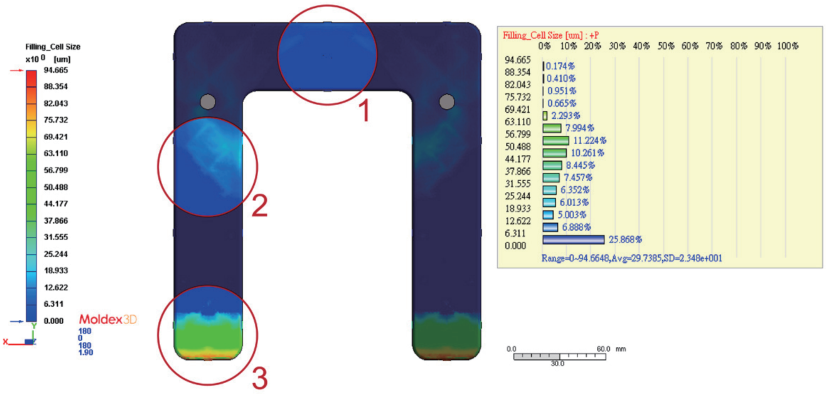
Moldex3D successfully predicted the corner effect for both the compact part and the MuCell® part and at the same time helped visualize the improvement on deformation using MuCell® before the part is actually injected.

	Nominal	Compact Molding		MuCell®		Variation (%)
		Simulation	Measurement on real part	Simulation	Measurement on real part	
A	100	108,76	109,17	109,22	109,16	-0.05
B	200	198,10	198,64	198,76	198,72	-0.02
C	200	198,61	198,92	199,18	198,86	-0.29
D	110	109,21	109,30	109,52	109,20	-0.29

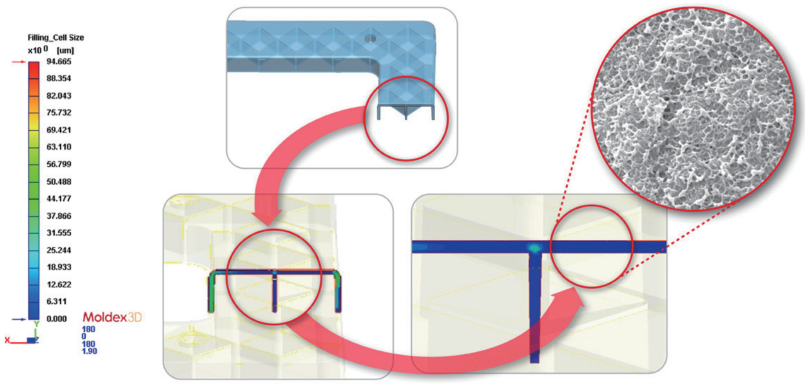
Both simulation results and real part measurements showed great improvement on deformation using MuCell®

3. Cells size prediction and validation:

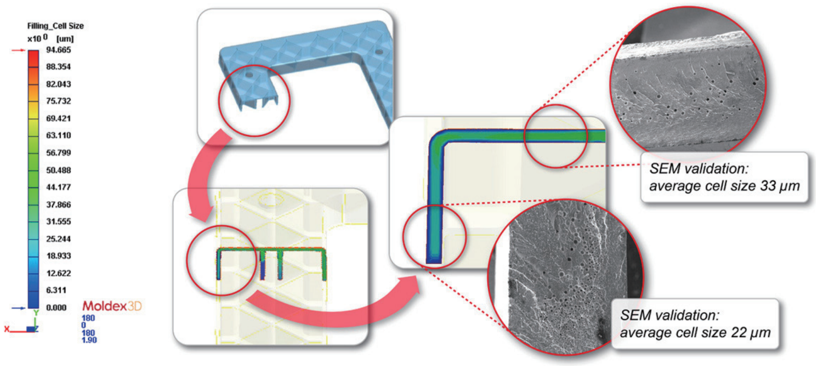
The cell size prediction is crucial for MuCell® process, as the part quality and mechanical strength rely on the uniform cell distribution and adequate cell size. Their correct prediction along the part is essential to make the design correct prior to production. In this case study, the validation focused on three locations (as shown in the following pictures): 1. Gating region, 2. Middle flow region, 3. End of flow region, in order to observe the cell growth along with the flow length, and to validate the reliability of the software on the cell size prediction.



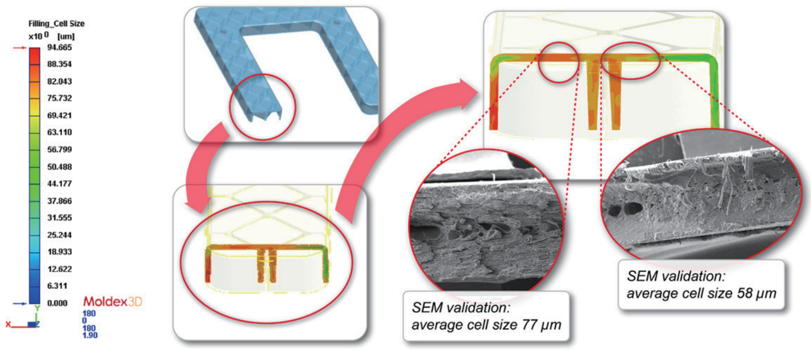
Location 1- Gating region: The cells remain small in size due to the high pressure near the gate location. The simulation result provided good prediction of the cell size, validated by the SEM.



Location 2-Middle flow region: The cells grow as they go further from the gate; both simulation and SEM revealed the same trend. The cells on the skin have less time to grow as compared to the core of the part, therefore the size is smaller.

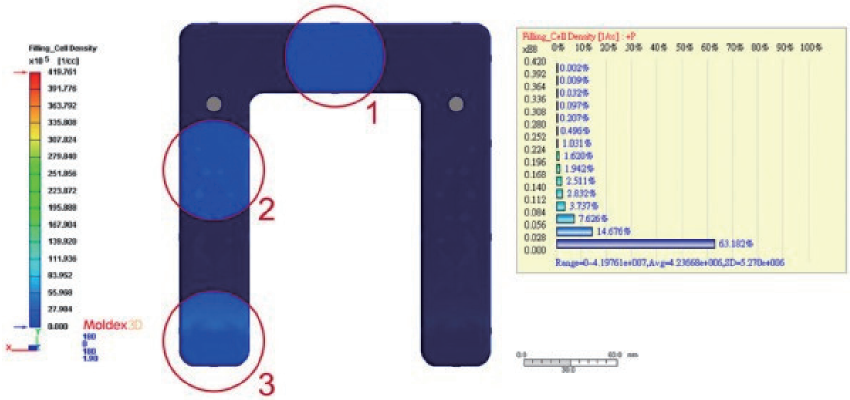


Location 3- End of flow region: At the end of the flow area, the material has travelled the entire path which allows the cell to grow; also, the pressure at the flow front is low and makes no constraints on the growth of the bubbles. It is observed in both simulation and SEM validation, that the large cells are formed. Also, the cell sizes may vary in different parts of this region.

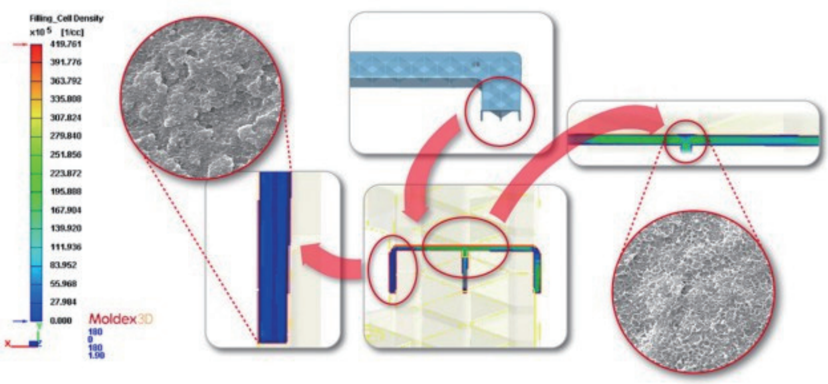


4. Cells density prediction and validation:

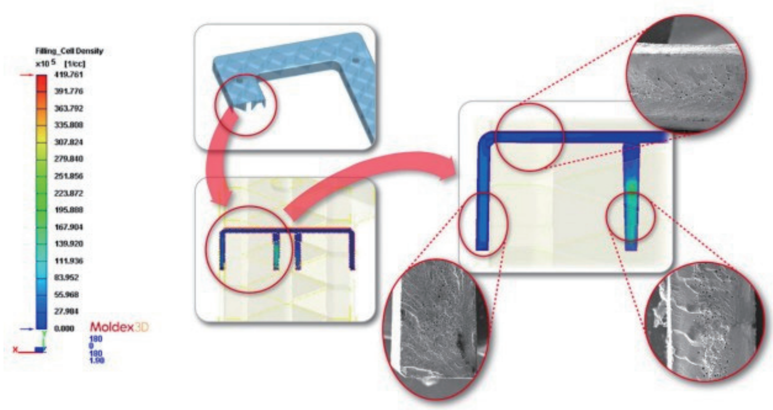
In addition to the cell size, cell density is equally important for MuCell® process. The cell density and cell size are in competition, when the average cell size grows along the flow length, it occupies a bigger area and inevitably the density of the cell drops along the way. Here, the simulation results and SEM are shown for the comparison (as shown in the following pictures).



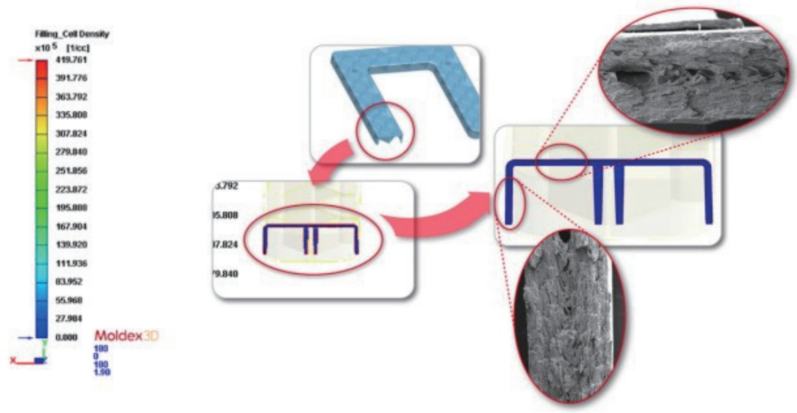
Location 1- Gating region: The density is more difficult to be measured in SEM. By comparing the simulation results and SEM, users are able to understand the relevance between the analysis and the experimental part in density calculation. At the gate area, when the pressure is higher than the saturation pressure, the bubble is not formed. While the bubble starts to grow in this area, the high pressure limits the cell size and allows the formation of each individual bubble (cell nuclearation) without merging them into one big bubble. Here, the simulation and SEM show the same results in this scenario.



Location 2-Middle flow region: As the flow advances down the path, the cells also grow. When they grow bigger, a given space contains fewer cells, resulting in lower cell density.



Location 3- End of flow region: At the end of flow area, the bubbles are much developed and merged together, resulting in very low density with only a few cells visualized by SEM.



Results

In summary, through this case study, we could recognize that:

- MuCell® technology is ideal for parts requiring minimized sink mark. Even when the part design is not conventionally optimal (high thickness regions far from gate, high rib/wall ratio), sink marks can be eliminated.
- MuCell® technology is able to significantly improve warpage in general.
- In theory, the improvement on the quality is influenced by the cell growth along the part, which depends on several factors, for example, the flow length and average thickness. In this case study we clearly see the cells growth in regard to this factor.

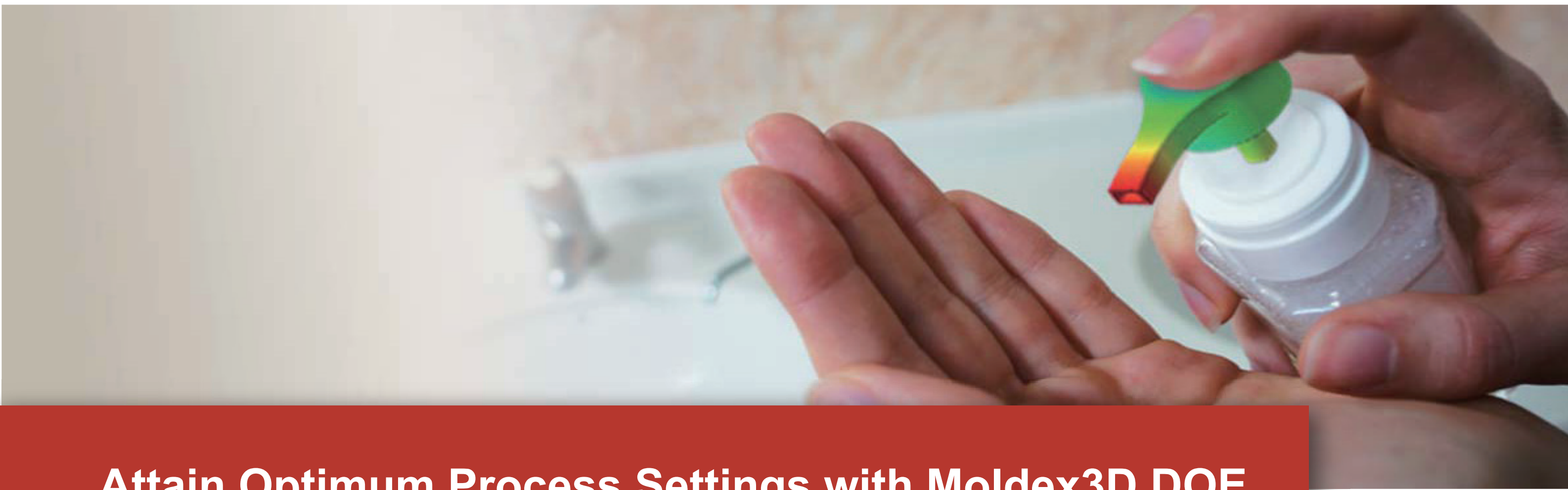
Most importantly, all these key points mentioned above are able to be precisely simulated and predicted by Moldex3D Foam Injection Molding simulation. With the help of Moldex3D, Proplast was capable of fully investiagting the MuCell® process to identify the key benefits, and sucessfully assisted their customers with the implementation of the MuCell® technology to achieve optimal surface quality.

The Value of CAE Simulation

“The methodology of CAE analysis, which was developed and assessed at Proplast, accurately and reliably simulate the MuCell® microcellular injection moulding process, and the quality and morphology of expansion. The flow simulation of MuCell® components performed using Moldex3D provides optimised process parameters and global molding quality (possible weight reduction, volumetric shrinkage, sink marks and warpage) as well as local microstructural description of the cellular structure (size, density and distribution of cells). A good predictive coherence has been observed regarding the here-mentioned study as far as process parameters, MuCell® expansion, weight reduction ability and warpage are concerned,” said Andrea Romeo, CAE Manager at Proplast.

“The flow simulation of MuCell® components performed using Moldex3D provides optimised process parameters and global molding quality as well as local microstructural description of the cellular structure.”

- Andrea Romeo, CAE Manager at Proplast



Attain Optimum Process Settings with Moldex3D DOE Module to Improve Part Quality

Customer: Plazology
Country: UK
Industry: Consultancy
Solution: Moldex3D eDesign, Expert Module

Image Courtesy of Plazology

Established in 2009 with the initial intention to supply injection mold tools globally, Plazology has expanded its services due to customers' requests. Plazology now take on full projects from part design to production roll out. As an experienced and dynamic company, Plazology strives to stay in touch with the latest technology within the Plastics Industry, applying their knowledge and experiences (subject to non-disclosure agreements) to the market/area of interest of our customers. This enables Plazology to support numerous customers to produce plastic components with high quality, good consistency and cost efficiency. Over the years, Plazology has built up excellent relationships with various organizations; this includes Universities both in the UK and overseas. (Source: http://www.plazology.co.uk/)

Executive Summary

In order to produce good quality injection molded parts with high consistency, a well-designed part and mold along with the right material and processing parameters is critical. Changes made to any of the mentioned four factors can have a significantly effect on the molded part. Without having true understanding of the polymer behavior inside the mold, more often than not, engineers tend to "process the part dimensions in". This leads to small processing window – slight change in process can cause the part dimensions to fall out of specification limit. The trial and error method is laborious, expensive and ineffective, making it infeasible to be conducted in today's fast moving industry.

Plazology, a leading company for injection molding technical consultancy based in United Kingdom, is seeing a big push in molding simulation, which is able to predict how parts behaves inside the mold and post molded phenomenon. According to Jasmin Wong, Project Engineer at Plazology, “Traditionally, customers look to prototype molds before commencing with large volume production molds. However, this adds cost and lead-time to the program,” Jasmin points out. “Using simulation is an element where we can look to gain great confidence that the parts are designed correctly for molding and the tools are designed with optimized cooling and gate positions.”

Plazology implemented Moldex3D because it helps them design faster with greater confidence. “Moldex3D has provided us with additional confidence in our own internal decision making,“ Jasmin stresses. “Not only do we use Moldex3D for full analysis work before building the actual tool, we can use it to troubleshoot current production quality issues too. This has aided our customers’ toolmakers who don’t have easy access to molding simulation, helping them to optimize their molds, cooling layouts and reducing cycle times.”

Challenges

- Warpage
- Concentricity

Solution

Use Moldex3D DOE module to determine the optimum process settings to improve warpage and linear shrinkage.

Cast Study

The following case study illustrates how Plazology utilizes Moldex3D plastic injection molding simulation software to attain optimum process settings.

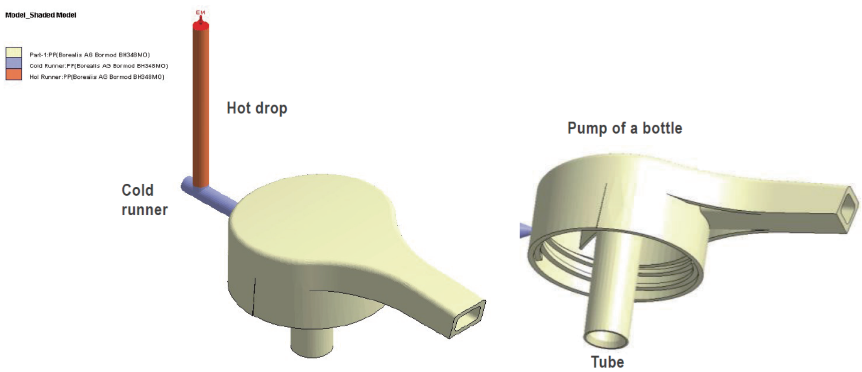


Figure 1. CAD model of a hand dispensing pump used in this case study

The above (Figure 1) is a hand dispensing pump of a sanitizer bottle. In this case study, the main area of concern for this model is the warpage as well as the concentricity of the tube, as it affects the fit and functionality of the pump. As the part has very tight tolerance, knowing the optimum process condition is required to keep warpage at the minimum and concentricity as circular as possible.

Plazology first carried out a preliminary Fill, Pack, Cool and Warp analysis to ensure that the part has no filling difficulty such as short shot or hesitation. DOE was then carried out. Since the area of concern is the warpage and concentricity, these two will be the quality factor/response used in this DOE. Four control factors that will affect warpage and concentricity will be used to carry out the DOE. In this case, melt temperature, packing pressure, cooling time and fill time was used. Taguchi L9 DOE was then conducted. (Note: Taguchi DOE assumes no significant interaction between factors which may not necessary be true. The reason why Taguchi was chosen in this case study is to find out the relationship between the factors and response using shortened simulation time.)

The Taguchi L9 DOE design can be seen in the Table 1.

No.	Control Factor	Level 1 (Low)	Level 2 (Original)	Level 3 (High)
1	Melt Temperature (°C)	225	235	245
2	Packing Pressure (MPa)	9	12	15
3	Cooling Time (sec)	8	10.6	12
4	Filling Time (sec)	0.1	0.2	0.3

Table 1. Taguchi L9 DOE design used in this case study

Table 2 shows the process setting of the 9 runs using Taguchi L9 Design. Moldex3D DOE then uses mathematical calculations based on user's specification (minimum warpage and linear shrinkage between nodes – used to measure concentricity which will be explained later in the article) to determine the optimum process setting, reflected as Run 10.

Run No.	Melt Temperature (°C)	Pack Pressure (MPa)	Cool Time (sec)	Fill Time (sec)
1	225	9	8	0.1
2	225	12	10.6	0.2
3	225	15	12	0.3
4	235	9	10.6	0.3
5	235	12	12	0.1
6	235	15	8	0.2
7	245	9	12	0.2
8	245	12	8	0.3
9	245	15	10.6	0.1
10	225	15	12	0.1

Note: Run 10 (optimized run) will be further explained under conclusion.

Table 2. Process setting of the Taguchi L9 runs

Warpage (Total displacement – mm)

From the 9 different runs, a main effect graph for warpage is plotted as seen in Figure 2.

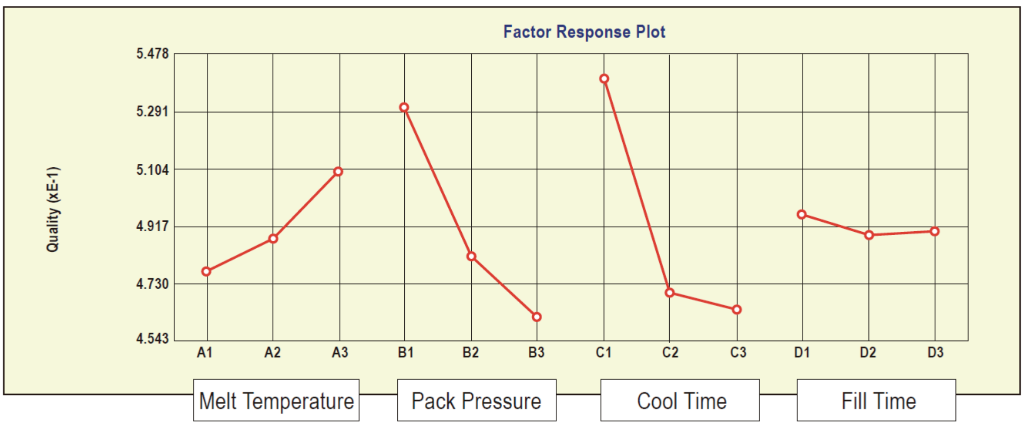


Figure 2. Main effect plot for part warpage

From Figure 2, it can tell that by increasing the pack pressure and cool time, warpage is reduced. Increasing melt temperature on the other hand, leads to higher warpage. Using fill time of 0.2 sec or 0.3 seconds seems to have slightly lesser warpage than 0.1 sec. **Hence, we know that in order to achieve lower warpage, the optimum process setting should be melt temperature – 225°C, pack pressure – 15MPa, cool time – 12 sec and fill time –0.3 sec.**

From the results obtained in Moldex3D, Plazology then make use of Minitab 17 (statistical software), to find out which of the four factors has the biggest influence in the part warpage. Based on the table in Figure 3, cool time which is ranked 1 has the biggest impact on part warpage, followed by pack pressure, melt temperature and lastly the fill time.

Response Table for Means

Level	Melt Temperature	Pack Pressure	Cool Time	Fill Time
1	0.4772	0.5305	0.5400	0.4955
2	0.4876	0.4818	0.4698	0.4888
3	0.5095	0.4621	0.4646	0.4900
Delta	0.0323	0.0685	0.0754	0.0067
Rank	3	2	1	4

Figure 3. Response table for means (warpage)

The area graph seen in Figure 4 also shows a quick comparison of the 9 different runs against warpage. Run number 3 seems to give lesser warpage as compared to the rest of the 8 runs.

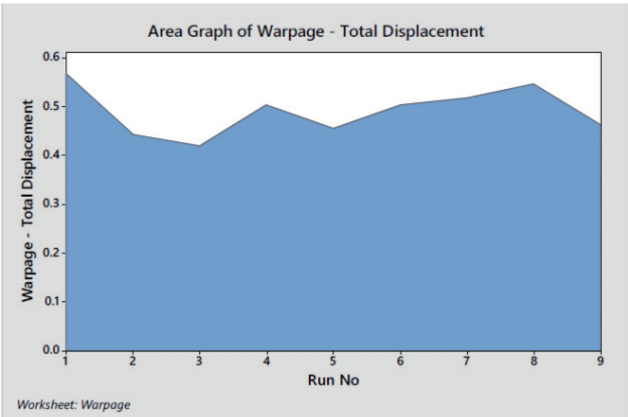


Figure 4. Area graph of part warpage (total displacement)

Concentricity (Linear shrinkage between nodes – %)

Concentricity is difficult to be measured, in real life or in simulation. In real life, distance between different points is measured using the coordinate-measuring machine (CMM). In Moldex3D, the linear shrinkage between different nodes is measured (see Figure 5 below). Eight different nodes were identified. The linear shrinkage of the diameter of the tube across A, B, C and D is measured. The lower the linear shrinkage, the more circular or better concentricity the tube of the part has.

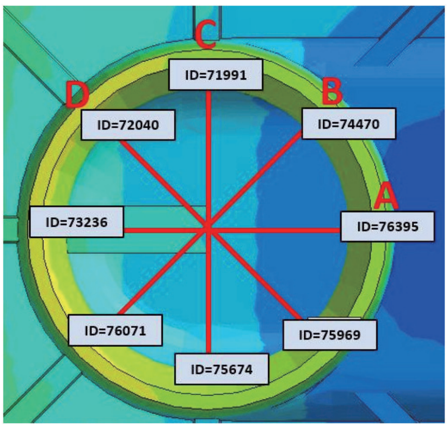


Figure 5. Eight different nodes measured for linear shrinkage

The main effect plot for linear shrinkage can be seen below in Figure 6.

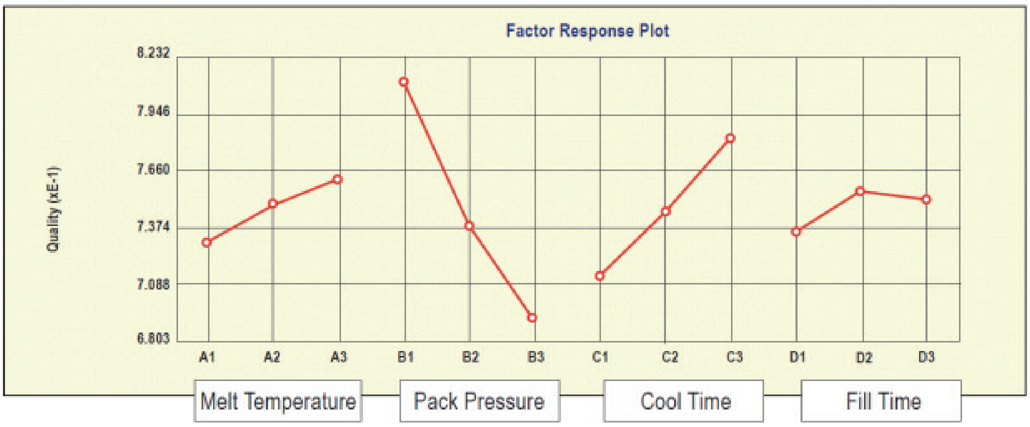


Figure 6. Main effect plot for linear shrinkage between nodes (measure of concentricity)

From Figure 6, it can be seen that in order to get better concentricity/linear shrinkage between the nodes, a lower melting temperature, cooling time and filling time with a high pack pressure is preferable. **Hence, we know that in order to achieve lower linear shrinkage, the optimum process setting should be melt temperature – 225°C, pack pressure – 15MPa, cool time – 8 sec and fill time – 0.1 sec.** However, a cool time of 8 seconds might not be practical since it will give high warpage (as seen in Figure 3).

Likewise, Minitab is used to find out which of the four factors gives the greatest impact on linear shrinkage. Based on the table in Figure 7, pack pressure is ranked 1. This is followed by cool time, melt temperature and lastly the fill time.

Since 8 sec cool time will lead to high warpage, a compromise may sometimes have to be made. As mentioned earlier, for linear shrinkage, pack pressure is more of a contributing factor than the cool time. Hence, it makes more sense to use 12 sec cool time with 15MPa Pack pressure.

Response Table for Means

Level	Melt Temperature	Pack Pressure	Cool Time	Fill Time
1	0.7302	0.8112	0.7135	0.7350
2	0.7491	0.7375	0.7451	0.7551
3	0.7617	0.6922	0.7824	0.7509
Delta	0.0315	0.1191	0.0690	0.0200
Rank	3	1	2	4

Figure 7. Response table for means (Linear shrinkage)

Comparing the 9 different runs for linear shrinkage (see Figure 8), run 6 gives lower linear shrinkage as compared to the other 8 runs.

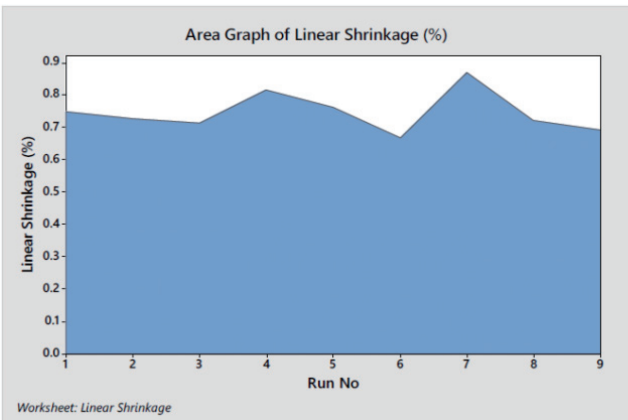


Figure 8. Area graph of linear shrinkage between nodes (measure of concentricity)

Benefits

Based on user specification, Moldex3D uses mathematical calculations to obtain the optimized run (Run 10). For this case study, weighting for warpage was the same as the linear shrinkage. However, based on the results above, the optimum process setting for lowest warpage is to have cool time of 12 sec and fill time of 0.3 sec. Optimum process for lowest linear shrinkage, on the other hand, requires a cooling time of 8 sec and fill time of 0.1 sec. Thus, Moldex3D came out with a compromise process setting (**melt temperature – 225°C, pack pressure – 15MPa, cool time – 12 sec and fill time – 0.1 sec**), which is used as the optimum run.

From the area graphs seen in Figure 9, it shows that Run 10 (optimized run), gives the lowest warpage compared to the other 9 runs, while continue having low linear shrinkage.

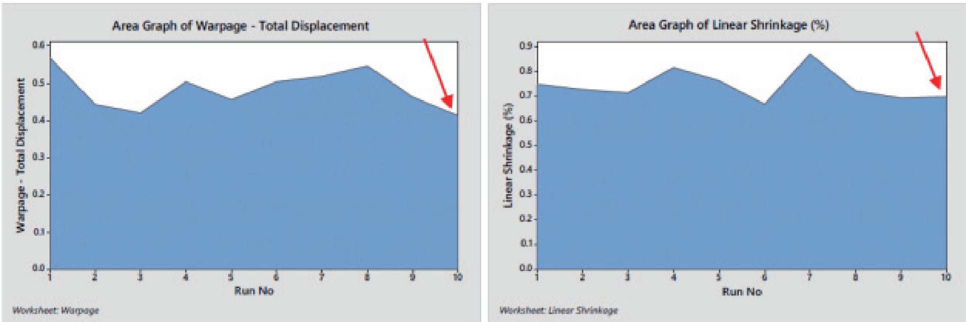


Figure 9. Optimized run (Run 10) is compared with the other 9 runs.

From the DOE simulation results (see Figure 10 and 11), it tells that the part warpage and concentricity of the tube has been significantly improved. Warpage is seen to have improved by approximately 20-30% while keeping a low linear shrinkage to approximately 0.6-0.7%.

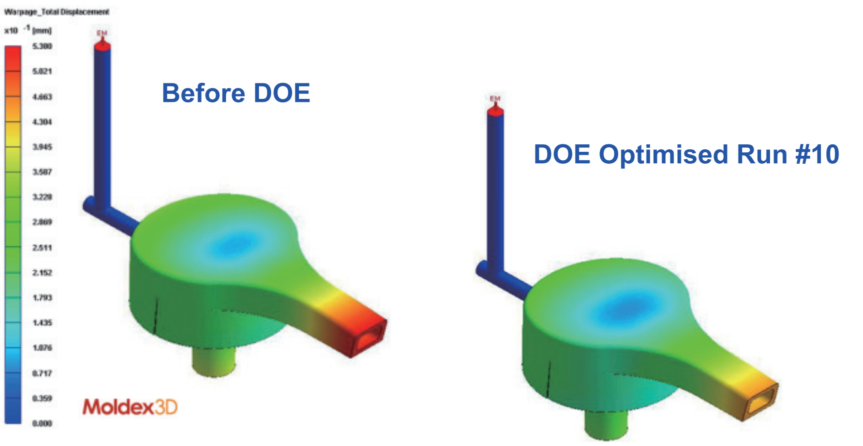


Figure 10. Improvement in warpage (total displacement) is observed

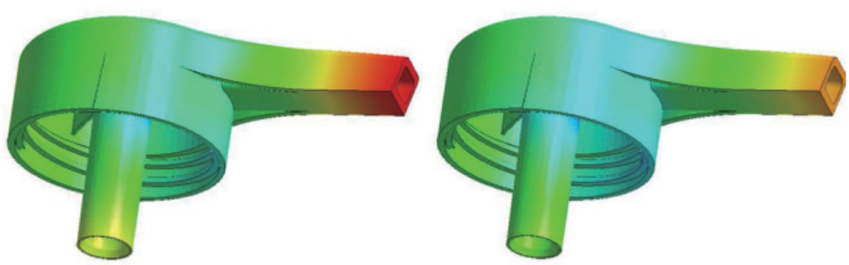


Figure 11. Improvement in warpage of the tube is also observed

Based on the above case study, it is important that designers/molders understand that these numerical results in simulation is a relative comparison and should not be treated as an absolute value. This is because there are various uncontrollable factors in the actual mold floor which cannot be reenacted in simulation. However, with the aid of Moldex3D DOE, it gives designers a head start on which are the control factors that should be focused on and the relationship it has with part quality.

“We feel that Moldex3D has been fundamental in growing this side of our business due to the accurate and reliable results it has shown to give Plazology,” Jasmin says. “Not only that, Moldex3D enables our customers to work better and smarter with more confidence,” she adds.

About Jasmin Wong

Jasmin Wong is a Project Engineer for Plazology, based in UK. Plazology works alongside with various global leading companies in the plastic industry, across Europe and Asia. They specialize in Product Design Optimization Injection Mold Flow Simulation, Mold Design, Precision Mold Procurement and Management; and Mold and Process Validation. Jasmin has also recently been awarded the Moldex3D Analyst Certificate by S4innovation, which supplies Moldex3D software in the UK.

“ Moldex3D has provided us with additional confidence in our own internal decision making. Not only do we use Moldex3D for full analysis work before building the actual tool, we can use it to troubleshoot current production quality issues too.
We feel that Moldex3D has been fundamental in growing this side of our business due to the accurate and reliable results it has shown to give Plazology.“

- Jasmin Wong, Project Engineer at Plazology

About Moldex3D

Moldex3D is the world leading CAE product for the plastic injection molding industry. With the best-in-class analysis technology, Moldex3D can help you carry out in-depth simulation of the widest range of injection molding processes and to optimize product designs and manufacturability. In addition, its high compatibility and adaptability have provided users with instant connection to mainstream CAD systems, generating a flexible simulation-driven design platform.

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