Modeling warpage and shrinkage in thermoplastic blow molded part using BlowView

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Modeling Warpage and Shrinkage in a Thermoplastic Blow Molded Part using BlowView

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AIP: Geoff Ward

33rd Annual Blow Molding Conference

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Chicago, IL, USA

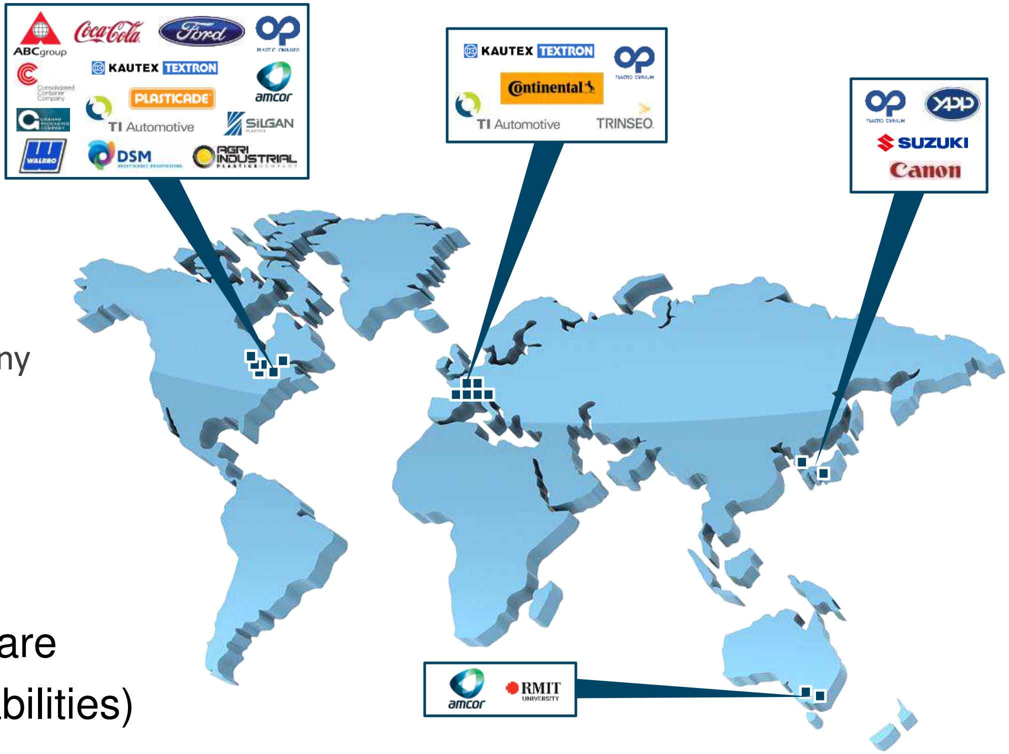
AGRI INDUSTRIAL PLASTICS COMPANY

Overview

- Who are we?
  - NRC
  - SIGBLOW consortium
  - BlowView Software
- Objectives of warpage model development
- Understanding shrinkage and warpage in blow molding applications
- Assessing the current cooling/warpage numerical tool available in BlowView based on a case study from **Agri-Industrial Plastics** (AIP)
- Validation and comparison with experimental results
- Conclusion and future work

NRC SIGBLOW/SIGFORM/SIGSuBM: Industrial R&D Groups

- Established in 1992
- Blow molding simulation research consortium, led by NRC: Development of in-house engineering software (BlowView) dedicated to simulate Polymer Forming Processes
- Small membership base - select group of OEMs, Automotive, resin manufacturers, packaging and suppliers, such as:
  - Ford Motor Company
  - Kautex Textron
  - Plastic Omnium
  - TI Automotive
  - ABC Group
  - The Coca-Cola Company
  - AMCOR
  - Graham Packaging
  - Agri-Industrial Plastics
  - Silgan Plastics
  - Plasticade
  - DSM
  - YAPP
  - Walbro
  - Consolidated Container Company
  - Conti-Tech
  - Trinseo



- Meet semi-annually
- Members provide input to govern software development (New functionalities, capabilities)

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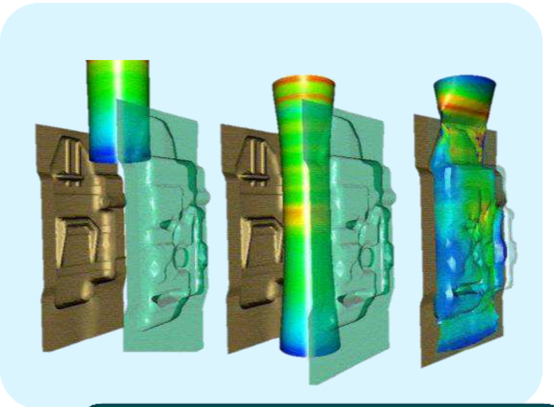
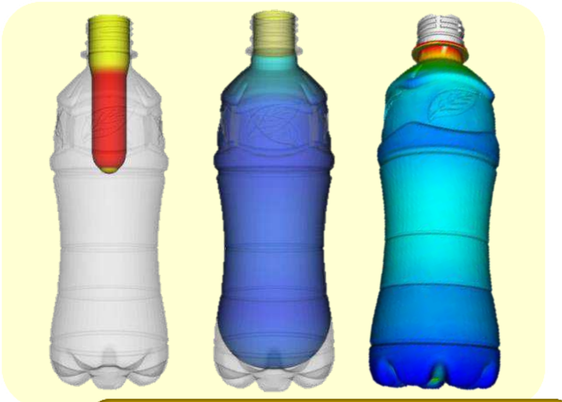
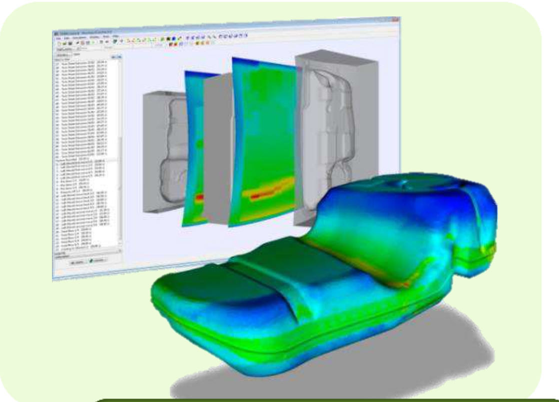
NRC BlowView software capabilities



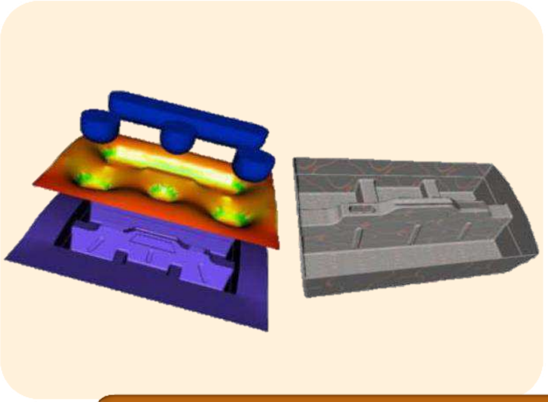
Extrusion Blow Molding (EBM)



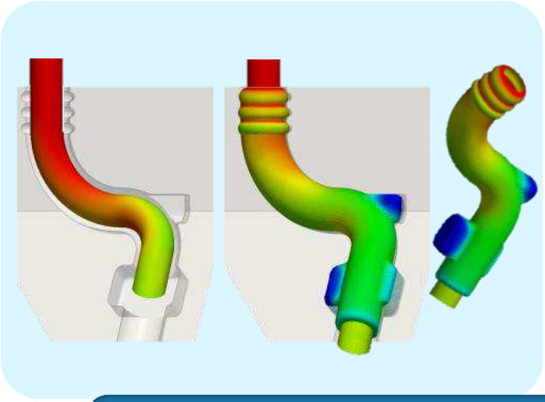
Stretch Blow Molding (SBM)



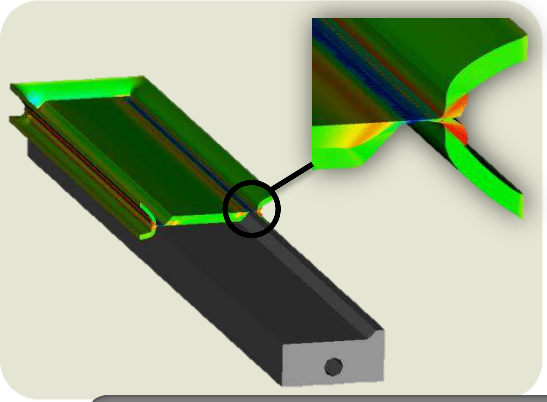
Twin Sheet Extrusion Blow Molding (TSEBM)



Thermoforming



Suction Blow Molding (SuBM)

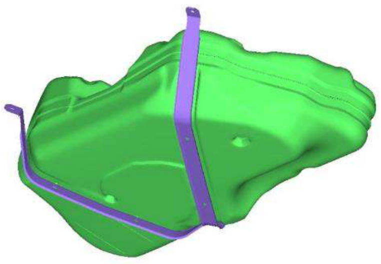


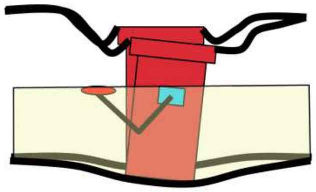
Form 3D

Objectives of Warpage Model Development

Background

- The shrinkage and warpage have been a big concern in the blow molding applications.
- For PFT in particular, poor dimensional stability due to warpage and shrinkage causes problems in:
  - Assembling the fuel tank components (tolerance issue)
    - Improper location and/or fitting of components (i.e. fuel line inside tank groove)
    - Increase tank strap tension/stress
    - Increase strap bolt force
    - Increase tank shell stress
    - Decrease plastic welds quality/strength
  - Erratic fuel volume level indication issues, due to
    - Changes in float location and/or orientation





Objectives of Warpage Model Development

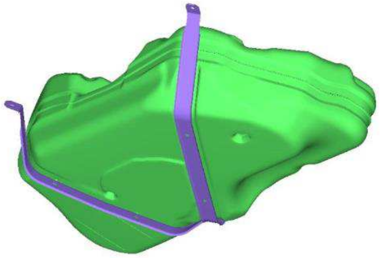
Background

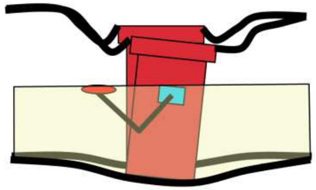
KAUTEX-TEXTRON/FORD MOTOR/NRC (2013)

Usman M., Ahmad S., Benrabah Z., Atsbha H., A Plastic Fuel Tank Deformation in the Post Blow Molding Phase due to Material Shrinkage/ Warpage.
SPE: Annual Blow Molding Conference, 8-9th October 2013, Atlanta. GA, USA

P.O/FORD MOTOR/NRC (2016)

Usman M., Ahmad S., Siddiqui S., Benrabah Z., Bardetti A., Mir H., Lempicki J., Kulevski J., Masse H,
Plastic Fuel Tank Deformation in the Post Blow Molding Phase: Warpage and Shrinkage Tolerance Issue.
SPE: Annual Blow Molding Conference, 3-5th October 2016, Atlanta. GA, USA





Objectives of Warpage Model Development

ACTIONS

- Since tolerance issue due to warpage deformation is decisive quality criterion for part acceptance, an increasing attention is paid to part warpage in the early stages of product design.

- Therefore, part warpage and tolerance issues need to be controlled and optimized using an accurate and suitable prediction tool using BLOWVIEW software

1. Benrabah Z., Mir H., Lempicki J., Bardetti A., Ahmad S., Siddiqui S., Usman M., **Contribution to Warpage Analysis Using BlowView Software,** 74th Annual technical conference of the Society of Plastics Engineers (ANTEC 2016); the plastics conference, 23rd-25th May 2016, Indianapolis, IN, USA

2. Benrabah, Z., MIR, H., Zhang, Y., 2013: "**Thermo-Viscoelastic Model for Shrinkage and Warpage Prediction during Cooling and Solidification of Automotive Blow Molded Parts**". *SAE International Journal of Materials and Manufacturing*, Volume 6, Issue 2, pp. 349-364.

3. Z. Benrabah Z., P. Debergue, R. DiRaddo, " **Deflashing of Automotive Formed Parts: Warpage and Tolerance Issues** ". *SAE 2006 Transactions Journal of Materials and manufacturing, Mechanical System: 493--501p*

4.P. Debergue, H. Massé, Thibault F., Diraddo, " **Modelling of Solidification Deformation in Automotive Formed Part** ", SAE 2004 . *Transactions Journal of Materials and manufacturing, Mechanical System: 112(5), 2004*

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Understanding Shrinkage and Warpage in Blow Molding

Warpage Causes ? Why does it occur

Process-induced Residual Stresses are the main cause of part warpage

- Thermal-Induced Residual Stresses:
  - Differential shrinkage
  - Inhomogeneous cooling conditions
  - Uneven Part Temperature (across the thickness and over the part)
  - Uneven Part Thickness (~ 3 – 10 mm)
  - Inhomogeneous materials across the part thickness (up to 6-7 layers with varying properties)

- Flow-Induced Residual Stresses :
  - Extrusion rate
  - Shear rate
  - Material viscosity
  - Shear & normal stresses
  - Melt temperature, Head pressure

Process prediction in BlowView : From Extrusion to Warpage Prediction

Process prediction in BlowView:

- Extrusion
- Pre-Blow
- Inflation
- Cooling in the Mold
- Cooling after Ejection:
  - Air
  - In Shell Cooling
  - Underwater
  - Others.

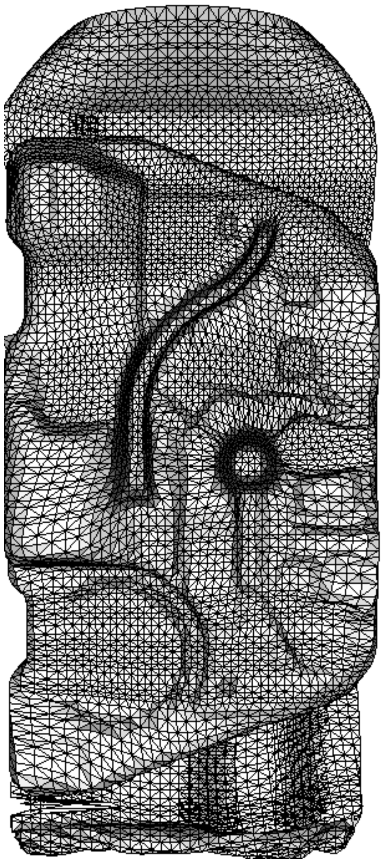
Extrusion and Blow Molding stages

In mold/out of mold cooling

Warpage Prediction Model in BlowView

Warpage analysis performed on the Part CAD vs the inflated parison

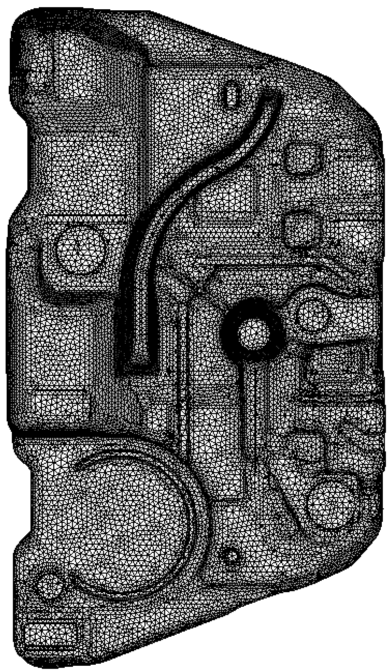
Mesh at the end of inflation



Thickness

Temperature

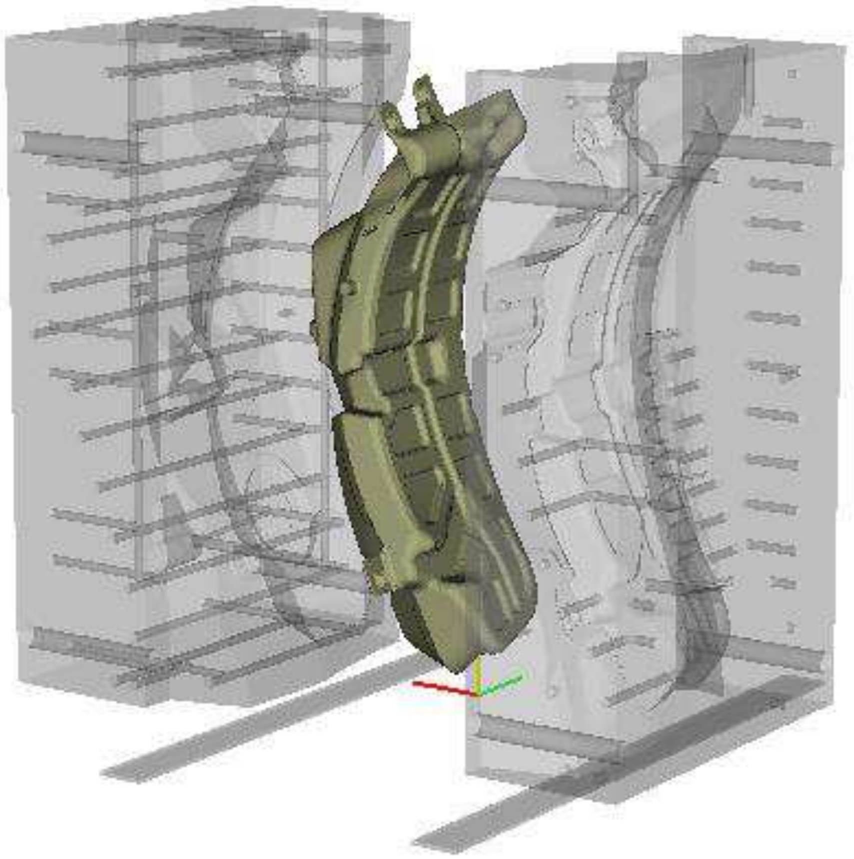
Contact, Stress



Part CAD Mesh

AIP Validation Case
General Information

Material:	Marlex HXM 50100
Total Mass Flow:	3733 Kg/hr
Extrusion Time:	7.0 sec
Cooling In-Mold:	180 sec
Total Shot Weight:	6.9 Kg
Tank Weight :	3.6 Kg
Flash Weight:	3.3 Kg



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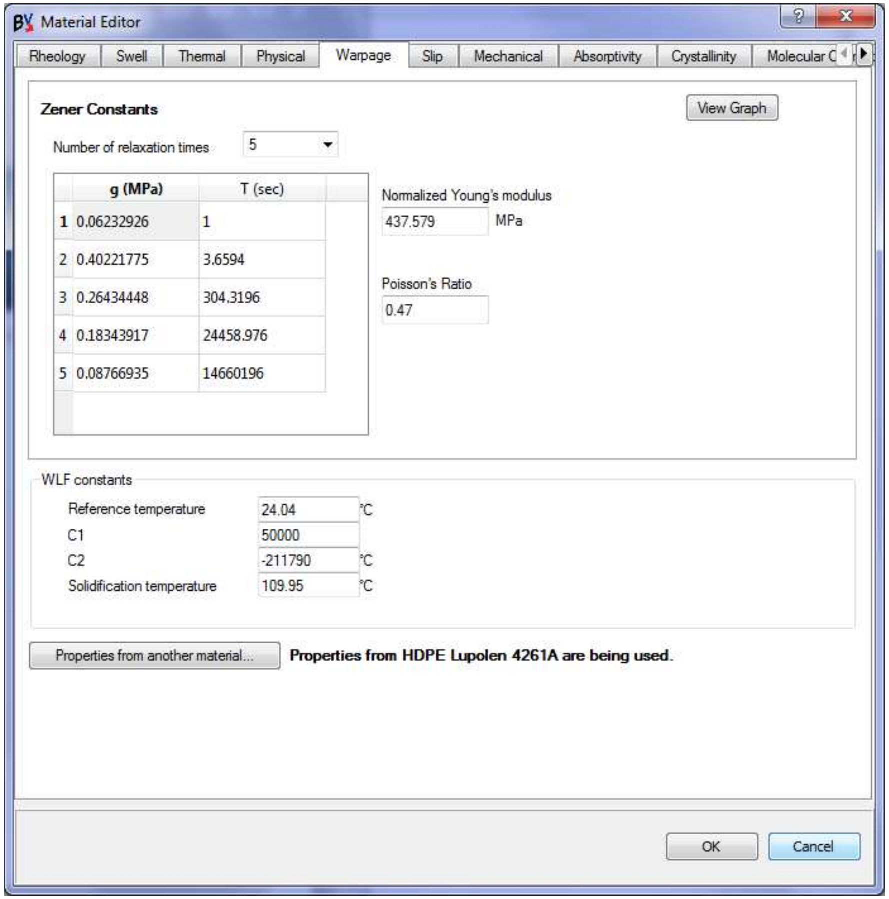
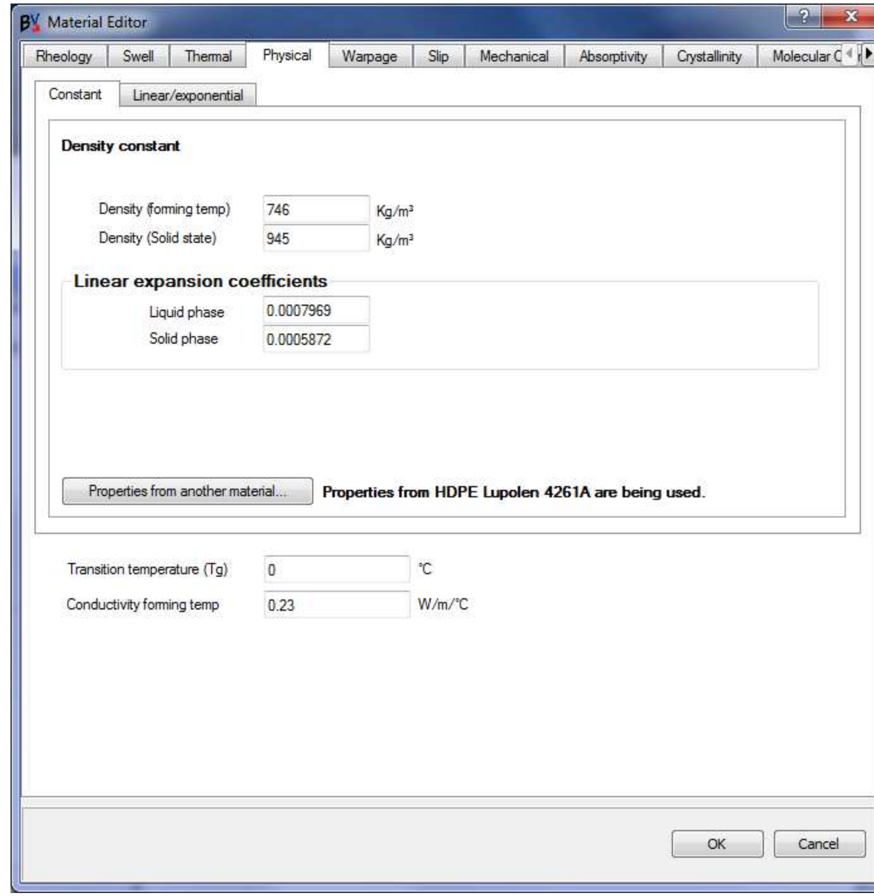
AIP Validation Case
Material Data

Warpage Model



Linear Expansion Coefficients



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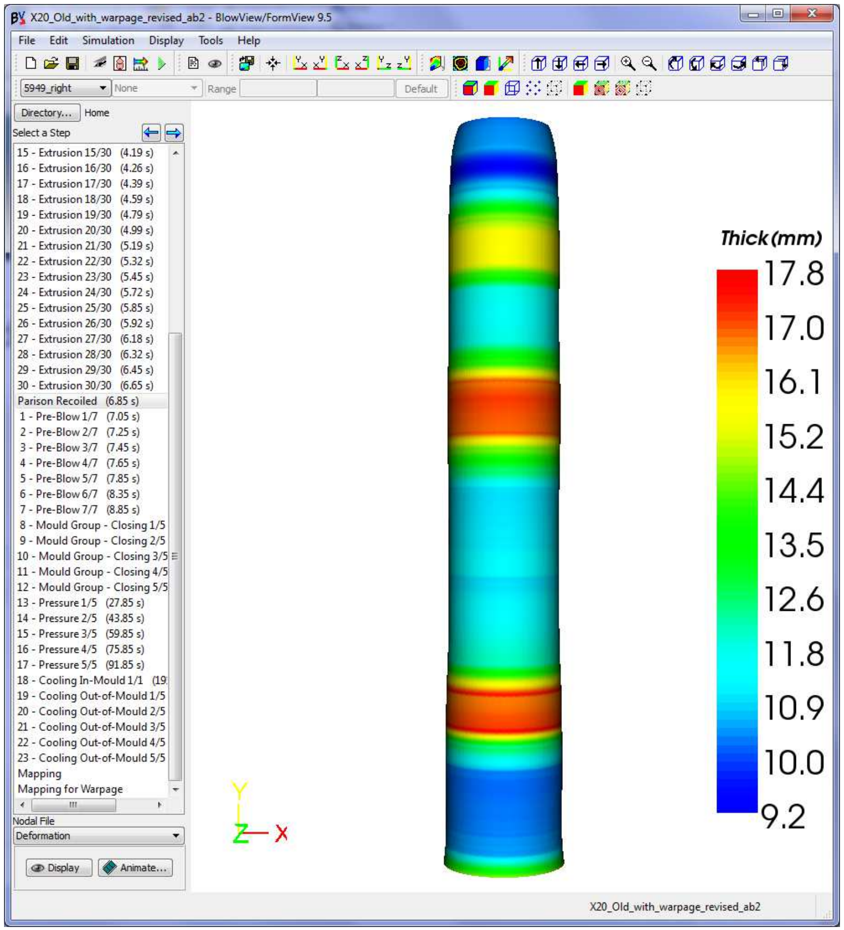
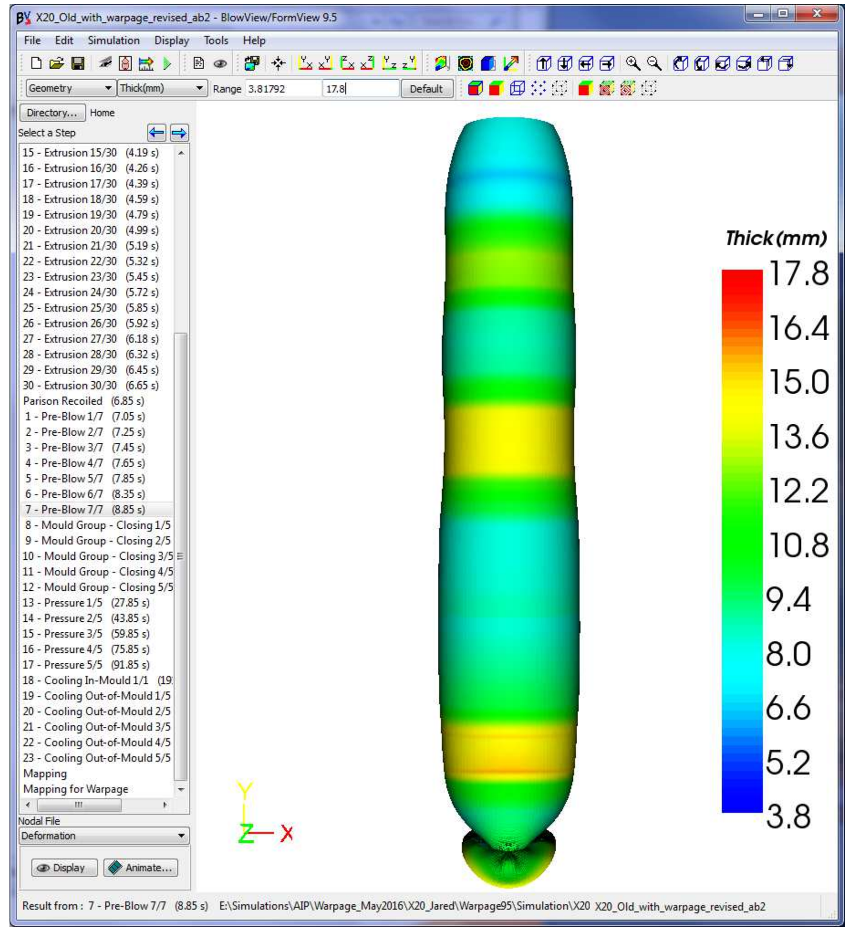
AIP Validation Case
Results - Parison Extrusion and Pre-Blow

End of Extrusion

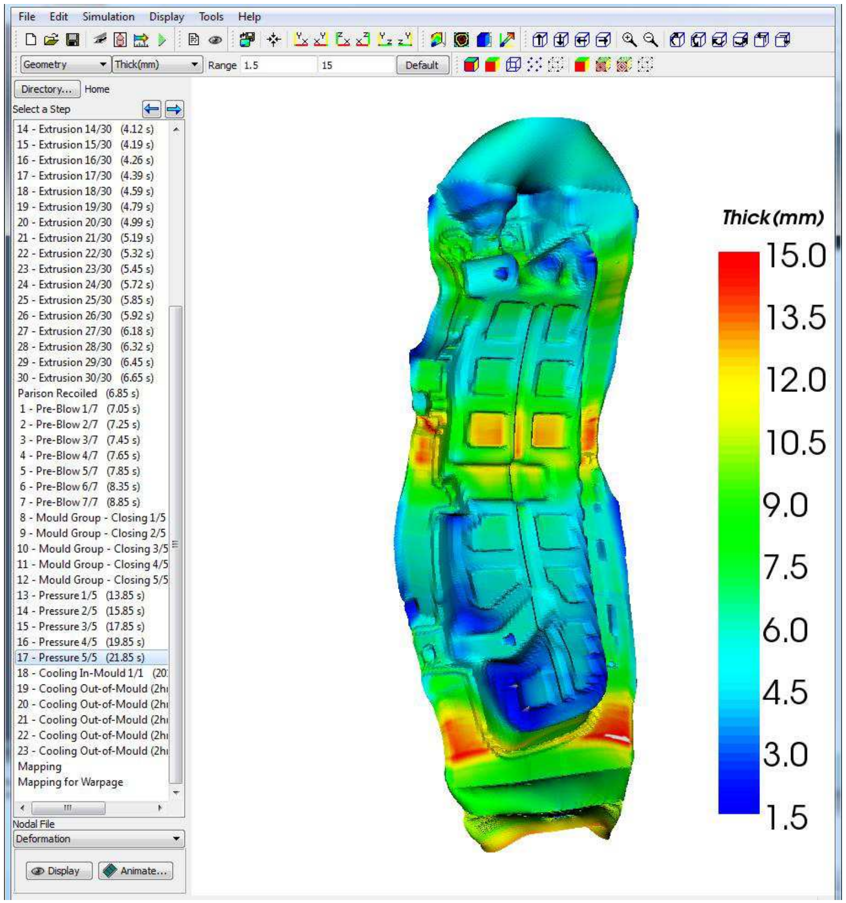


End of Pre-Blow

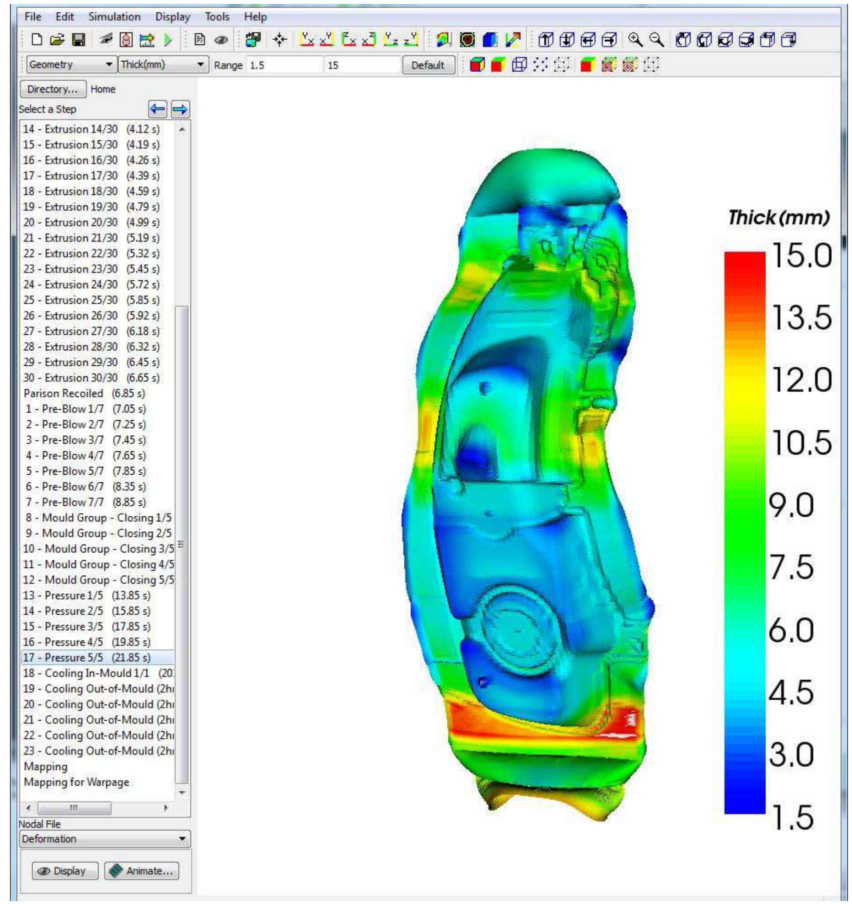


AIP Validation Case
Results - End of Inflation

Lower Shell

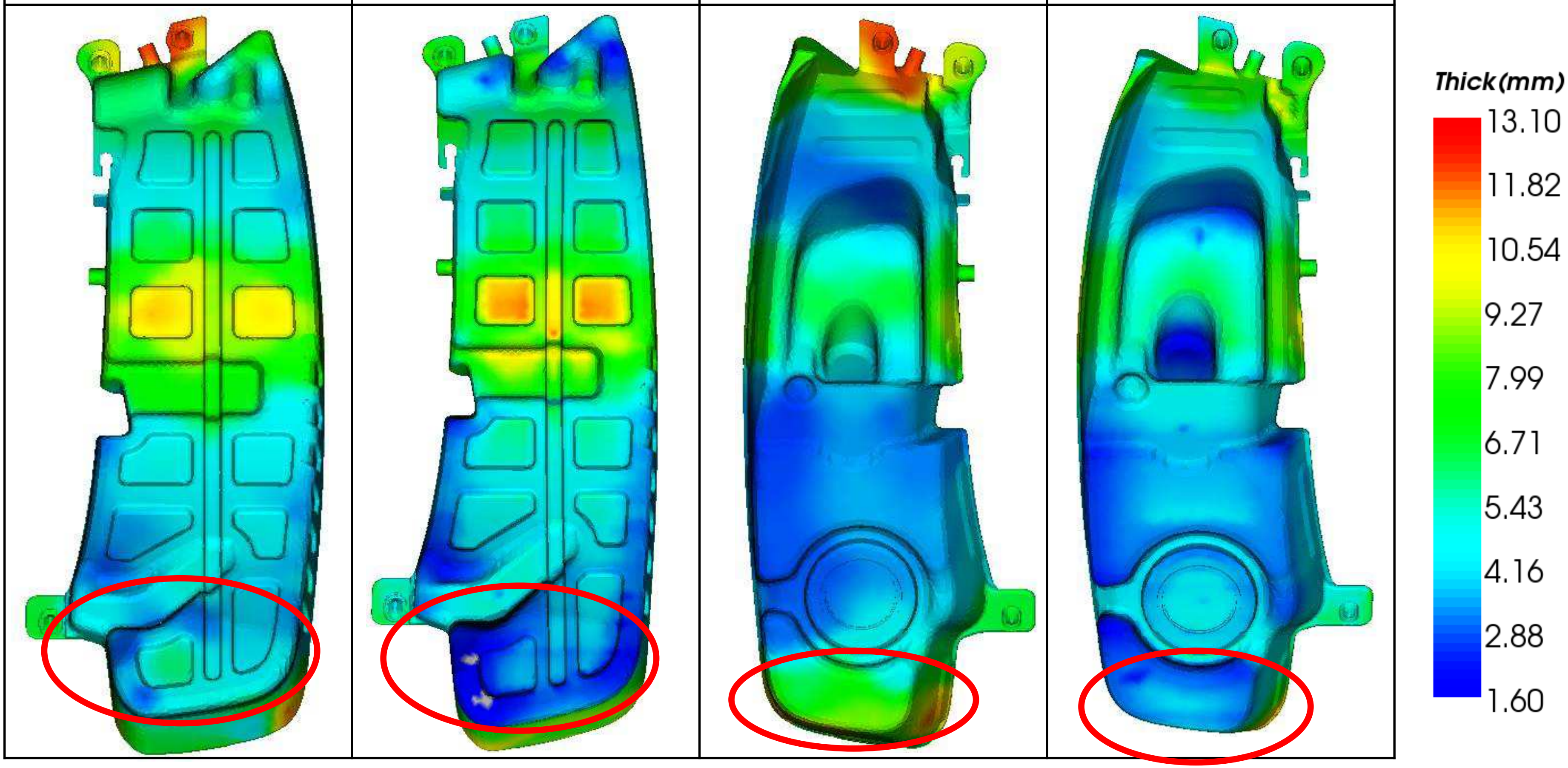


Upper Shell



AIP Validation Case
Thickness Comparison with Measured Data

Measured *data provided by AIP*	Predicted *BlowView Simulation* *(15 % Shrinkage applied)*	Measured *data provided by AIP*	Predicted *BlowView Simulation* *(15 % Shrinkage applied)*



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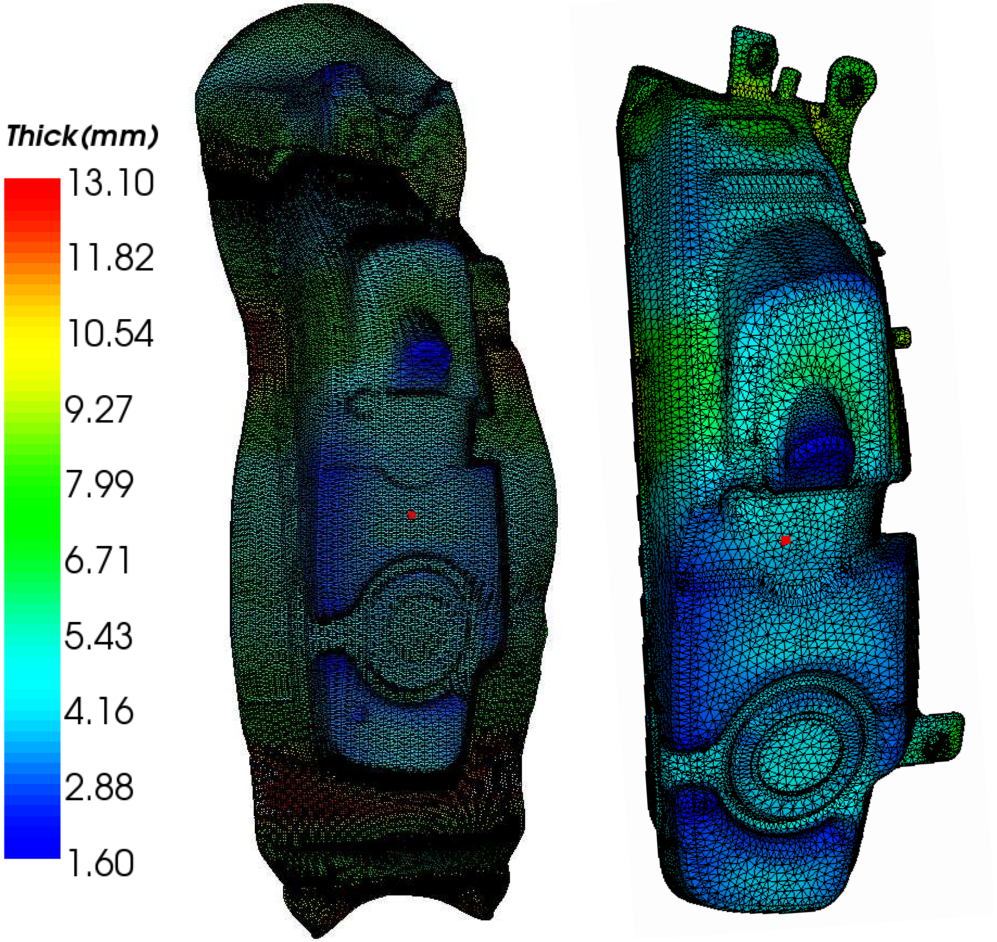
AIP Validation Case
Warpage Simulation

Two warpage simulations were considered:

- Warpage on Inflated Parison
- Warpage on Part CAD



Warpage on Inflated Parison

Warpage on CAD Part

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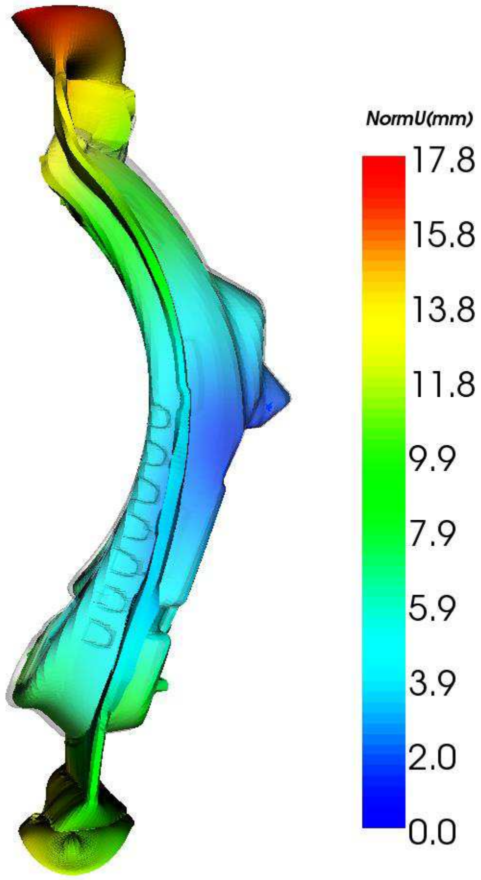
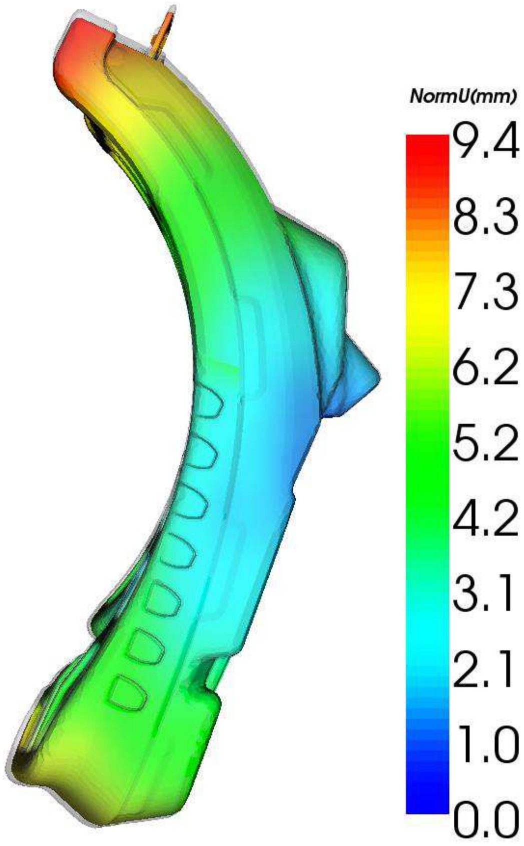
AIP Validation Case
Warpage Results

Warpage Prediction on Inflated Parison (with flash)



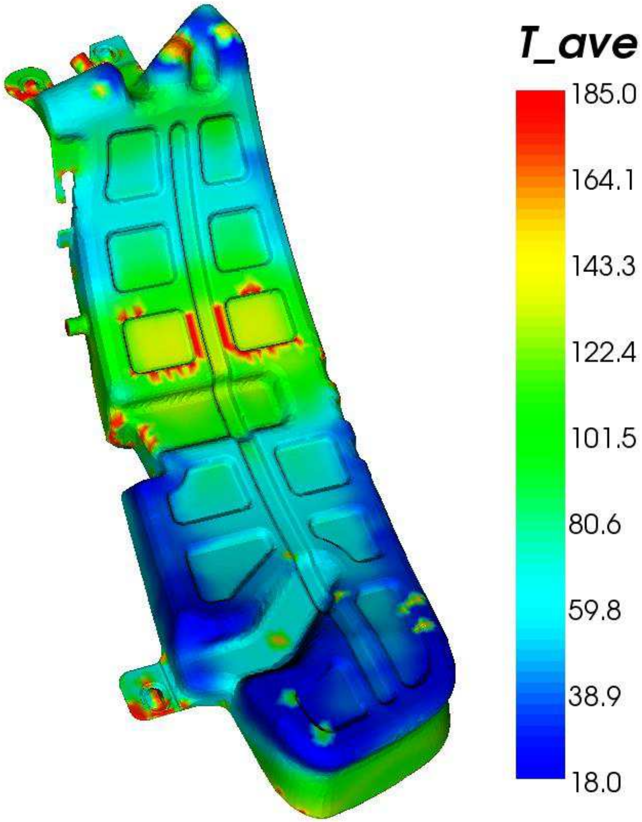
Warpage Prediction on Part CAD



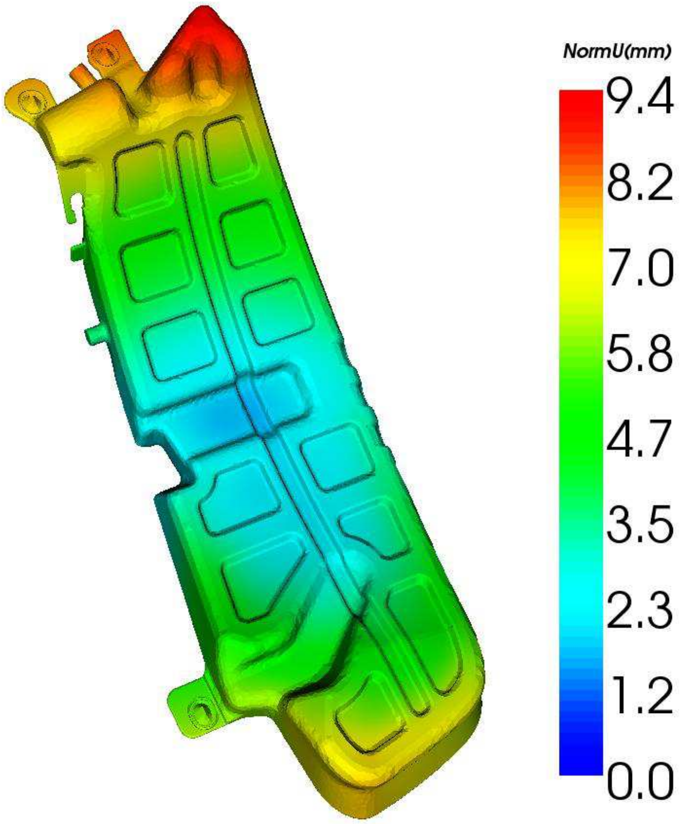
Note: NormU is the total magnitude of the displacement in mm

AIP Validation Case
Warpage on part CAD Results

Average Temperature at end of Cooling-in-Mold



Warpage Prediction



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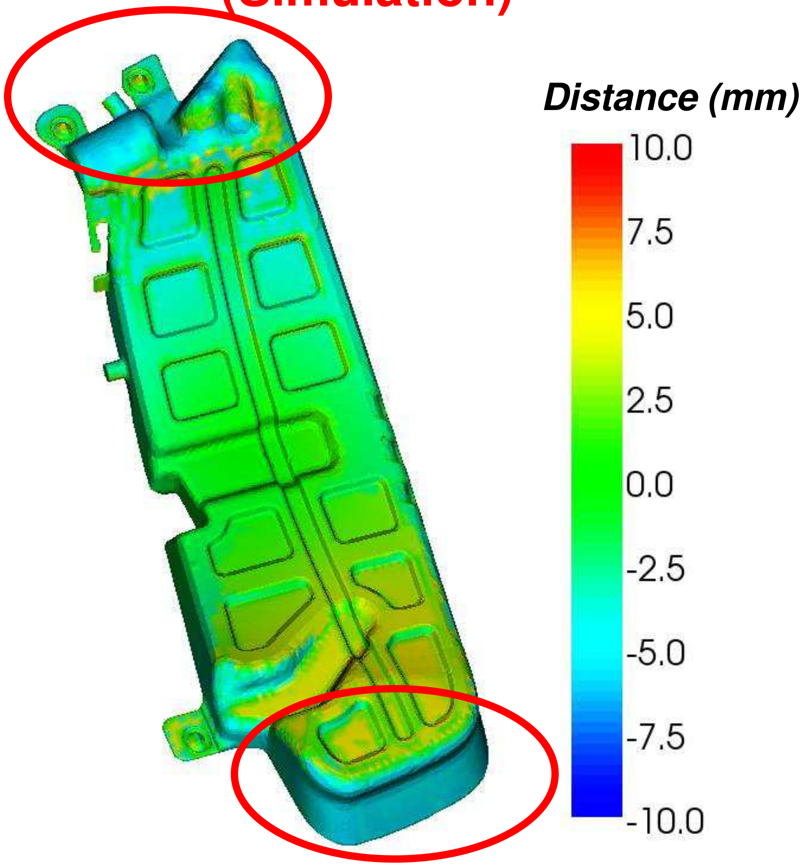
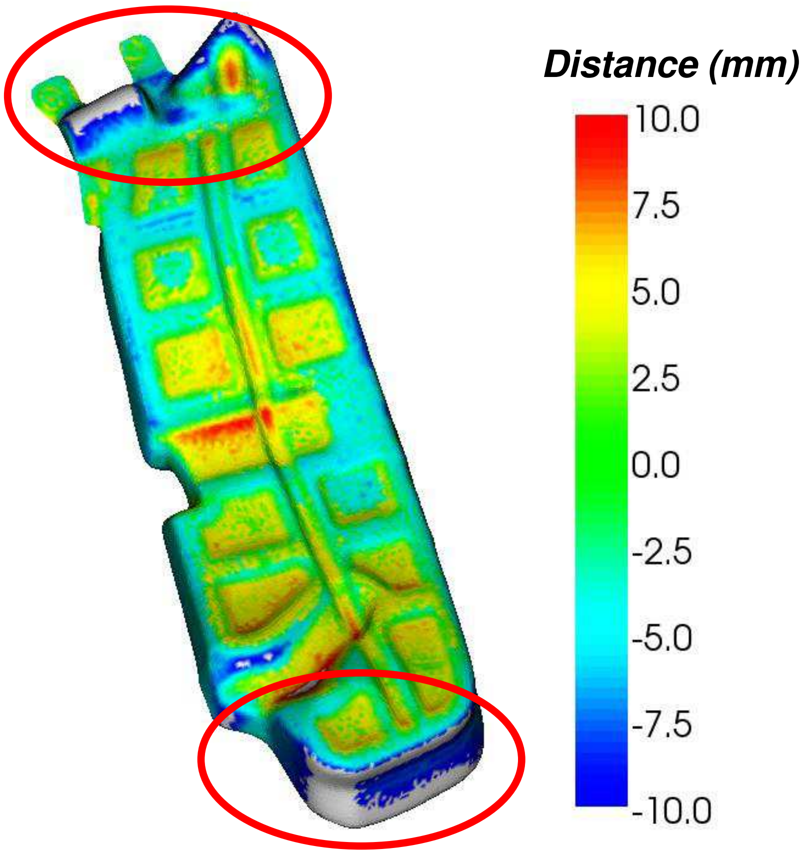
AIP Validation Case
Warpage on part CAD Results vs Experimental

Difference between simulated warped Part CAD and initial Part CAD
(Simulation)



Difference between engineered scan of actual part and initial Part CAD
(Experiment)



Note: Distance is the normal magnitude of the displacement between meshes

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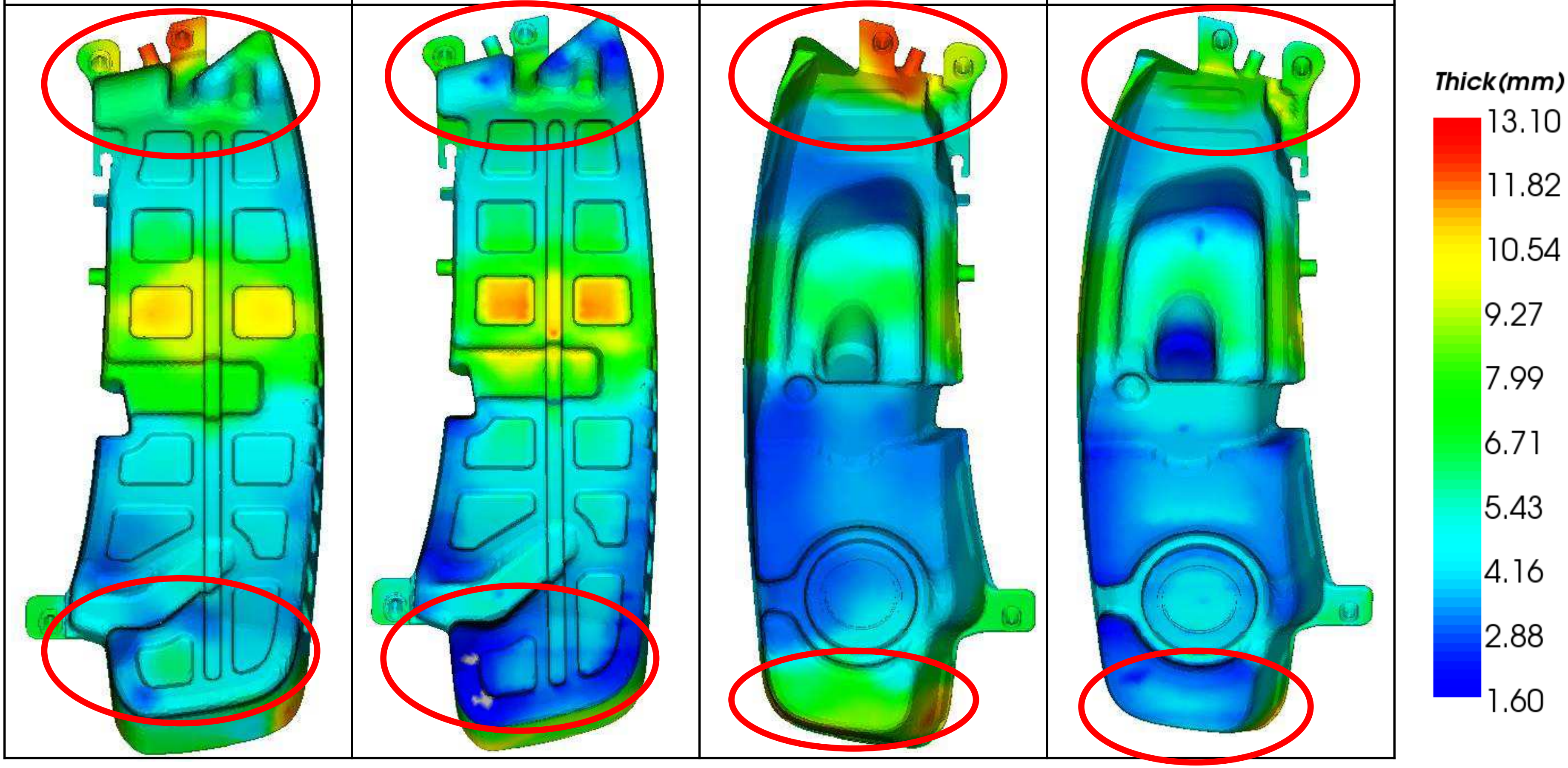
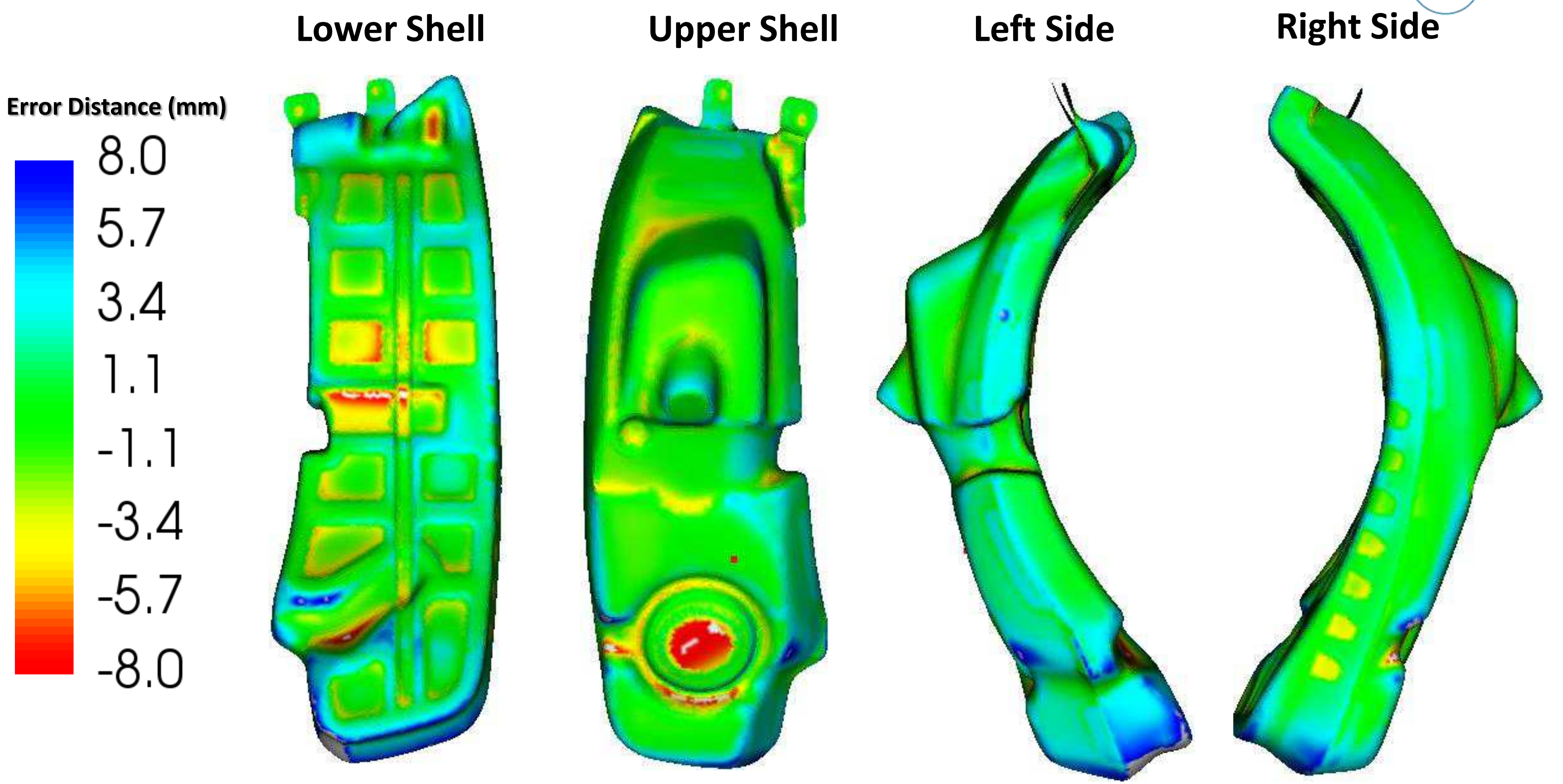
AIP Validation Case
Thickness Comparison with Measured Data

Measured *data provided by AIP*	**Predicted** *BlowView Simulation (15 % Shrinkage applied)*	**Measured** *data provided by AIP*	**Predicted** *BlowView Simulation (15 % Shrinkage applied)*



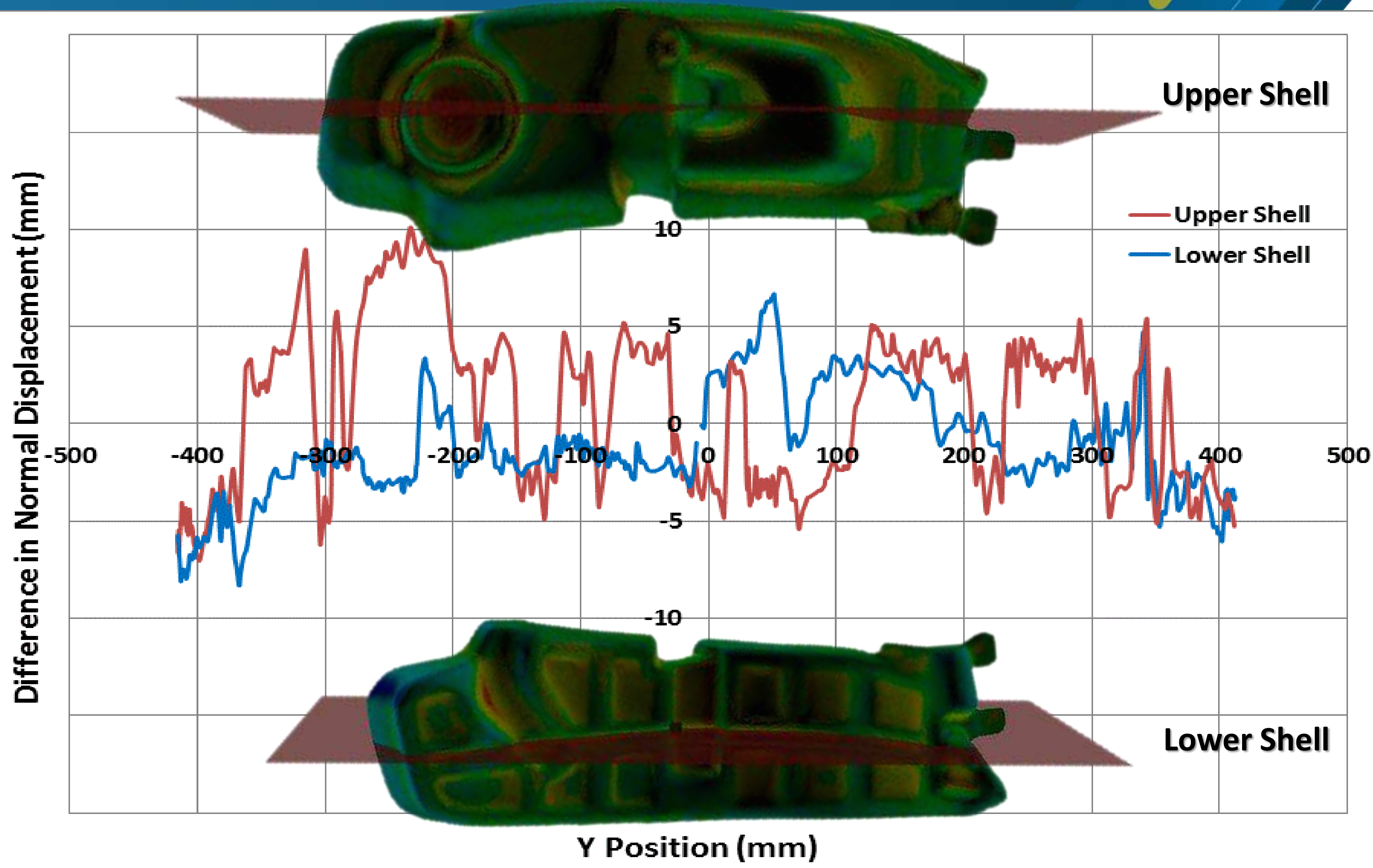
AIP Validation Case
Error between Warpage Simulation and Actual Part Scan



Average Error: 2.05 mm and STD : 1.76 mm

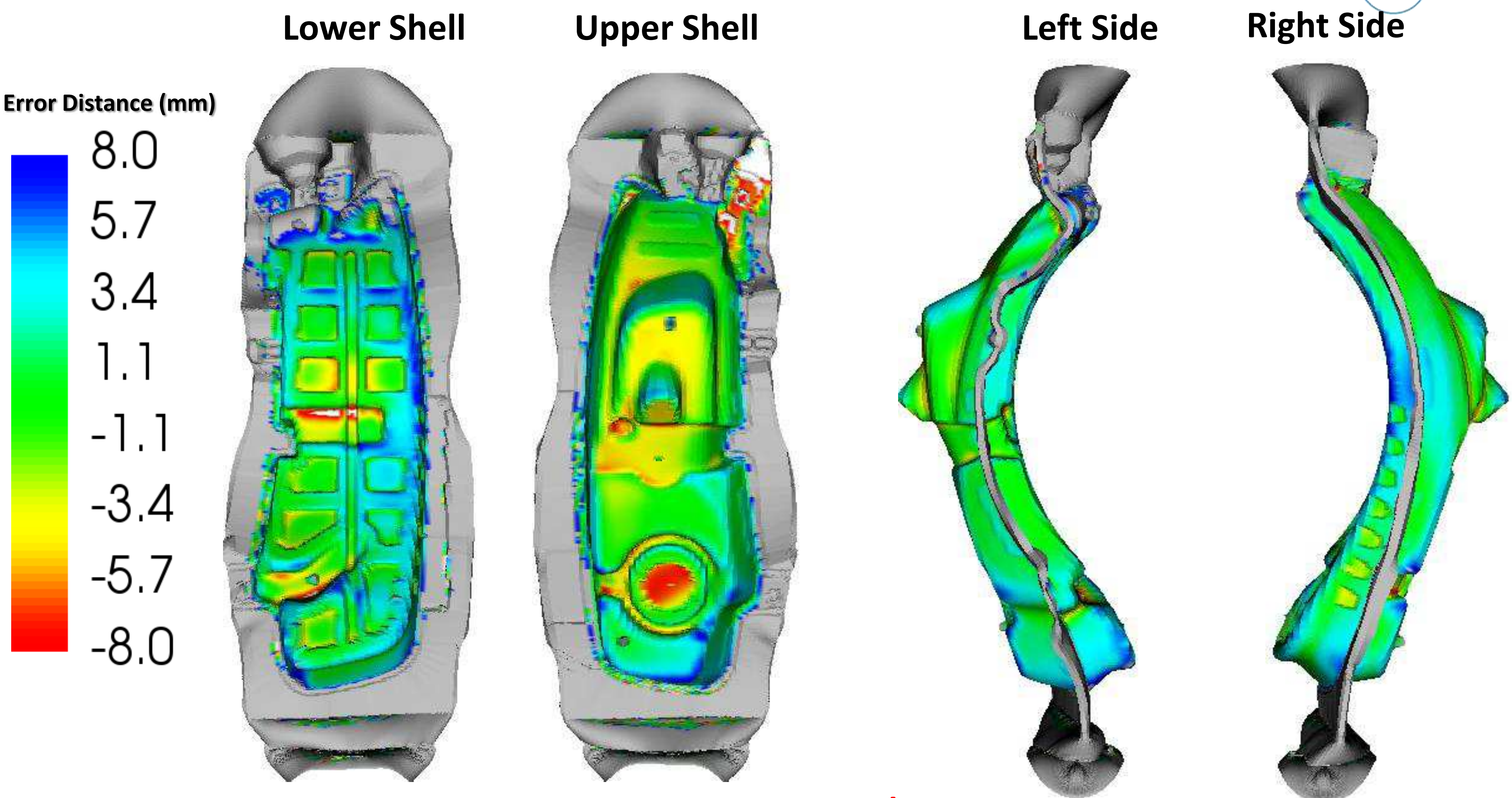
Note: Error Distance is the normal magnitude of the displacement between meshes

AIP Validation Case
Error between Warpage Simulation and Actual Part Scan



AIP Validation Case

Error between Warpage Simulation (on inflated parison) and Actual Part Scan



Average Error: 3.53 mm and STD : 11.01 mm

Conclusion and Future Work

- This work was intended to validate the warpage prediction using BlowView for an industrial part provided by Agri-Industrial Plastics
- The predicted thickness are in good agreement with the measured data provided by AIP
- Two warpage simulations were considered:
  - The results show that the Warpage on CAD Part improves the warpage prediction, due to better mesh quality
  - The predicted warpage results are in relatively good agreement with the measured data provided by AIP
- Take into account a cooling channel in the mold
- Sensitive analysis on material properties (i.e., L.E.C, HTC, etc...)