Improving Structural Performance of Parts through Moldex3D FEA Interface

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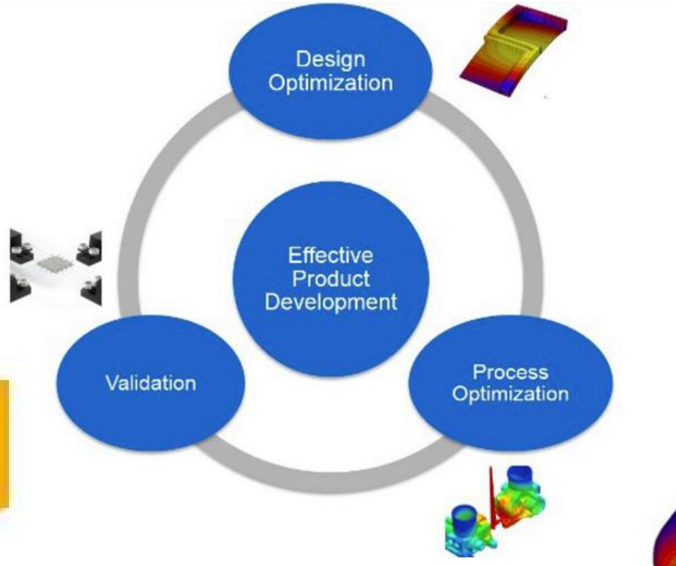
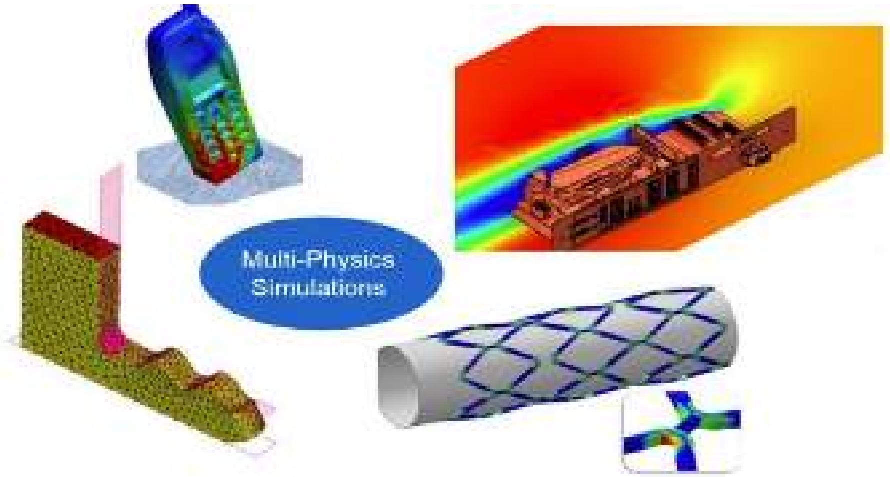
Agenda

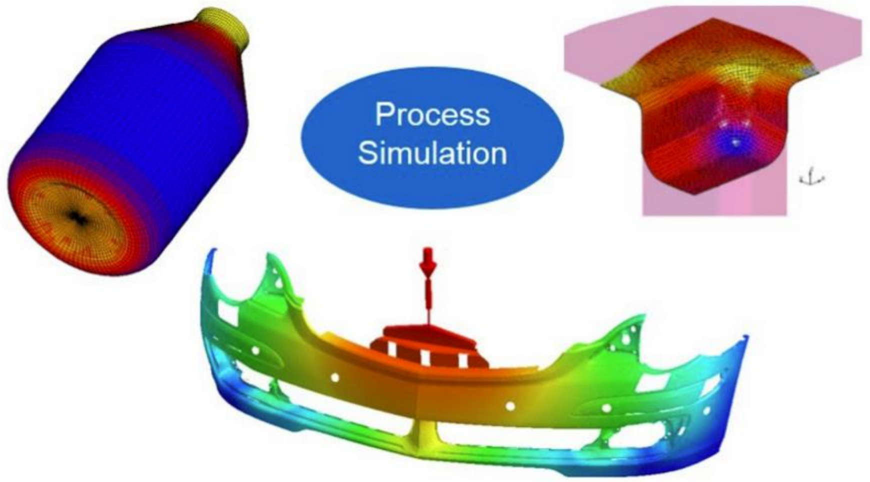
- Innova Engineering Inc.
- Introduction : Moldex 3D FEA Interface
- Case Study: Automobile Component
    - ❑ Unfilled Plastic Part
        - Molding Simulation and FEA
    - ❑ Filled Plastic Part
        - Molding Simulation and FEA
- Failure Predictions using Digitmat
- Optimal Design Workflow

Innova Engineering Inc.

- Innova Engineering is a design solutions provider
- More than 25 years of helping customers develop better products
- Offering a full range of expertise: CAD, manufacturing processes, performance analysis, rapid prototypes







How does Innova Engineering complement and partner with clients?

- Innova provides:
  - Product, tooling, and fixtures design;
  - Manufacturing and engineering process and method development;
  - Materials selection and characterization;
  - Rapid prototyping, metrology, and testing;
  - Technology/software guidance and mentoring;
  - PLM implementation and administration;
  - On site staffing and staff augmentation.

Innova's Capabilities to Deliver Solutions

- Industry expertise
  - Medical
  - Consumer products
  - Aerospace
  - Automotive and Machinery
- Engineers with more then twenty-five years of experience and/or advanced degrees
- Extensive experience with advanced materials:
  - Composites (thermoset laminates, short and long fiber injection molded)
  - Injection molding (thermoplastics, thermosets, MIM)
  - Tooling design, build and process optimization
- Full range of CAD and CAE:
  - Implicit and Explicit Nonlinear FEA
  - Aero-elasticity, CFD and fluid/structure Interaction
  - Thermal Analysis
  - Loads and multi-body dynamics

Introduction

- Metal to thermoplastics
  - High performance material properties at lower cost

- Challenges
  - Making the part moldable
  - Making the part structurally durable

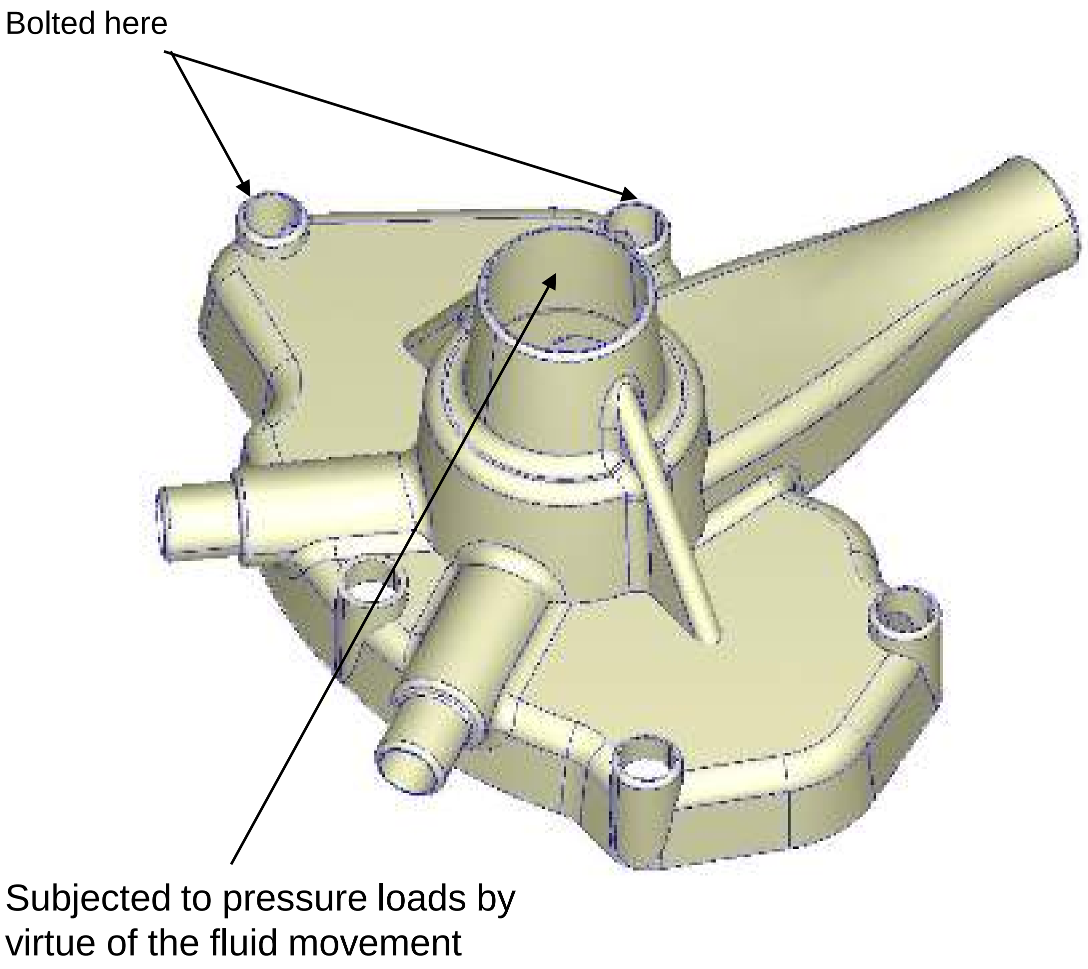
Metal part performance is largely driven by geometry

Injection molded part performance is driven by:

- fiber volume fraction
- fiber orientation and alignment
- weld lines
- shrinkage
- warpage
- compaction
- mold considerations (e.g. – draft angles)
- etc.

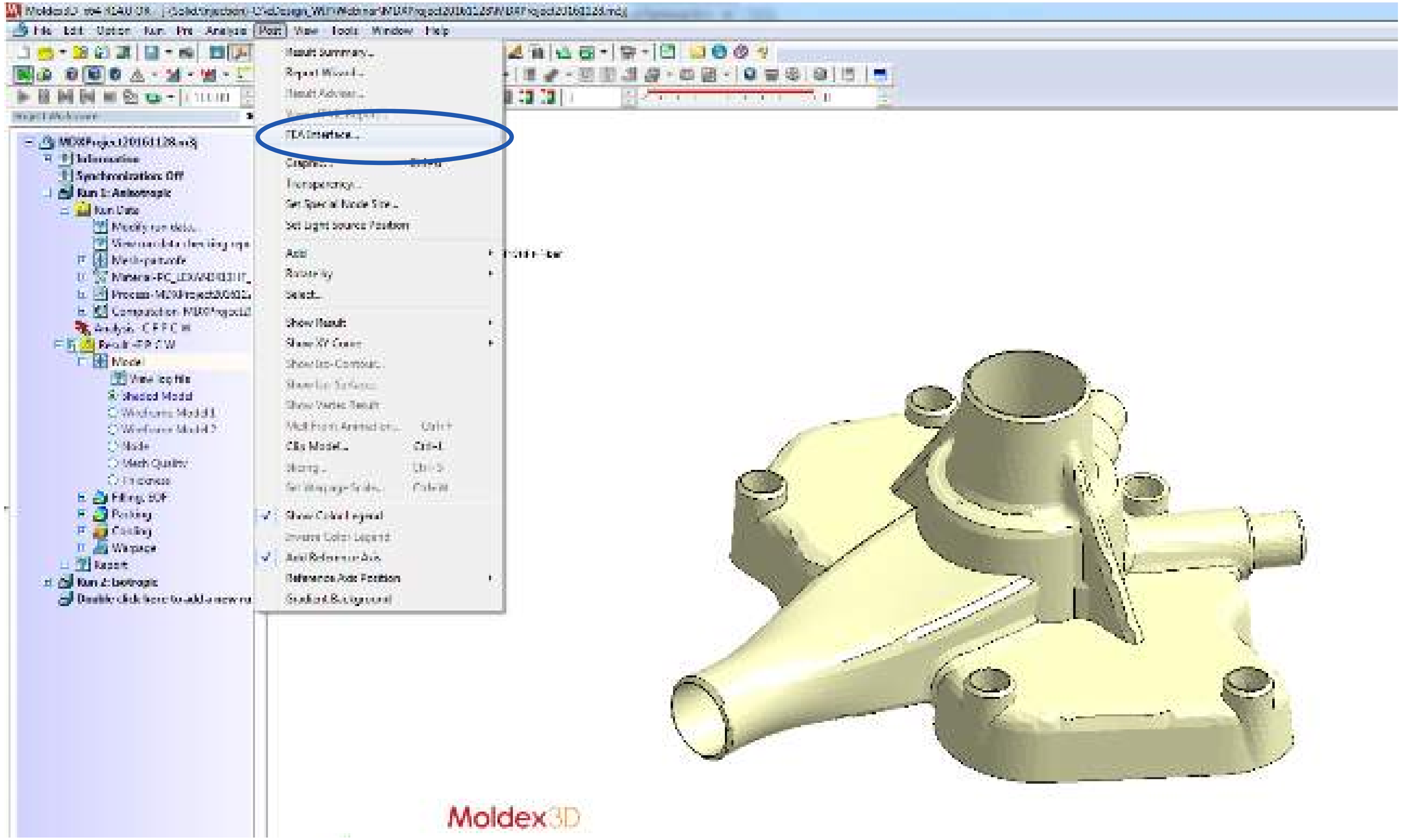
- FEA interface in Moldex3D allows mapping of these critical variables to your FE models to obtain accurate part performance predictions.

Case Study: Automobile Component

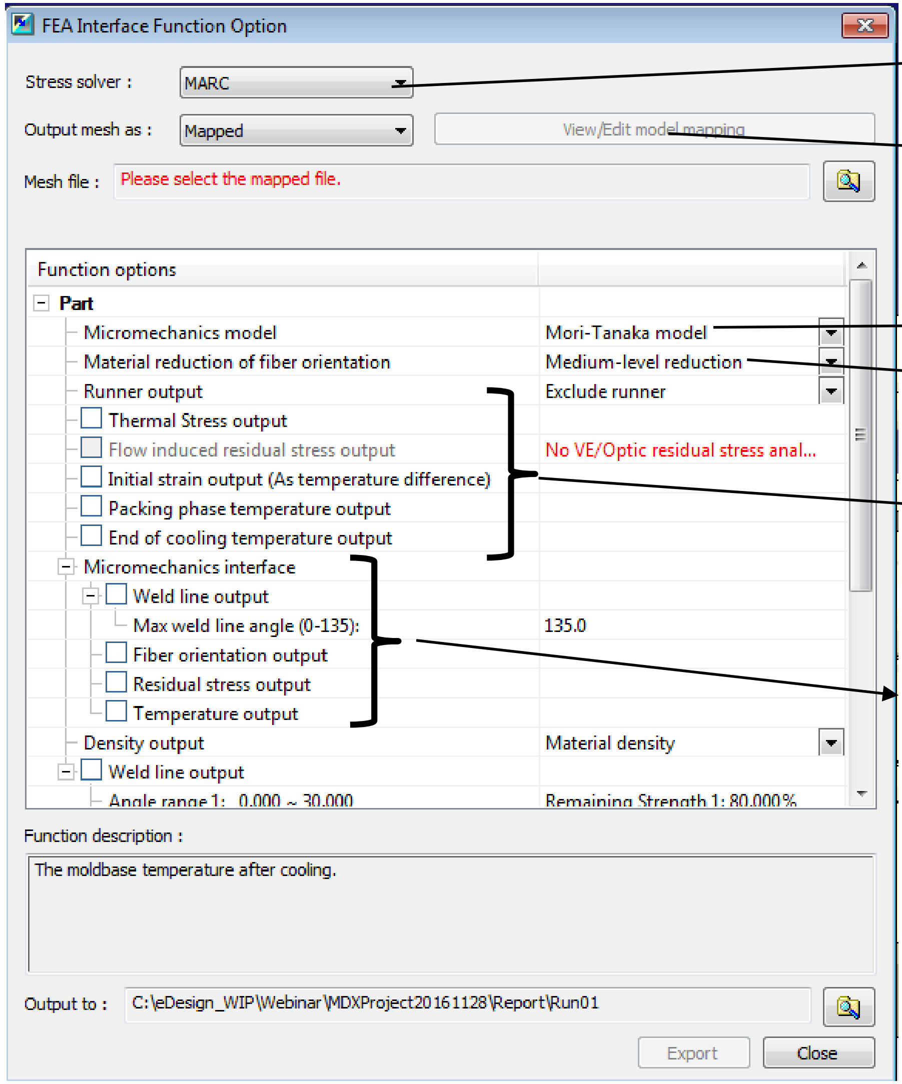


- Originally made of Aluminum with thicker crossection.
- Design modified to be suitable for injection molding by coring out the thicker areas.
- Decision has to be made whether an unfilled or a filled material is needed to handle the operating loads.
- Concerns about the long-term performance under operating loads.
- Failure predictions.

FEA Interface



FEA Interface I



ANSYS, MARC, ABAQUS etc.

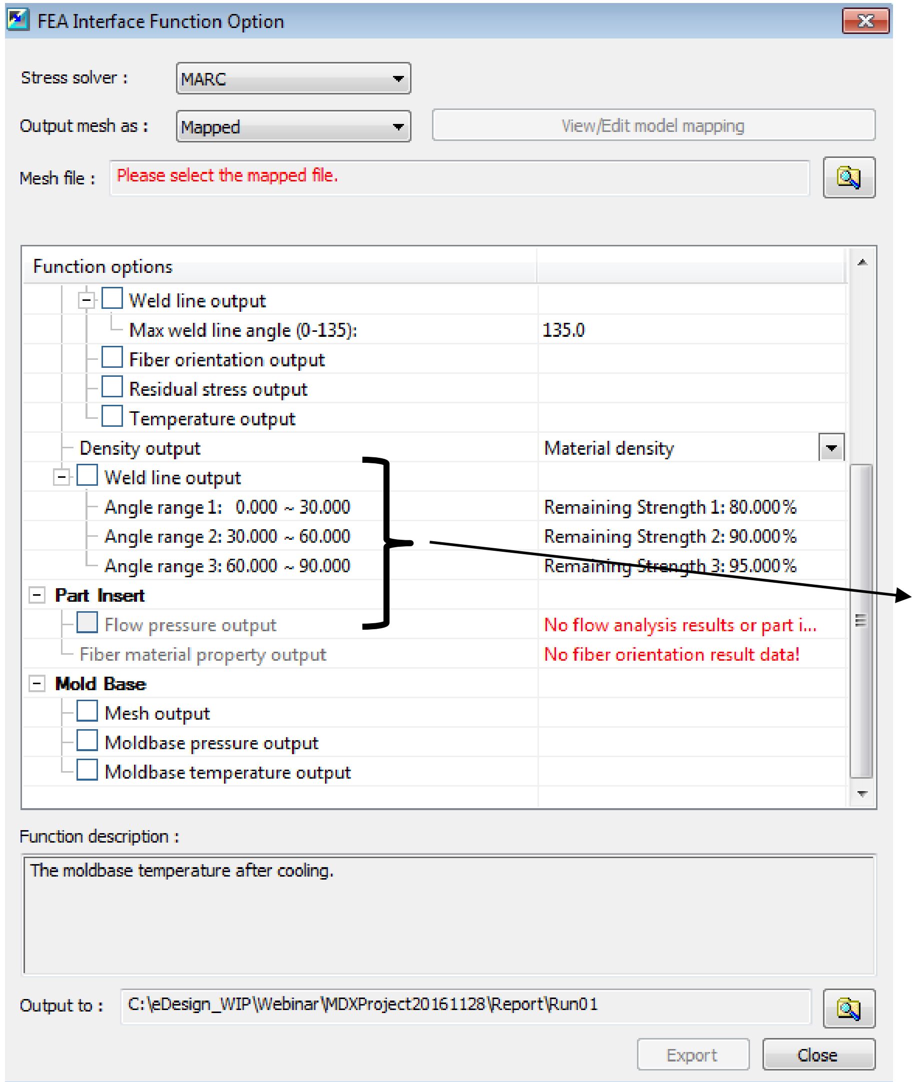
Mapping visualization of Moldex3D vs FE Mesh

Choice of micromechanics models to predict stress-strain tensors

Control the number of material cards in FE input deck

Thermal outputs including residual stresses

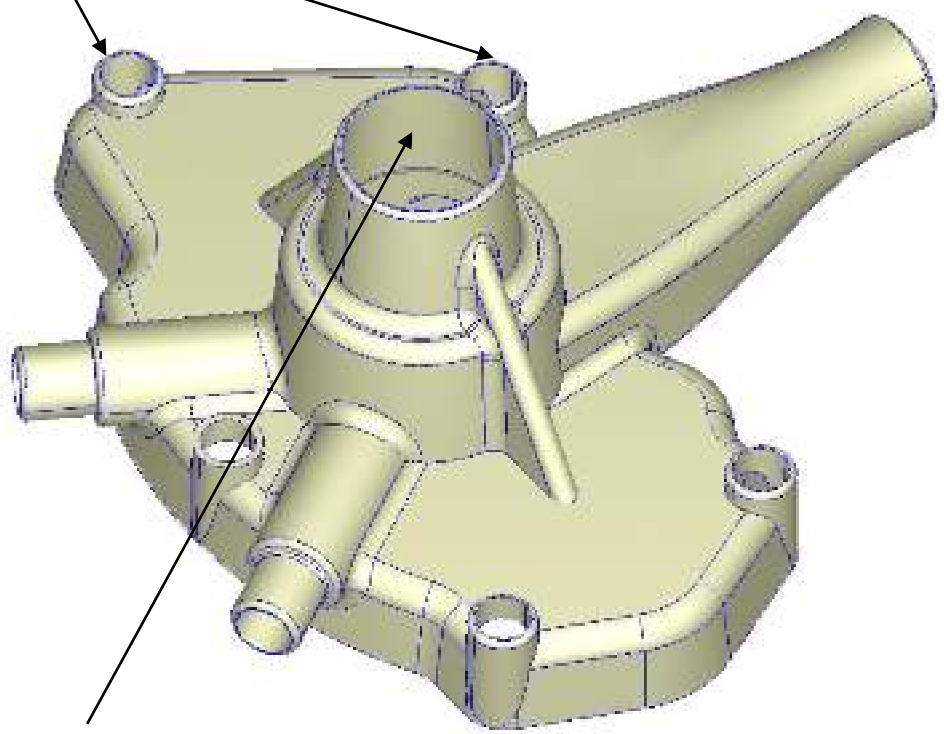
Micromechanics algorithm is used to output stress-strain tensors to be used in FE Model directly.



In addition to fiber orientations, further stiffness reductions can be applied based on the weld line mating angles.

Case Study: Automobile Component

Bolted here



Subjected to pressure loads by virtue of the fluid movement

- Originally made of Aluminum with thicker crossection.
- Design modified to be suitable for injection molding by coring out the thicker areas.
- Decision has to be made whether an unfilled or a filled material is needed to handle the operating loads.
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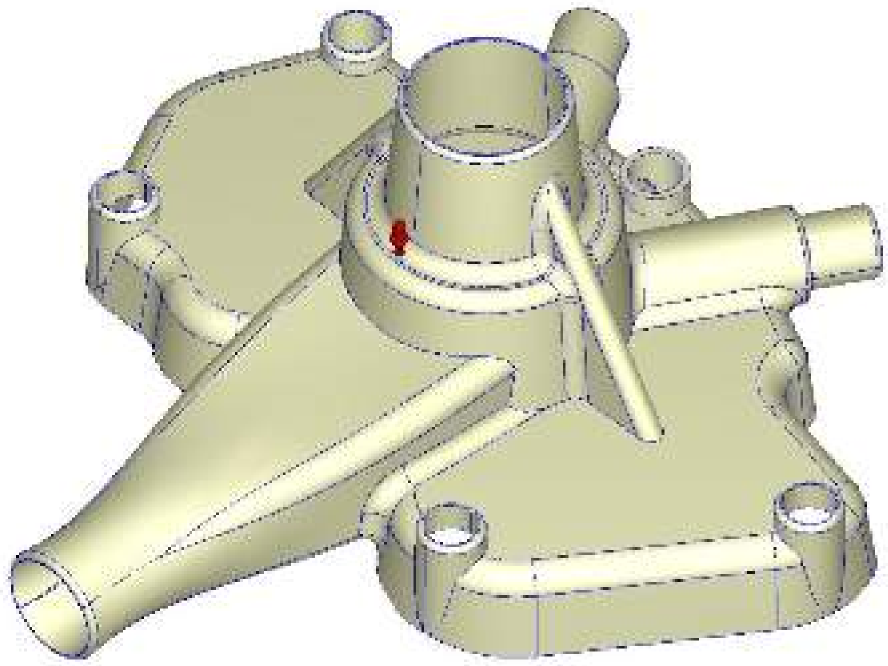
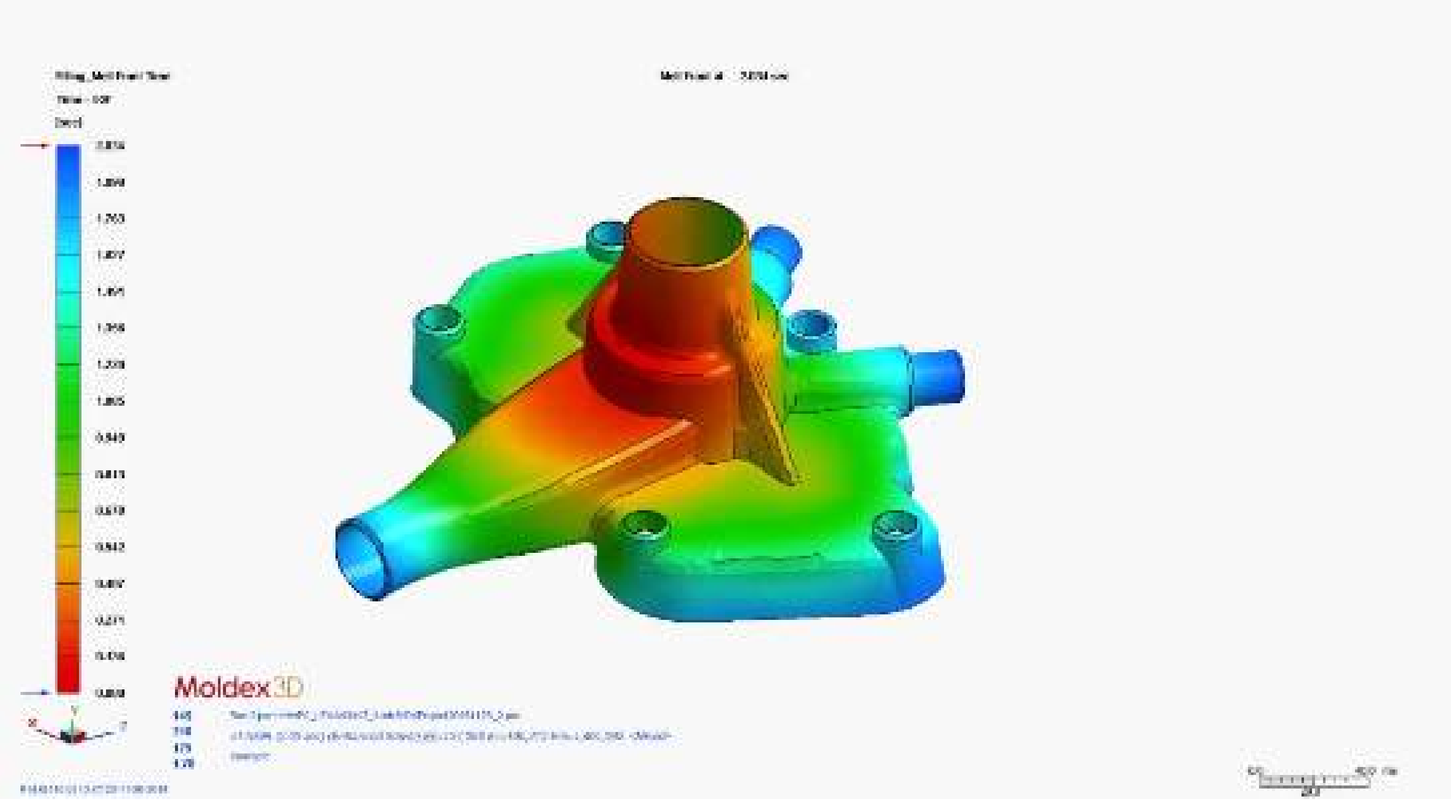
Unfilled Material: Injection Molding Simulation

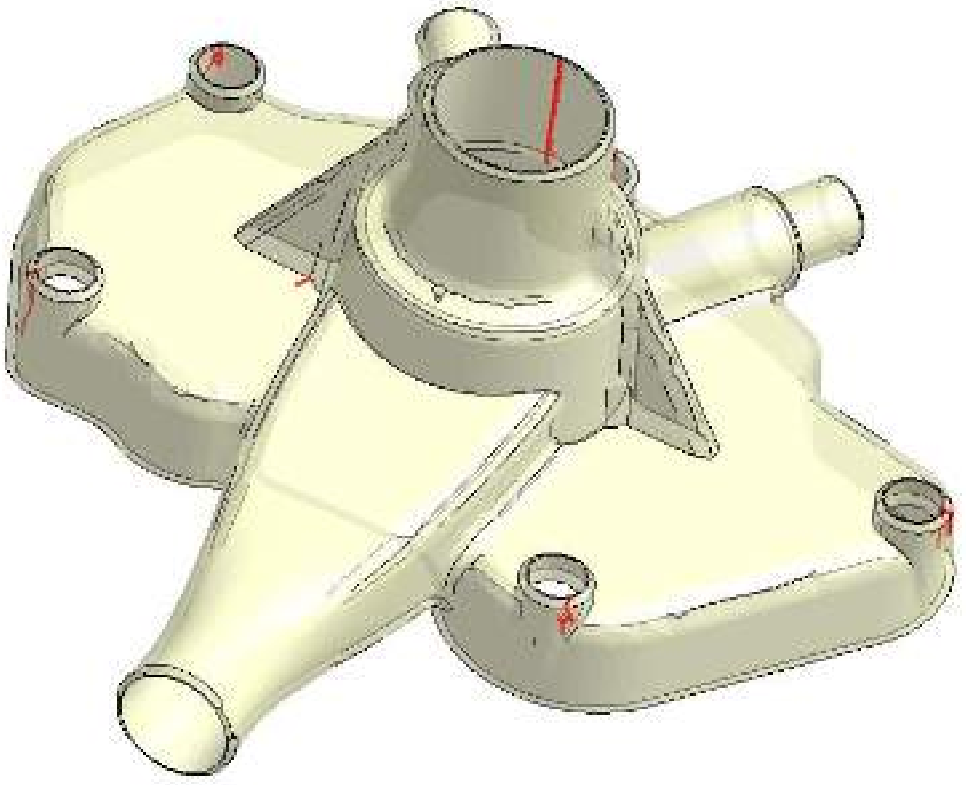
Material: PC, LEXAN 3413



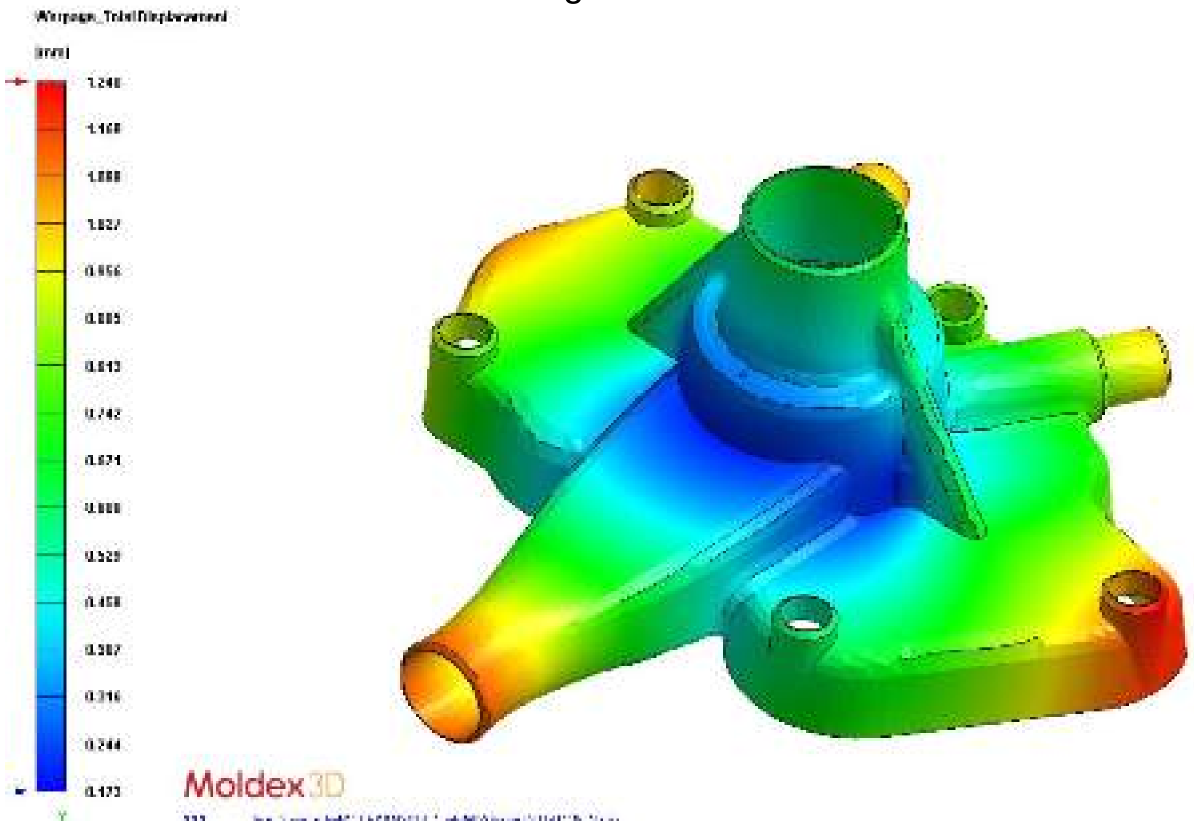


Weld Line and Warpage

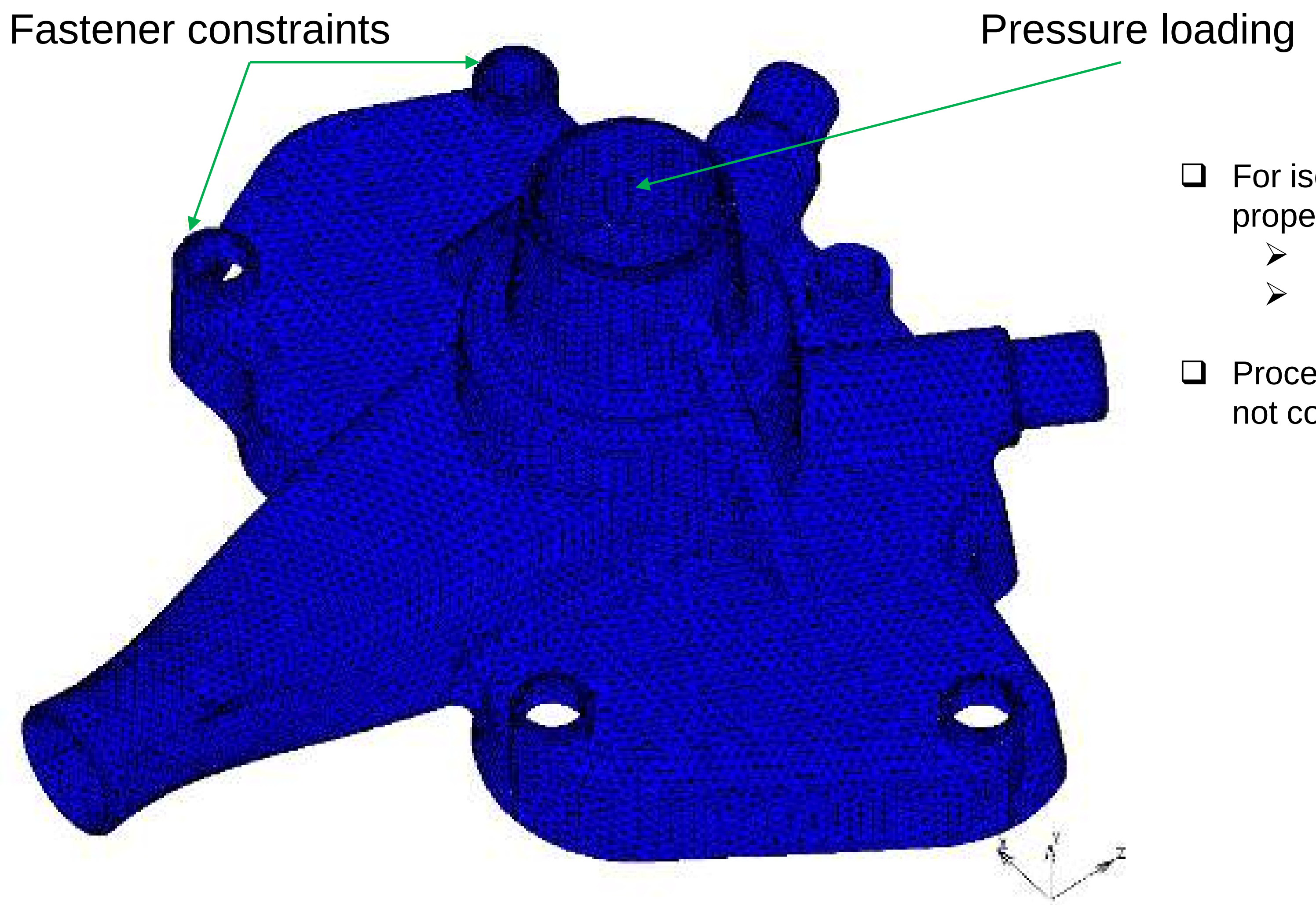
Weld line here could cause higher strains. Hence structural analysis is required with mapped properties.



Warpage is not a concern. However, addition of fiber may reduce the overall shrinkage.

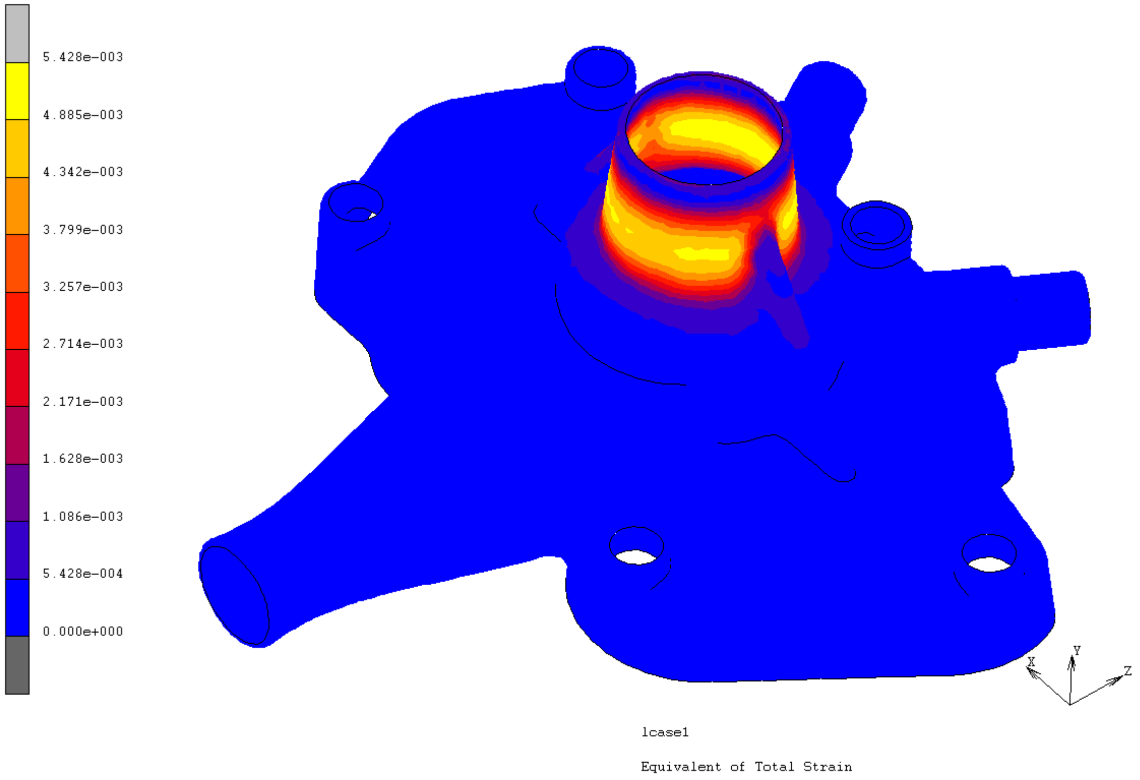


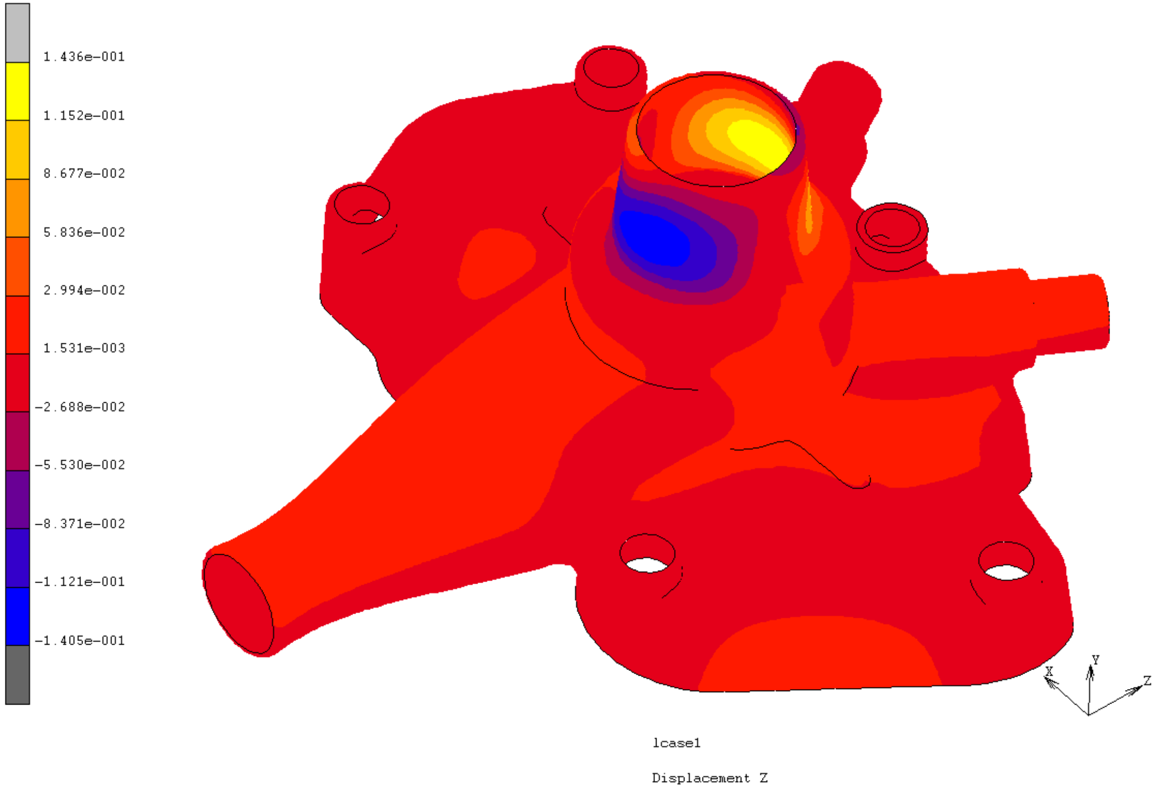
Unfilled Material: Isotropic FEA



- For isotropic analysis using Lexan 3413 following properties are used in FEA
  - E= 2800 MPa
  - Poisson's ratio = 0.4
- Process information such as weld line properties are not considered.

FE Results for Strains and Displacement

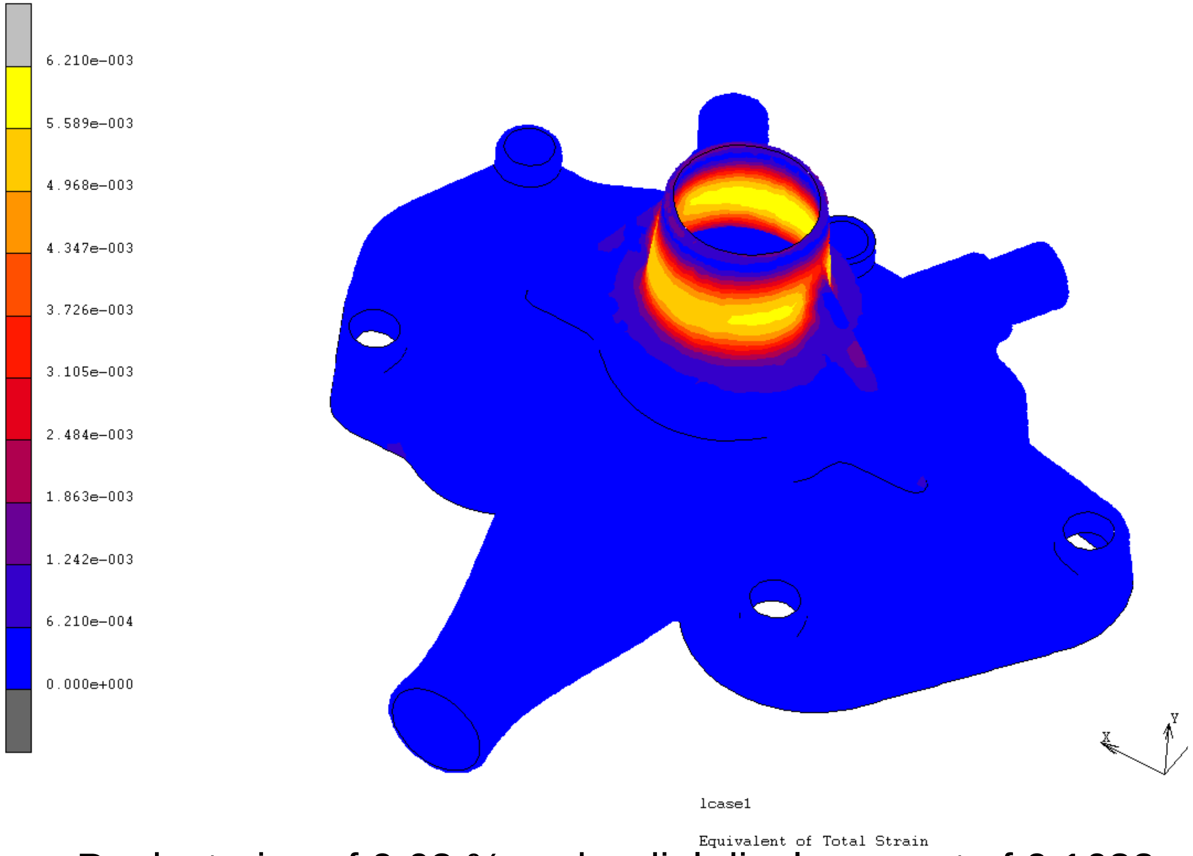


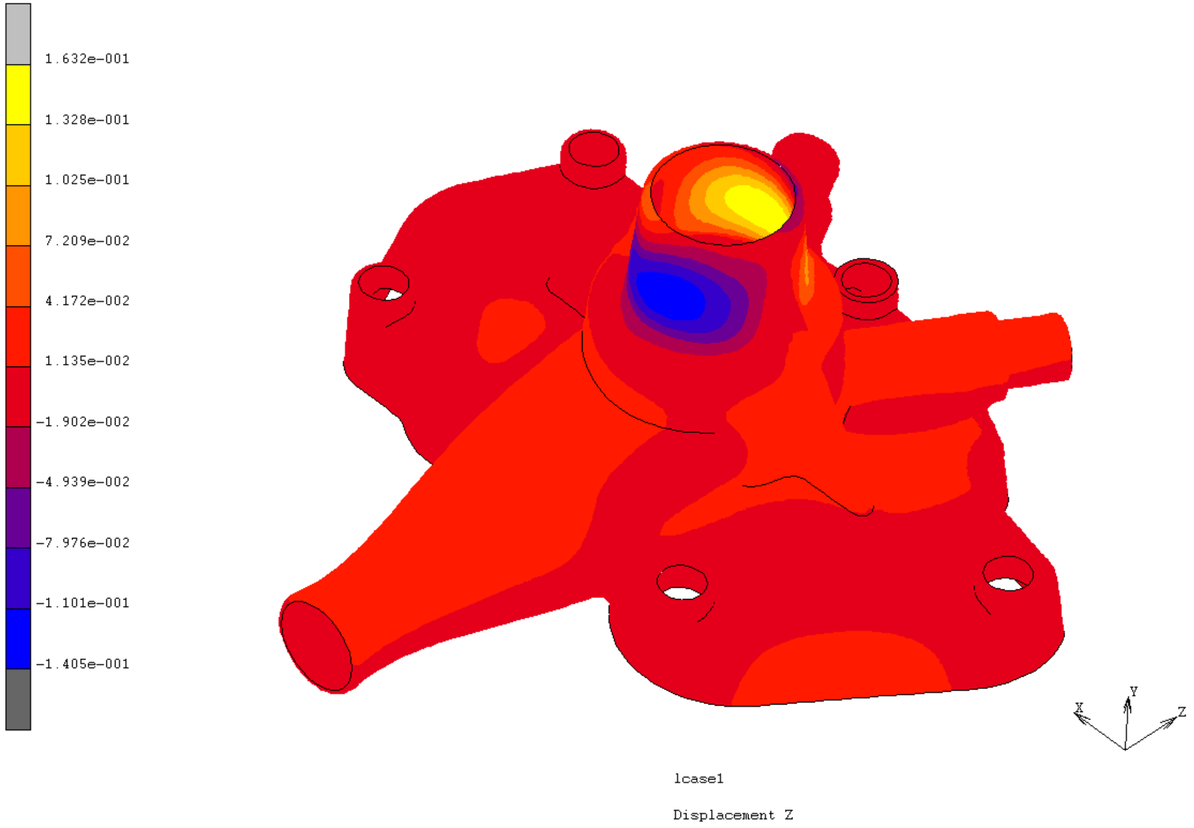


- Peak strains of 0.54 % and radial displacement of 0.1432 mm is observed

Weld Line Effect: Material Property Mapping to FE Solver using FEA Interface

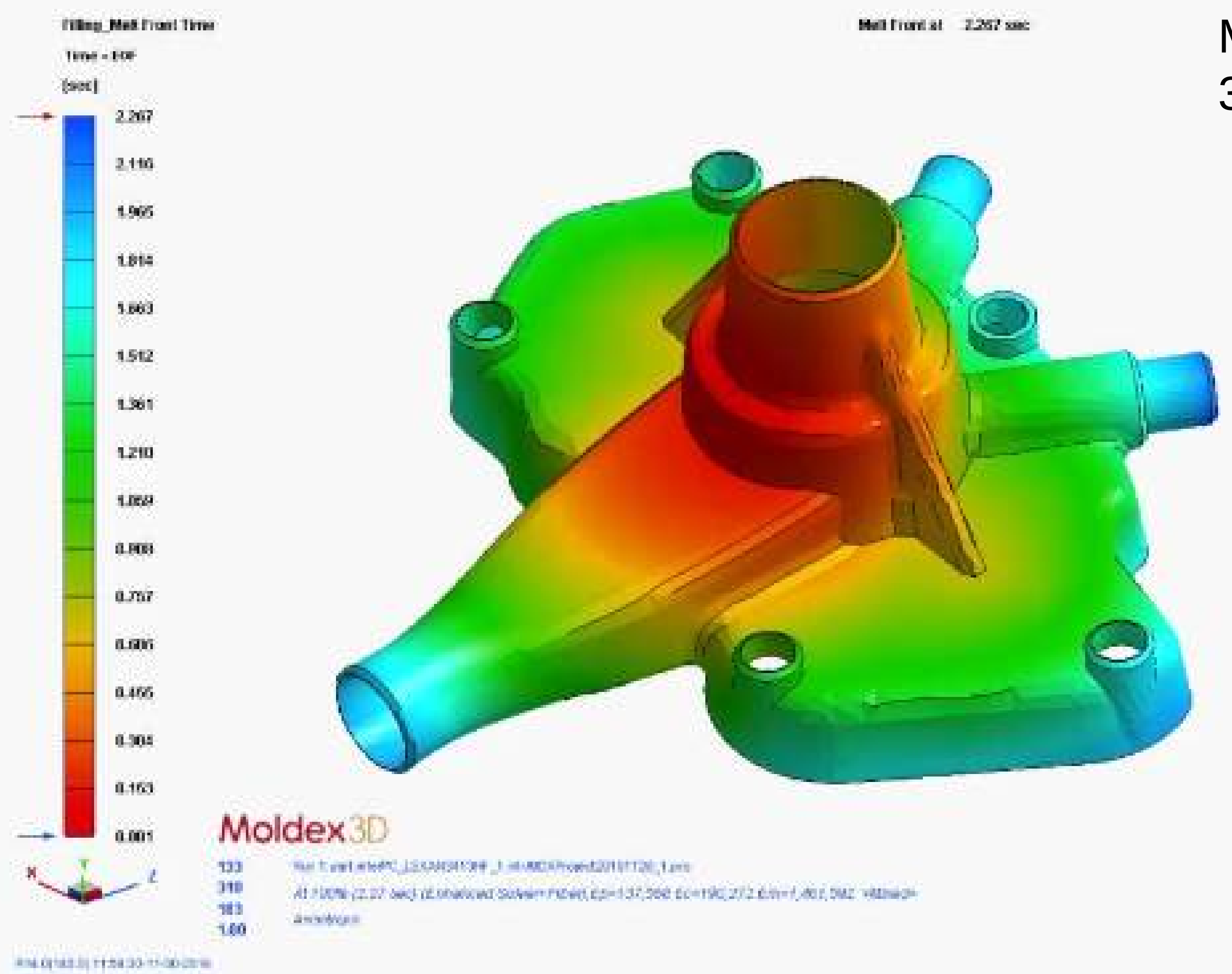
Weld line output	
Angle range 1: 0.000 ~ 30.000	Remaining Strength 1: 80.000%
Angle range 2: 30.000 ~ 60.000	Remaining Strength 2: 90.000%
Angle range 3: 60.000 ~ 90.000	Remaining Strength 3: 95.000%
Part Insert	





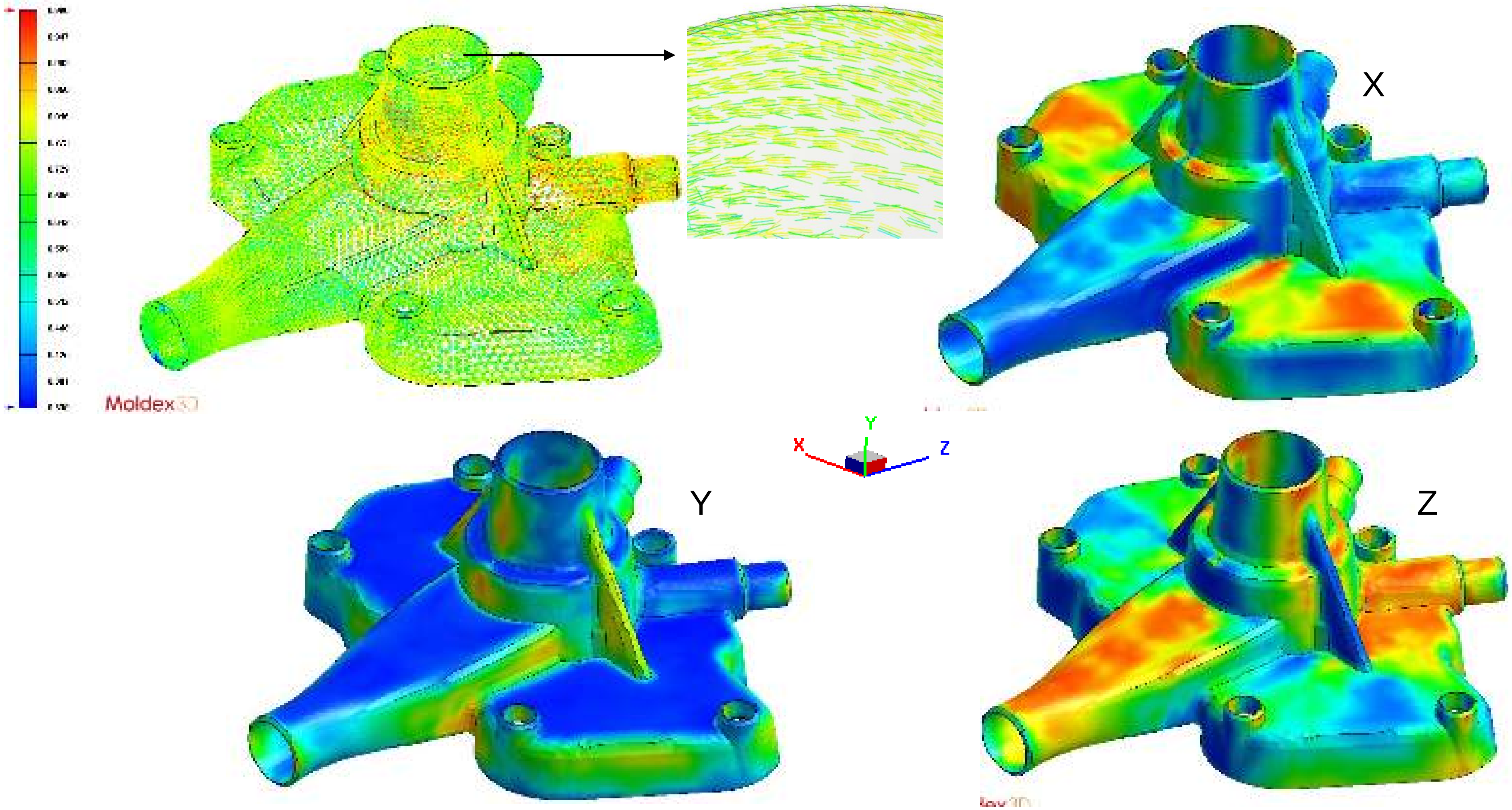
- Peak strains of 0.62 % and radial displacement of 0.1632 mm is observed

Filled Material: Injection Molding Simulation



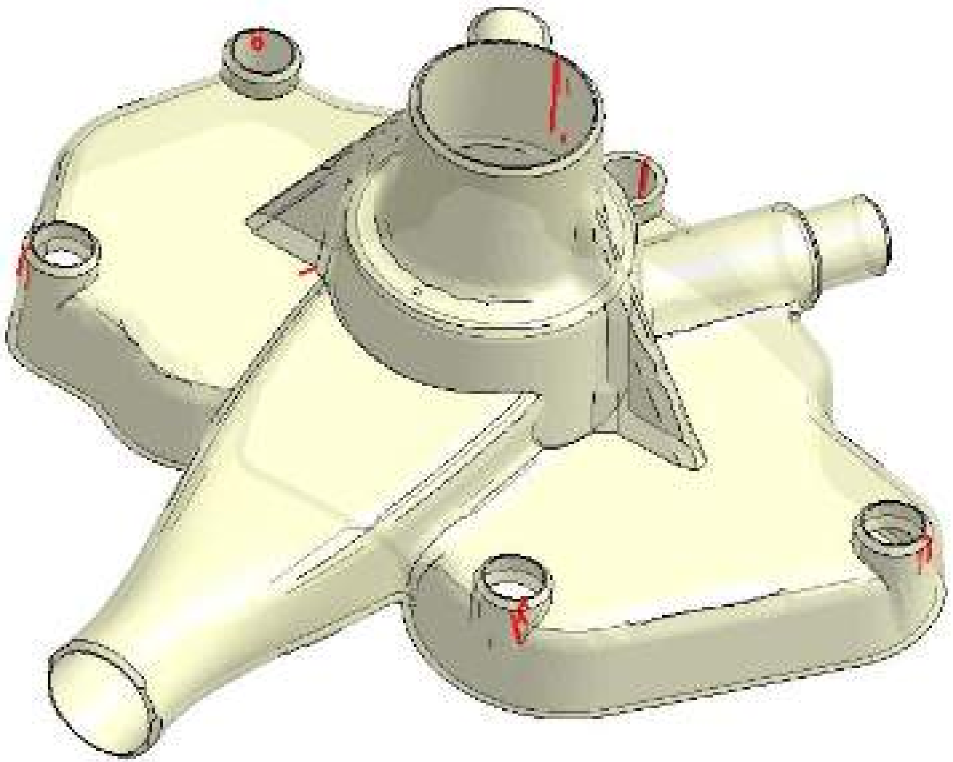
Material: PC, LEXAN 3413HF
30 % GF

Fiber Orientations

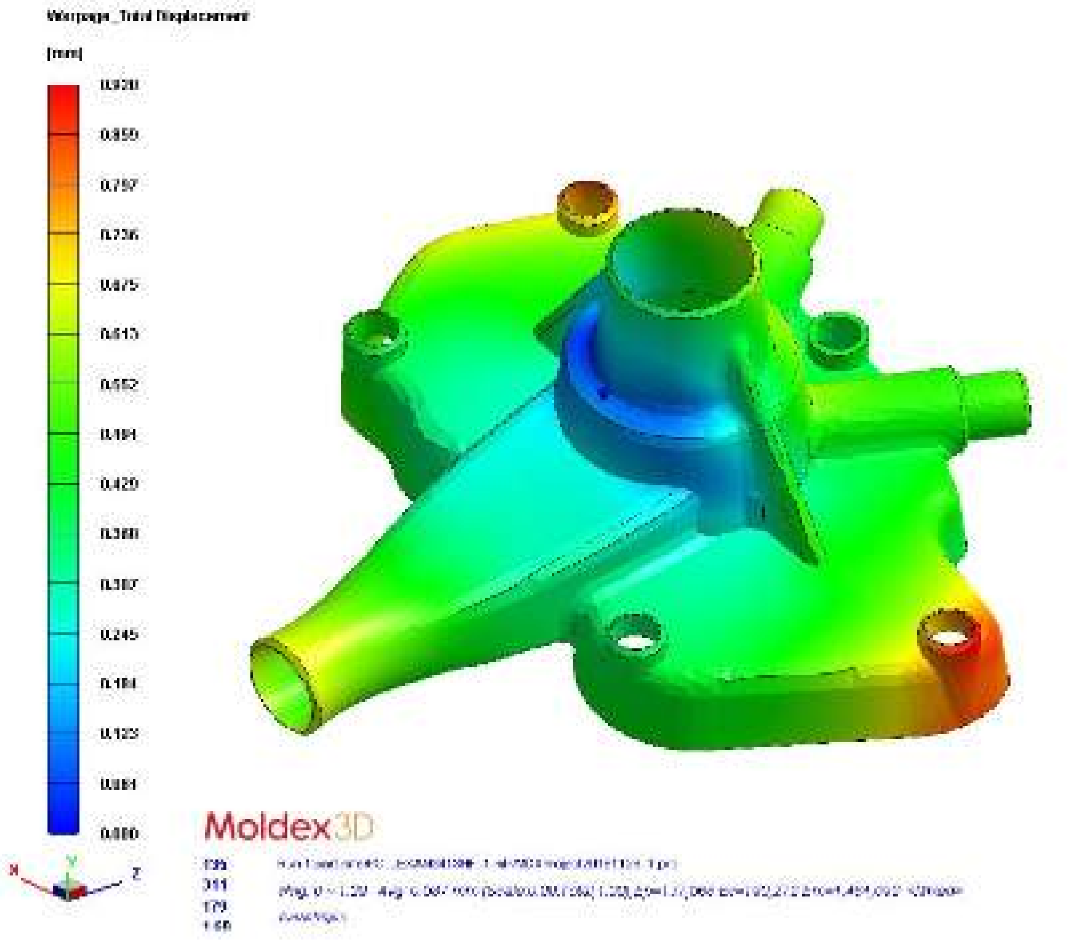


Weld Lines and Warpage

Weld line is still there. However, the length has reduced marginally.



Lower warpage predictions with the fiber orientated material.



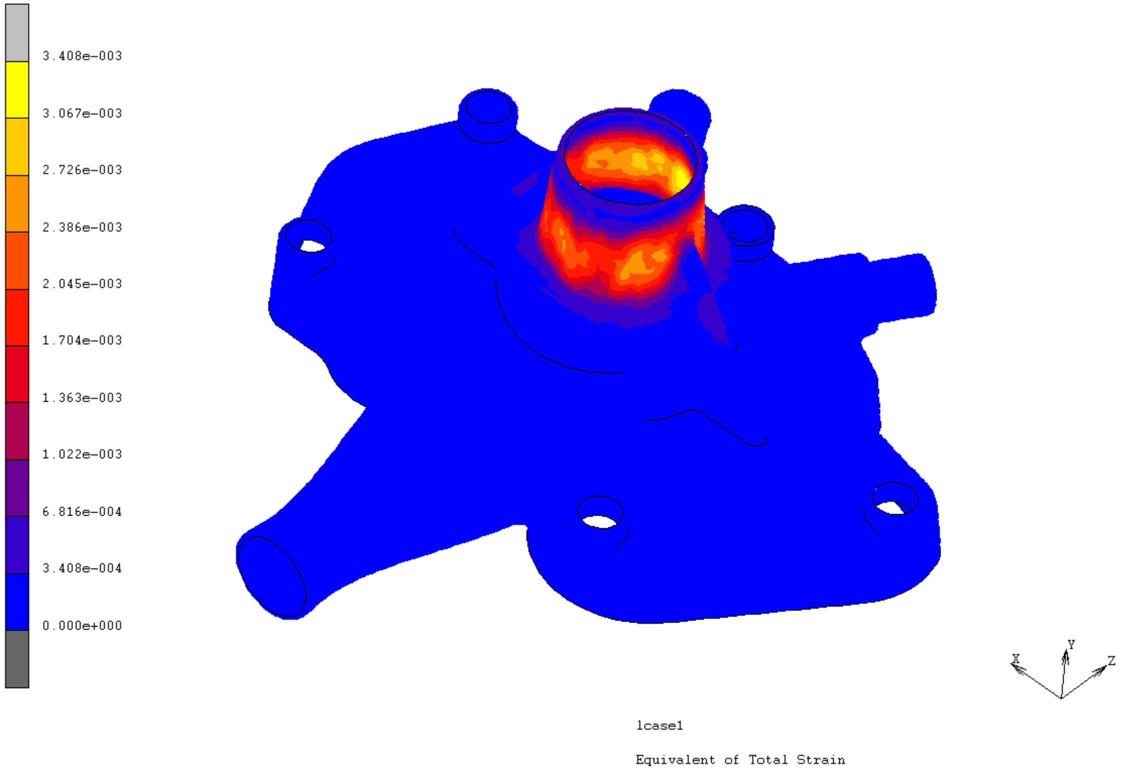
Mapping using FEA Interface

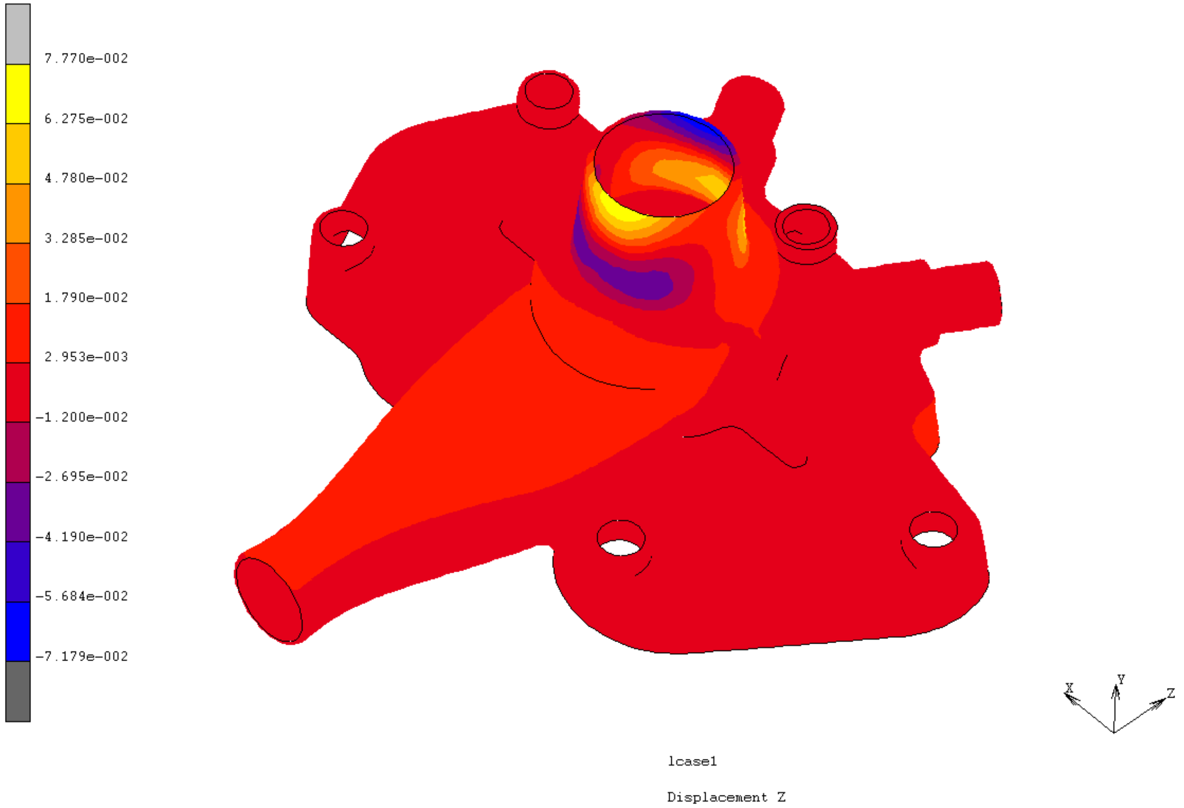
C[i,j]

11	4754.74	12	1480.48	13	1380.42	14	-233.849	15	228.706	16	-814.142
T		T		T		T		T		T	
21	1480.48	22	8790.83	23	1076.28	24	1574.07	25	745.665	26	160.748
T		T		T		T		T		T	
31	1380.42	32	1076.28	33	3427.7	34	-99.4304	35	-48.7359	36	26.2036
T		T		T		T		T		T	
41	-233.849	42	1574.07	43	-99.4304	44	1564.16	45	163.393	46	224.803
T		T		T		T		T		T	
51	228.706	52	745.665	53	-48.7359	54	163.393	55	1167.27	56	-104.663
T		T		T		T		T		T	
61	-814.142	62	160.748	63	26.2036	64	224.803	65	-104.663	66	1487.15
T		T		T		T		T		T	

- Using FEA interface, anisotropic material properties corresponding to fiber orientations are mapped to the FE Mesh. Total, 34000 material cards were created for this part. Number of cards can be controlled by choosing the appropriate reduction level.
- Orthotropic tensors are outputted by Moldex3D and can be used in MARC or any other FE tool directly.

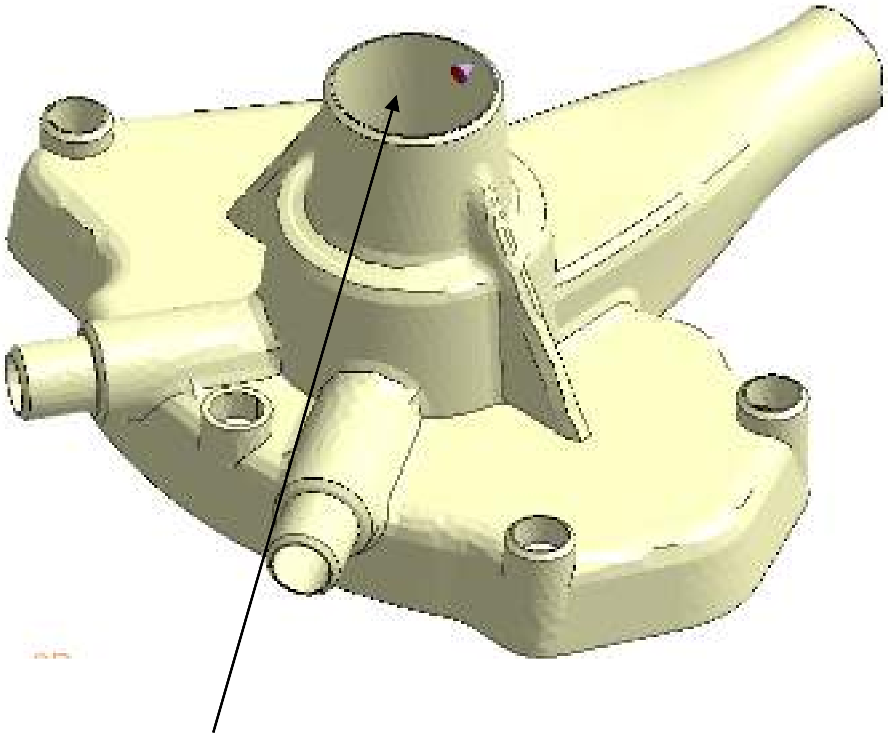
FE Results for Strains and Displacement



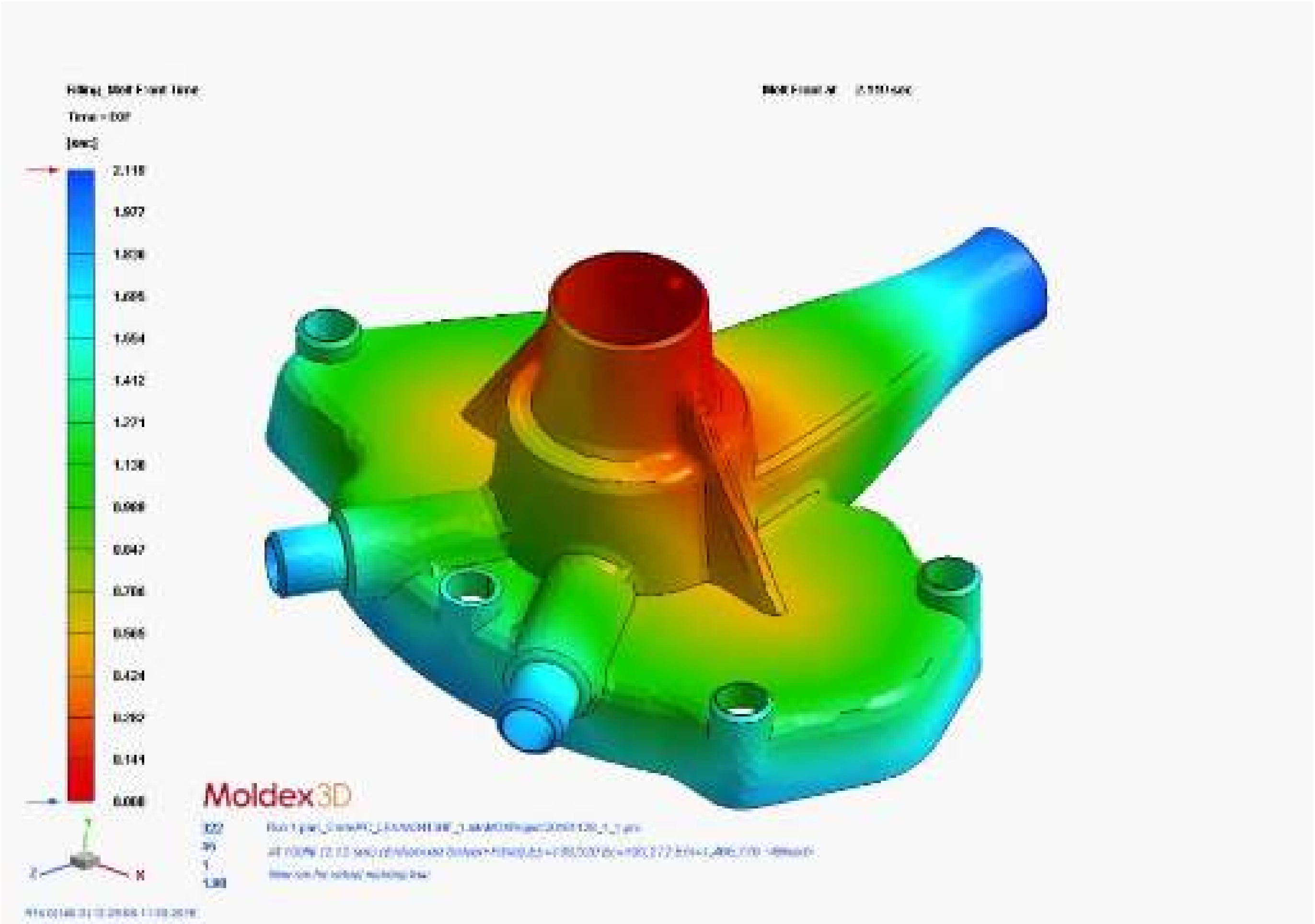


- Peak strains of 0.34 % and radial displacement of 0.077 mm is observed
- ~ 50% reduction in the strains and displacements due to additional strength.

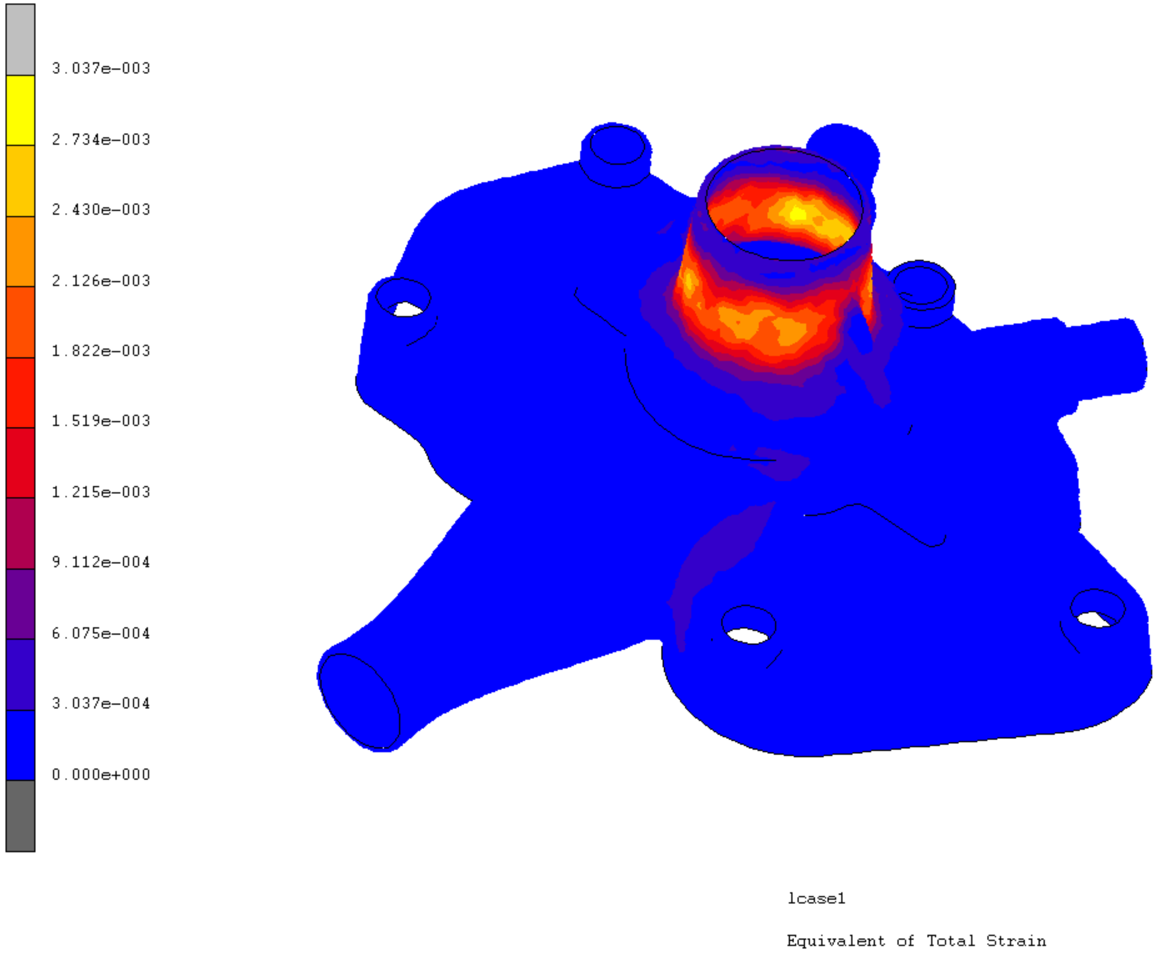
Changing Gate Location For Better Fiber Alignment

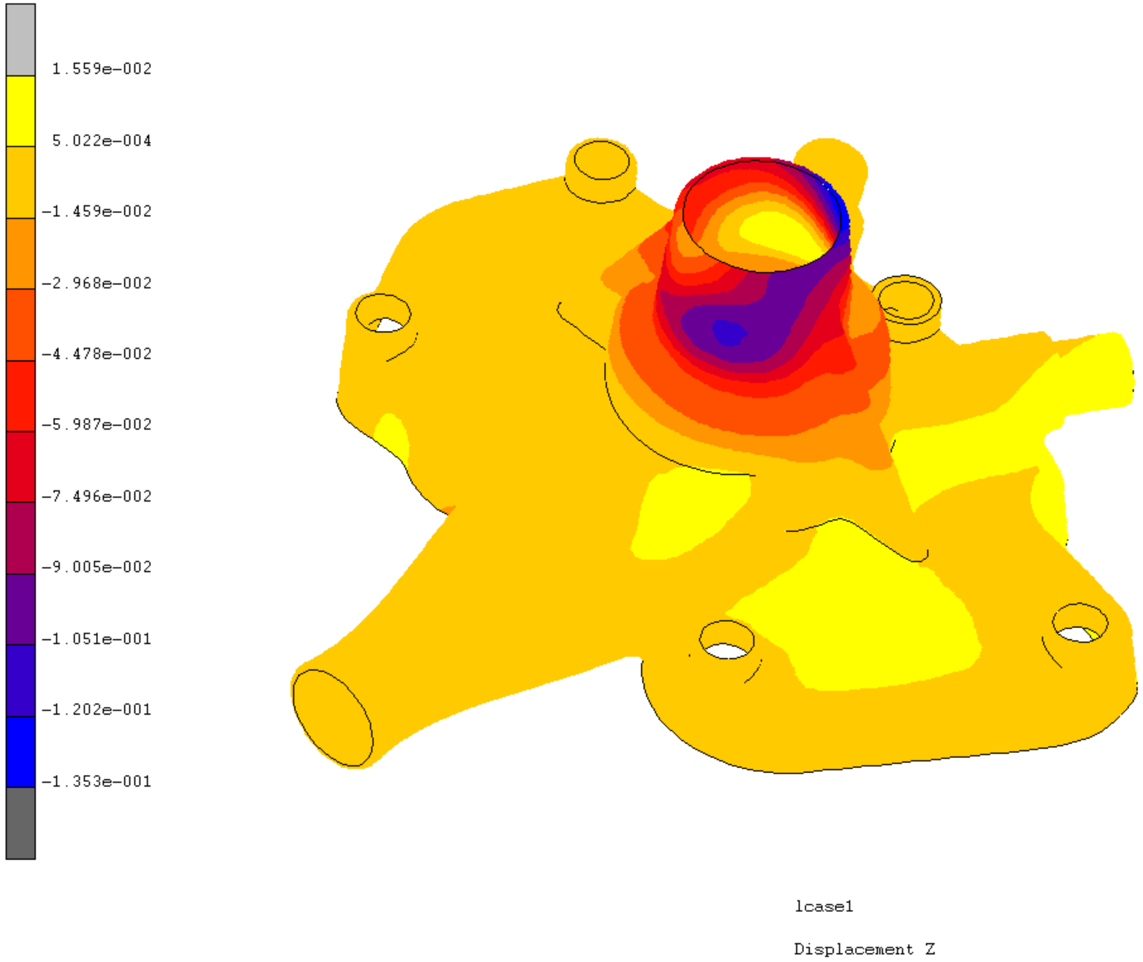


New gating strategy to induce more circumferential fibers in this area.



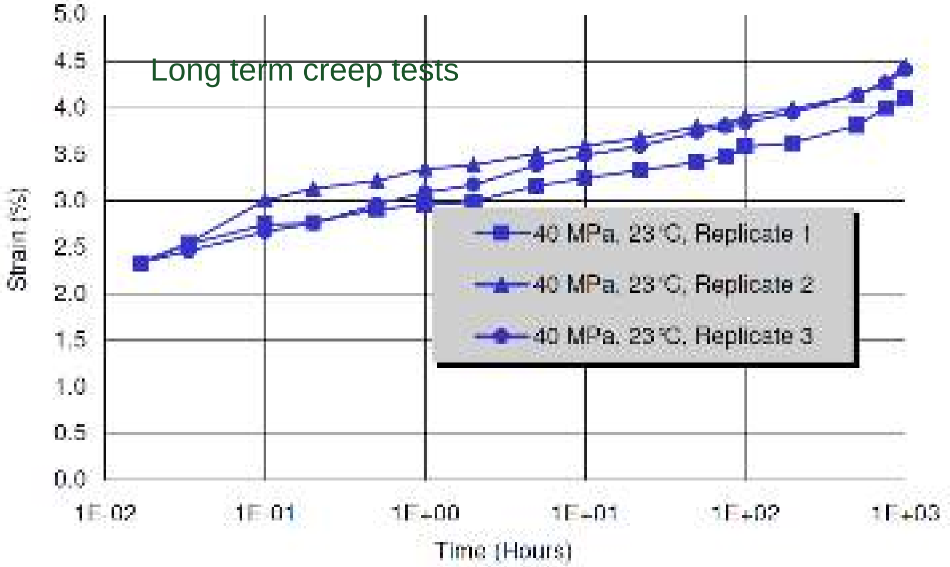
FE Results

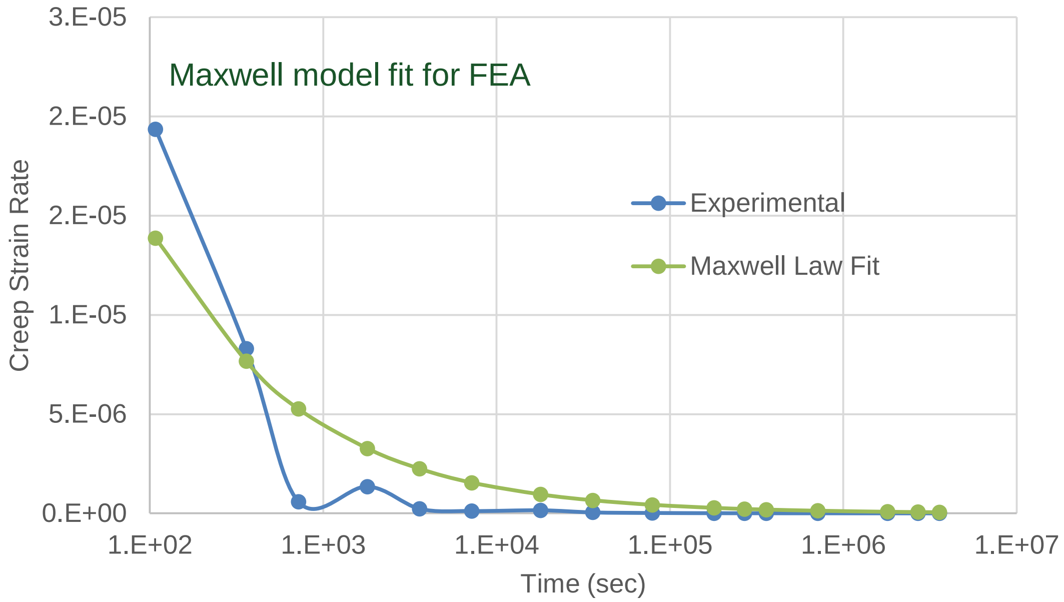


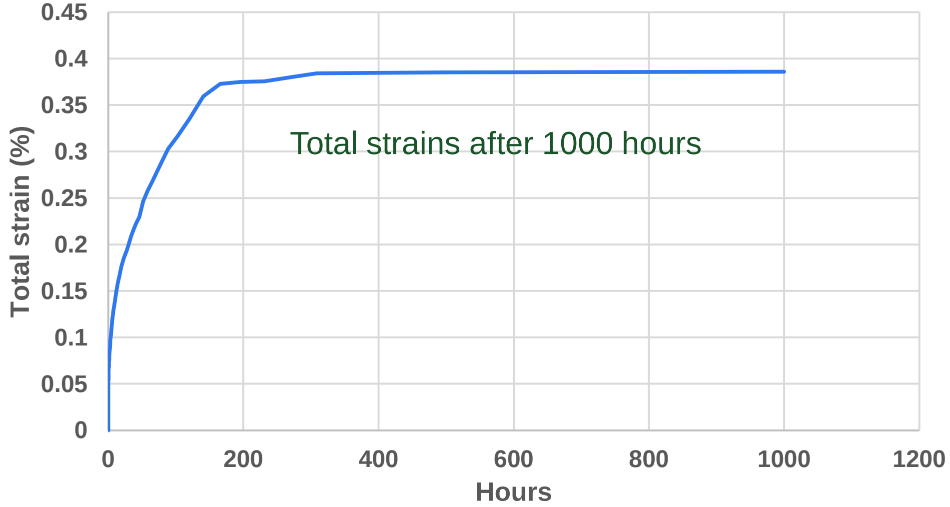


- Peak strains of 0.3 % and radial displacement of 0.015 mm is observed
- Strains and displacements are further reduced due to additional circumferential fibers. In this way structural analysis on *as-molded* parts can be a huge benefit to designers as it helps to accurately predict part performance considering the process effects.

Long-Term Loading and Failure Predictions



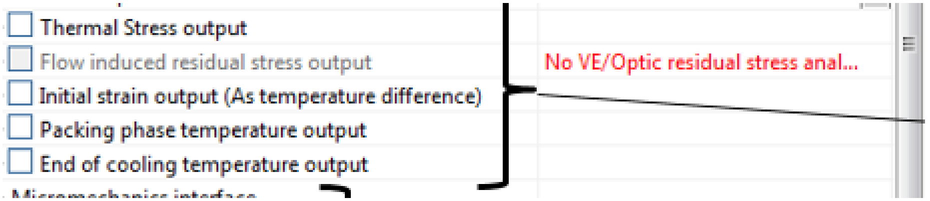




- Thermoplastics are known to creep even at lower temperatures compared to metals/alloys, which show creep at higher temperatures.
- As such, for loads that are held for longer duration must be analyzed with creep in mind.
- Long term creep tests are typically performed to obtain the Maxwell model fit for the material. Creep analysis can then be performed on "as-molded" thermoplastic part to predict final strains.
- Automobile component of interest, shows the final strains of 0.38 % after the 1000 hour loading of constant magnitude.
- Total strains are lower than the breaking limit for this material (2%).

Effect of Residual Stresses

- Process induced residual stresses can have detrimental effects on the part performance
  - Should be minimized using the injection molding simulation as much as possible
  - Non avoidable residues should be mapped to FE model using FEA interface and used as initial condition for running analysis.
  - Multiple ways of mapping the residual stresses via temperatures or temperature differences (strains) or stresses directly.

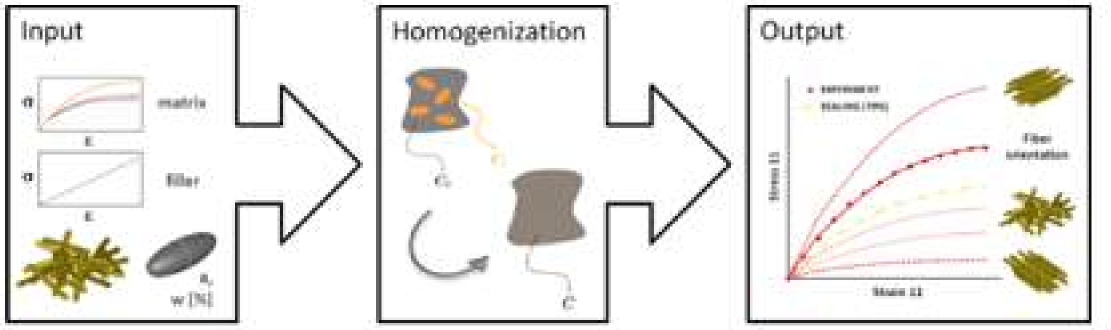


  - If the FE software has thermal-structural analysis capability, then the temperatures can be exported to run a convection cooling analysis to obtain accurate thermally induced-residual stresses.

- For some thermoplastic parts, relaxation of these residual stresses results in shape changes, which may affect how these part interact with the other components in the system. As such, a long-term creep analysis can be performed with residual stresses as initial condition to predict such shape changes.

- For thermoplastic parts with relatively larger instantaneous loads, FE analysis should include residual stresses as initial condition to predict the total stresses and strains in the part.

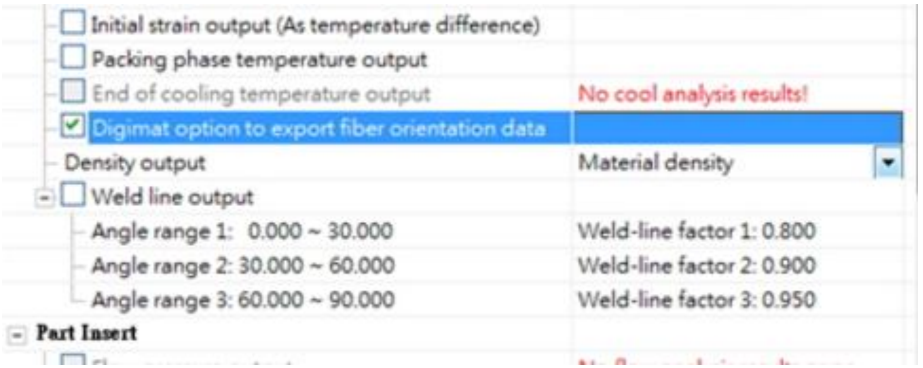
Advanced Performance Predictions using Digimat



Individual matrix and fiber stress-strain data + Orientation tensors from Modlex3D

Multiscale algorithms to process the properties

Stress-strain data for each material point in the mesh as a function of fiber orientation.



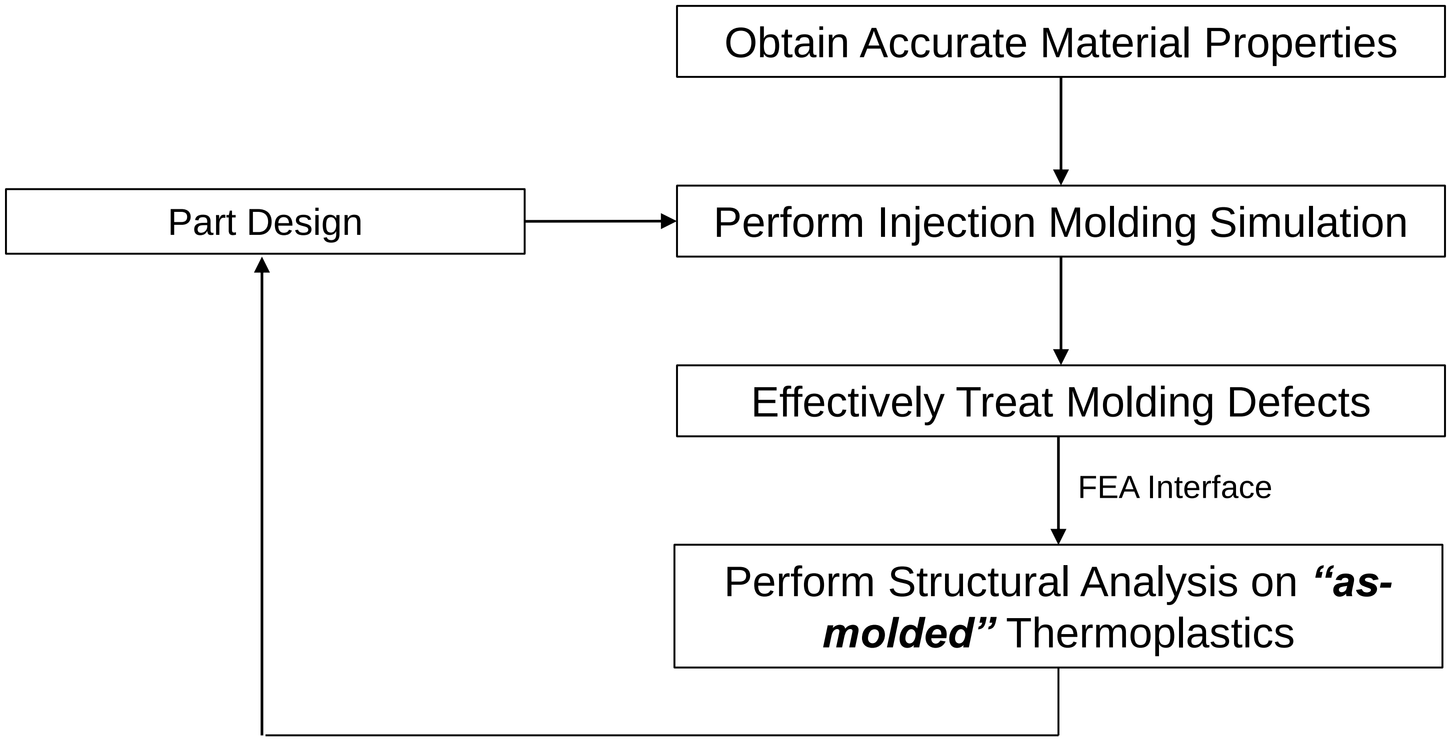
- Digimat allows non-linear FE analysis on the anisotropic filled plastics by combining the orientation results from Moldex3D with the multiscale algorithms. Resulting constitutive laws are then used as user subroutines to MARC (or any other FE solver) to run a non-linear FE analysis. Material properties are iterated at every material point as a function of applied strains using the multiscale models.

- Non linear analysis is ideal if the goal is predict the ultimate failures (cracking etc) of the fiber oriented thermoplastics under operating conditions. Digimat allows the failure predictions by providing non-linear constitutive behavior.

- In addition, long term fatigue loading predictions can be effectively made using the complex multiaxial theories in digitmat tailored especially for the filled thermoplastics.

- FEA Interface allows outputting only fiber orientation tensors (*.od2) files that can be directly imported in Digimat.

Optimal design Workflow (CAE Centered) For Thermoplastics



Article by Innova Engineering : **An optimized part-design workflow for structural injection molded parts**
(http://www.plasticstoday.com/injection-molding/optimized-part-design-workflow-structural-injection-molded-parts/213494898744357)

Thank You !

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