Hydrostatic (Pneumatic) Bulge Testing of Magnesium e-Form Plus (Batch-3) Sheets at 200 °C

Report Submitted to United States Automotive Materials Partnership (USAMP)

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Overview

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Materials and Tests
Designations

- *One material was received; the material was given an internal FADI-AMT designation (these are designations used internally for: (1) consistency of labeling data files and test samples (2) to maintain privacy since we test/analyze many materials by many suppliers).*

- *Material label for the sheets provided by USAMP is:*
  - ***M12**: Magnesium e-Form Plus Batch-3 (~1.18mm thick sheets)*

- *The material was provided in ~600x600mm square sheets*

- *Test Label Format: **M**α**_**β**(**γ**)-200C-**$\zeta\psi$*

M *: Magnesium Alloy*

α *: Material number (12 in this case)*

β *: Test Type (BBT: Balanced Biaxial Tension Test)*

γ *: Test Approach (PB: Pneumatic Bulge Test)*

200C *: Test Temperature*

ζ *: Orientation (TD)*

ψ *: Test Repeat Number (1, 2, 3, …)*

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Thickness Measurements

- *Thickness measurements were taken at different locations across the provided blanks; the recorded measurements are shown below:*

Thickness Measurements (mm) ►	Thickness Measurements (mm)											
	1	2	3	4	5	6	7	8	9	10	**Avg.**	STD
M12 (Magnesium e-Form Plus Batch-3)	1.171	1.178	1.174	1.184	1.187	1.183	1.173	1.178	1.180	1.181	**1.179**	0.0051

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Bulge Tests Performed

Overview

- *The below table summarizes the sheets that were used to perform the bulge tests included in this report, and the type/number of samples tested successfully:*

Materials Tested	Material Orientation	Sample Geometry	Tested Samples (Reported)
M12 (Magnesium e-Form Plus Batch-3)	TD	6” Square blank	6 (5)

Testing and Analysis Details

Pneumatic Bulge Testing

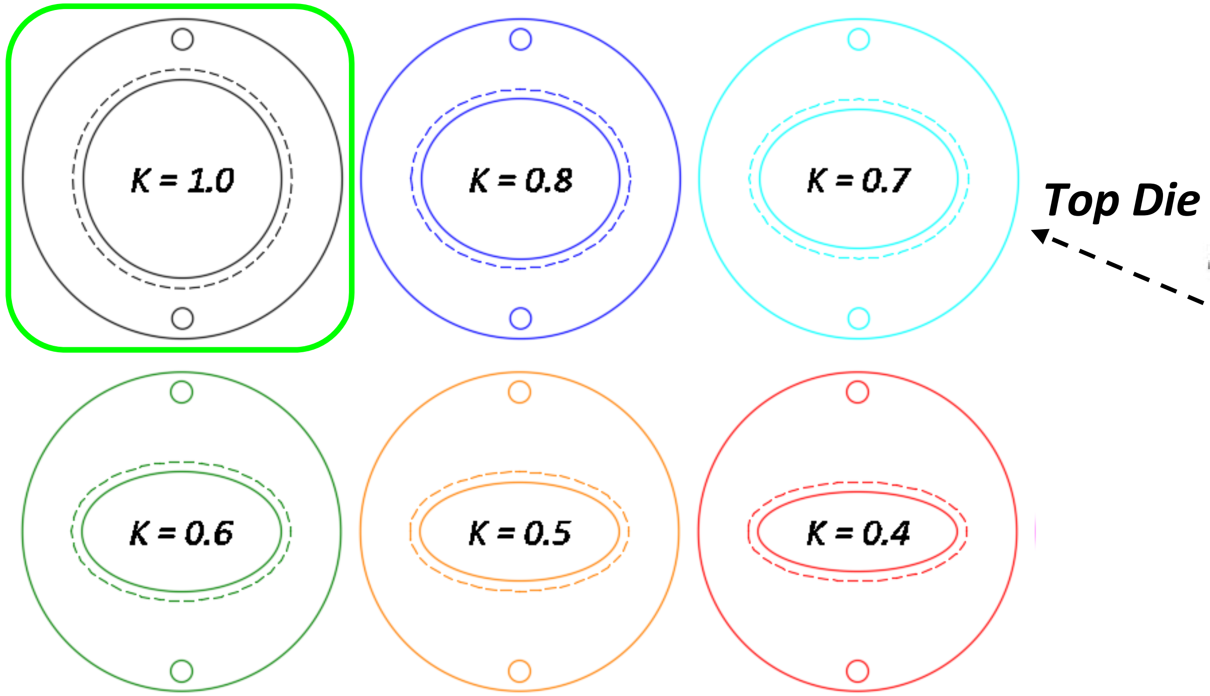
Setup and Approach

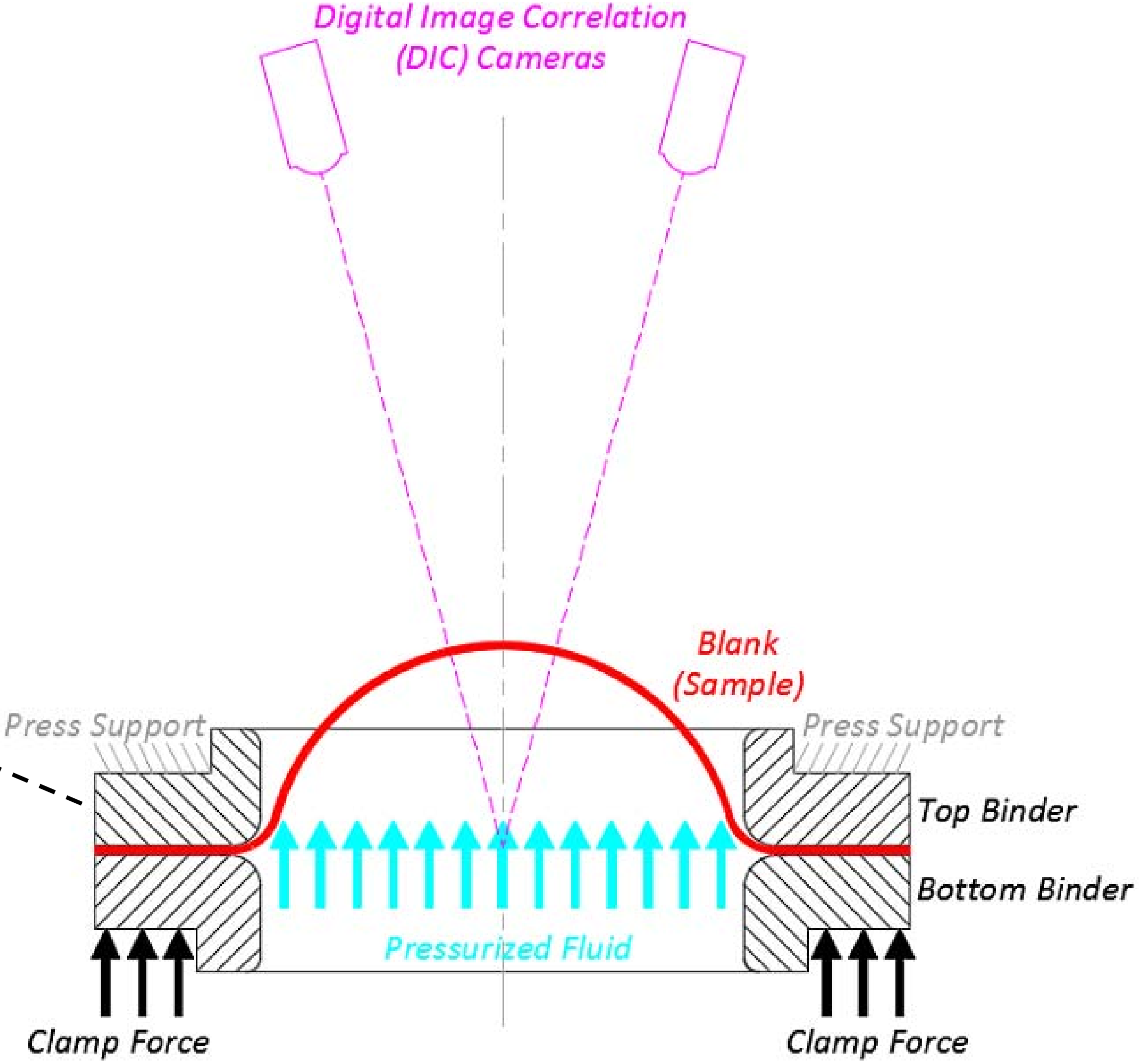
Setup:

Pneumatic bulge testing was performed using an experimental setup per this schematic ▶

Die Inserts

One die insert was used here (K1.0) to induce balanced biaxial deformation in the tested material ▼





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Hydraulic Bulge Test Schematic

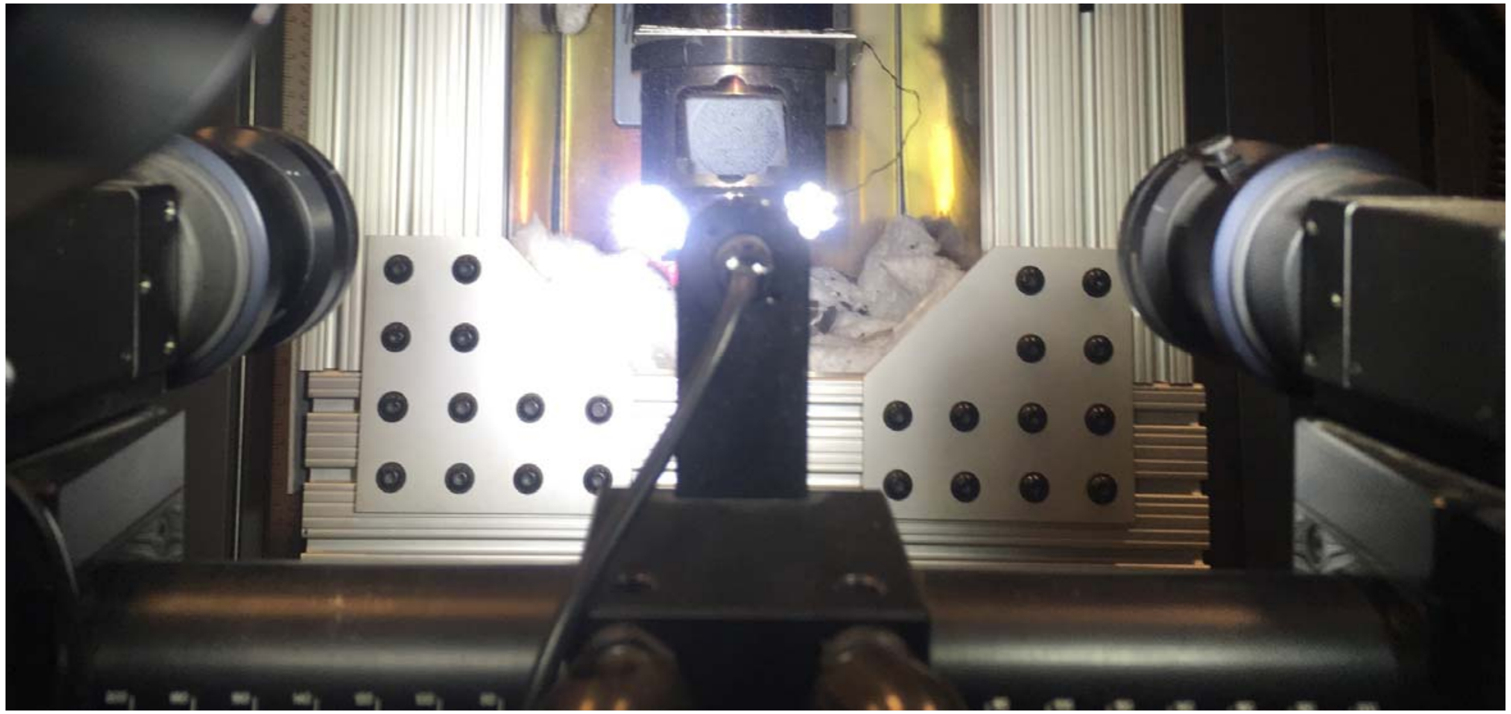
Pneumatic Bulge Testing

Setup and Approach

Setup:

The actual bulging setup used was inverted and a special mirror was used to enable monitoring the sample during deformation with a front-looking DIC system ►

The entire bulging setup was housed within an environmental chamber to achieve homogeneous temperature distribution during testing at elevated temperatures ▼



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Experimental Details

Test and DIC System Parameters

Test Parameters and Conditions :

- *Test Setup: Custom pneumatic bulge setup fitted within an environmental chamber, and two cameras (for 3D DIC strain measurements).*
- *Test Sample Geometry: square @ ~153mm (clamped round Φ=~153mm).*
- *Deformed Gage Area [Bulge Cavity]: Φ=101.6mm.*
- *Testing was performed at 200 °C, at a quasi-static rate.*
- *All tests were performed by linearly increasing the gas pressure at a constant rate (~0.033 MPa/s); testing stops before rupture.*
- *Camera frame rate: fixed @5 fps.*
- *Six samples were tested; five tests were successful with good DIC data (good correlation at 200C).*

Digital Image Correlation (DIC) :

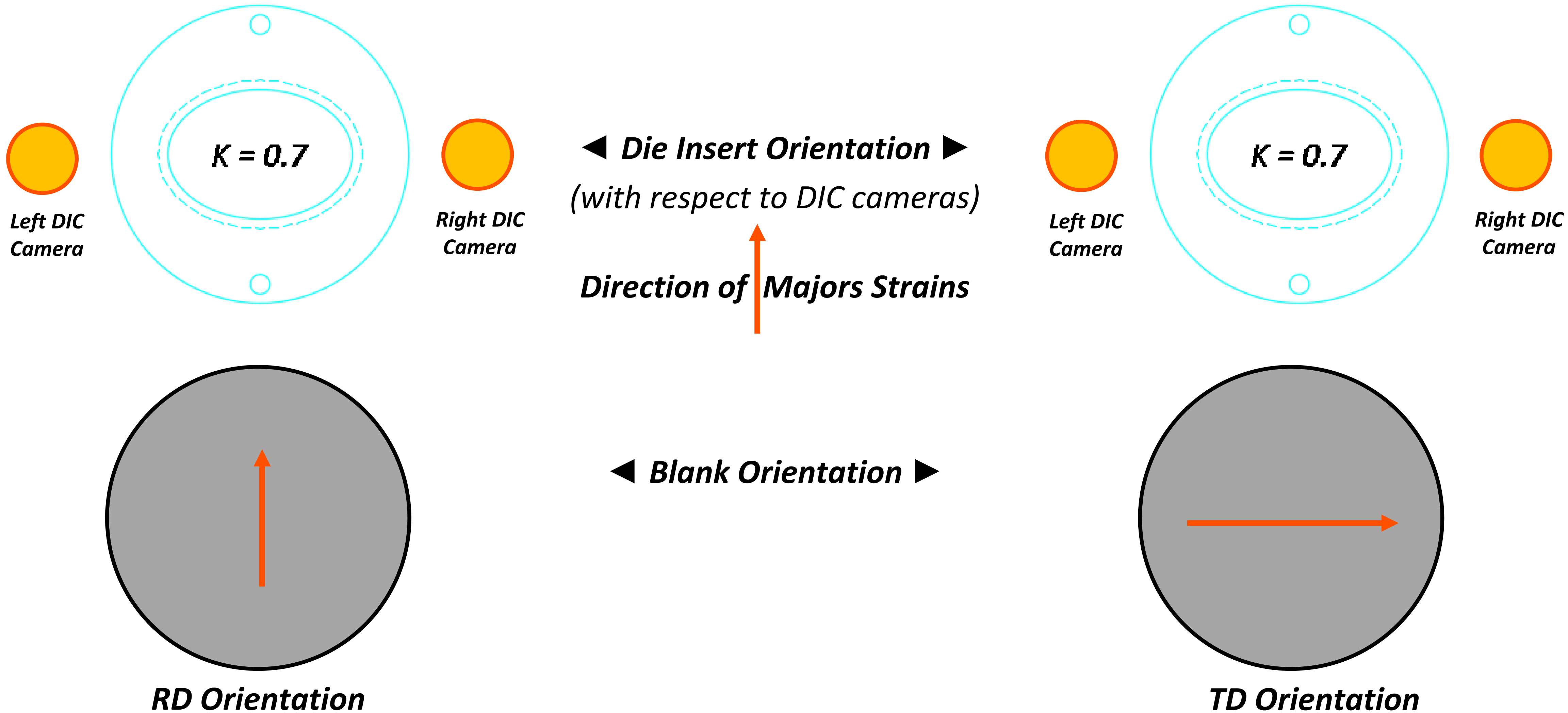
- *All strain measurements were done based on DIC of recorded images.*
- *The GOM ARAMIS software was used for processing and post processing the images.*
- *Pixel resolution of the measurements:* ***~60 microns/pixel***

Experimental Details

Other

Orientations ▶

Below is a schematic of the RD and TD orientations (for K1.0, there is no difference between the two):



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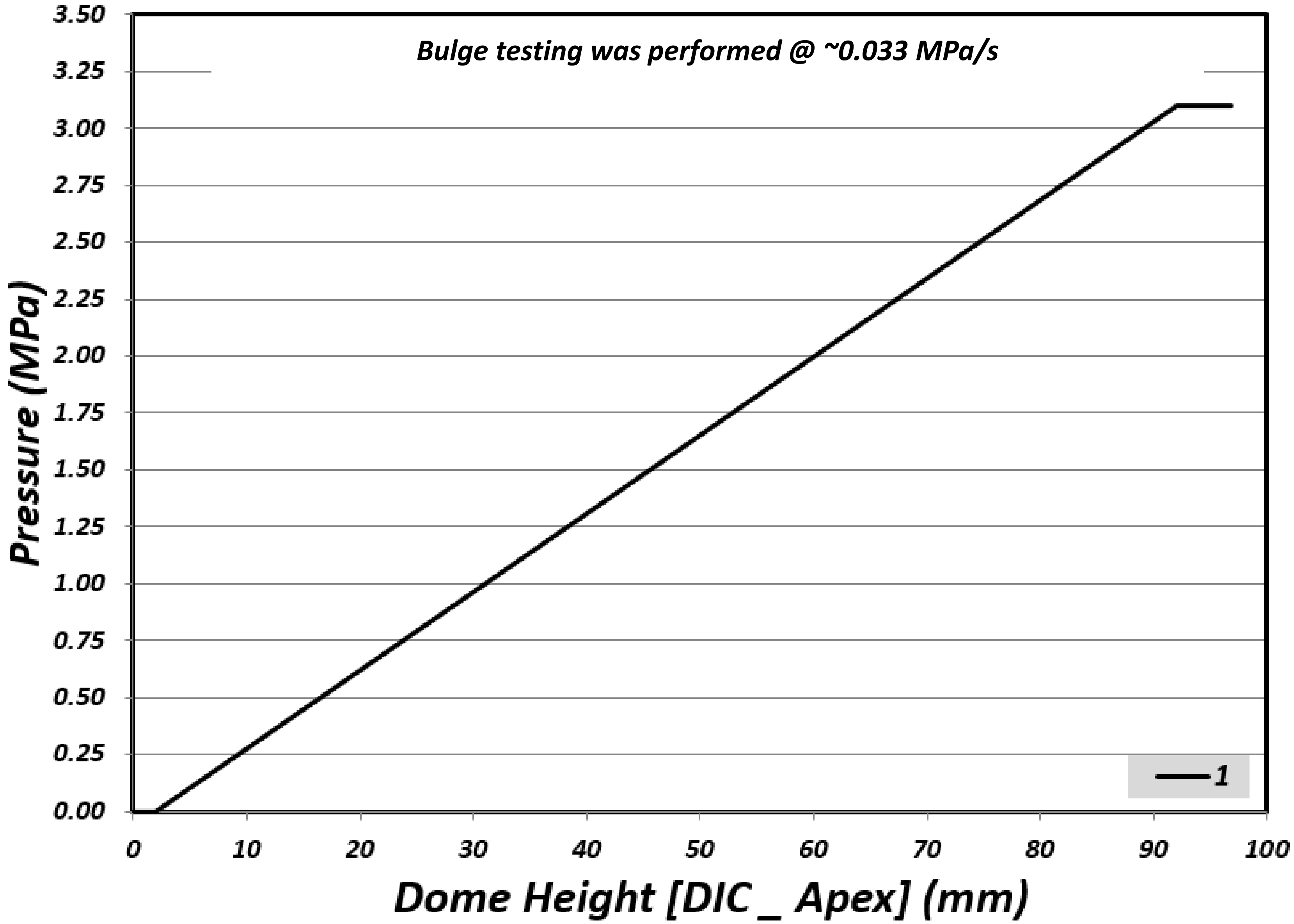
Testing
Pressure Curves



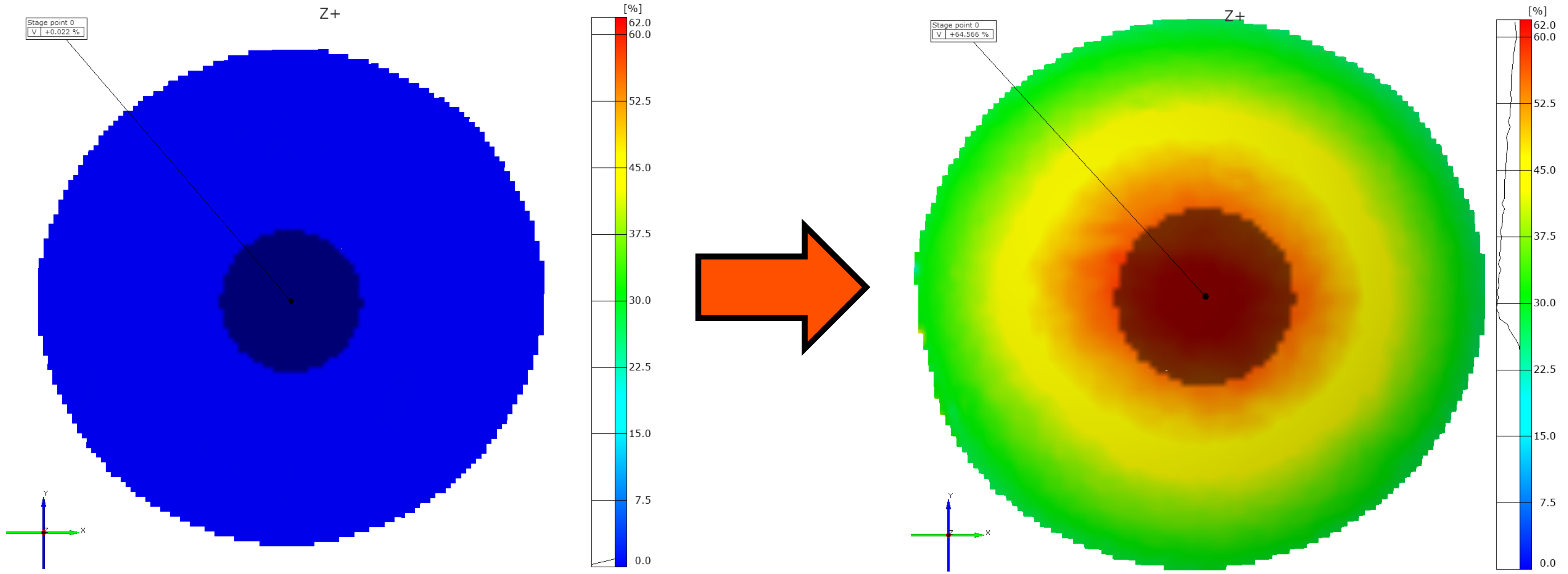
DIC Analysis

DIC Analysis Parameters and Details

DIC Post-Processing Analysis:

- *Surface strains were averaged over a ~10mm diameter circle close to the sample's failure point (maximum strains noted before rupture) within the apex of the formed dome.*
- *The strain path (minor -vs- major strains) was constructed accordingly.*
- *Stresses were computed per ISO-16808, and the corresponding stress/strain curve was constructed.*

This is a schematic



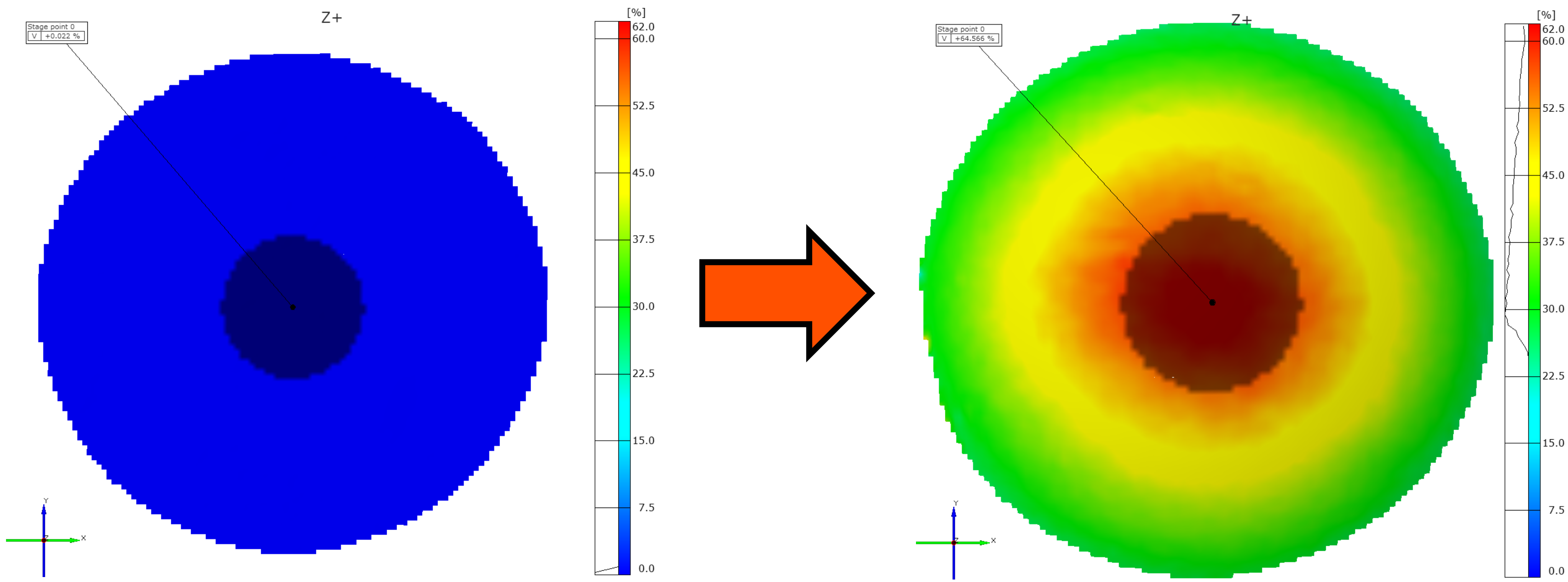
DIC Analysis

DIC Analysis Parameters and Details

DIC Post-Processing Analysis:

- *Due to the higher noise level in DIC measurements (as expected: high temperatures, glass of the environmental chamber, use of a mirror), an averaging algorithm based on the Hollomon model was used to smoothen the resulting "effective stress/strain" curve. The latter was done by taking the DIC data from 4+4 frames around the current DIC frame of analysis, in order to compute the parameters of the stress-pressure relationship.*

This is a schematic



Results Summary

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Testing

Tested Samples

Rolling Direction

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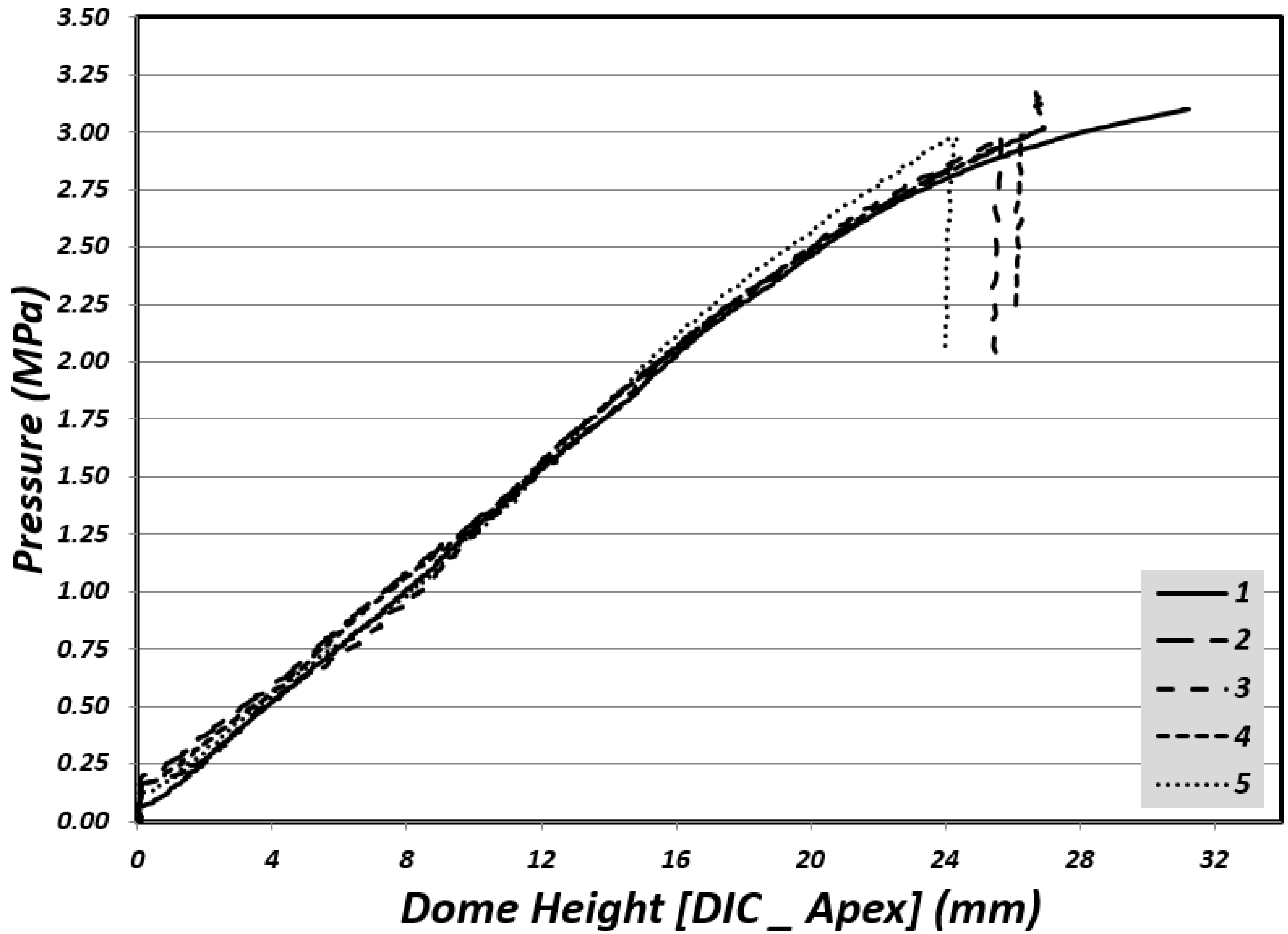
Test Results

Bulge Pressure vs Dome Height



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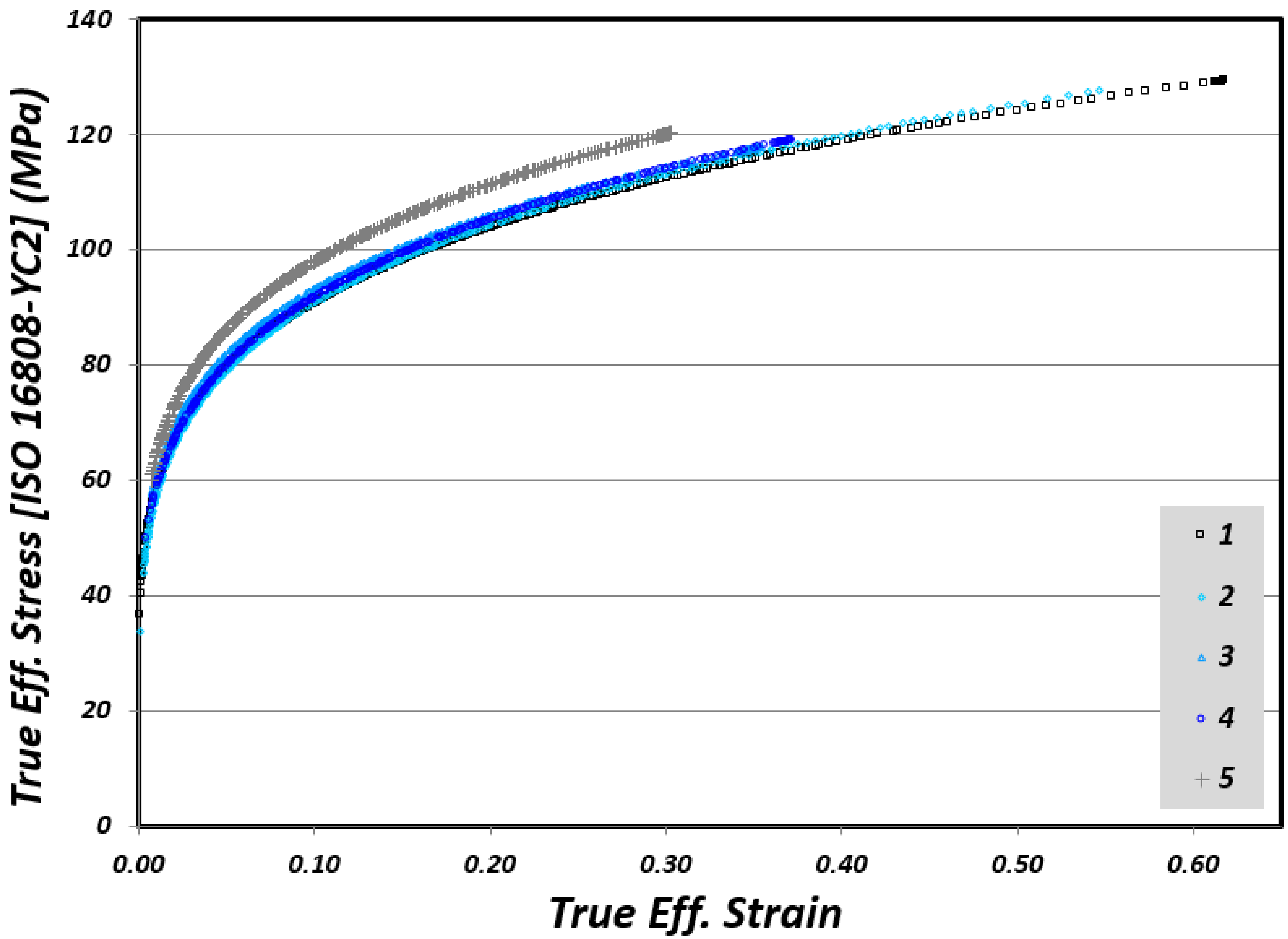
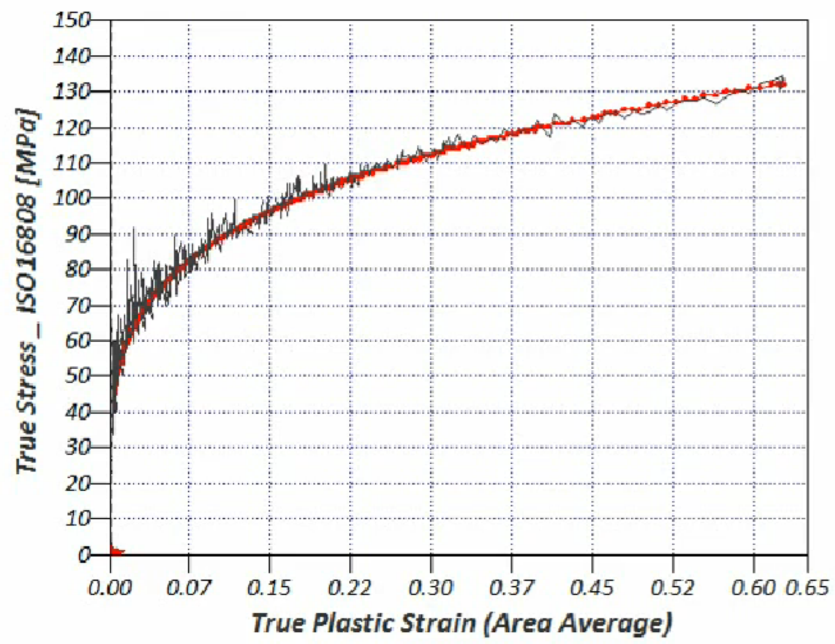
Test Results

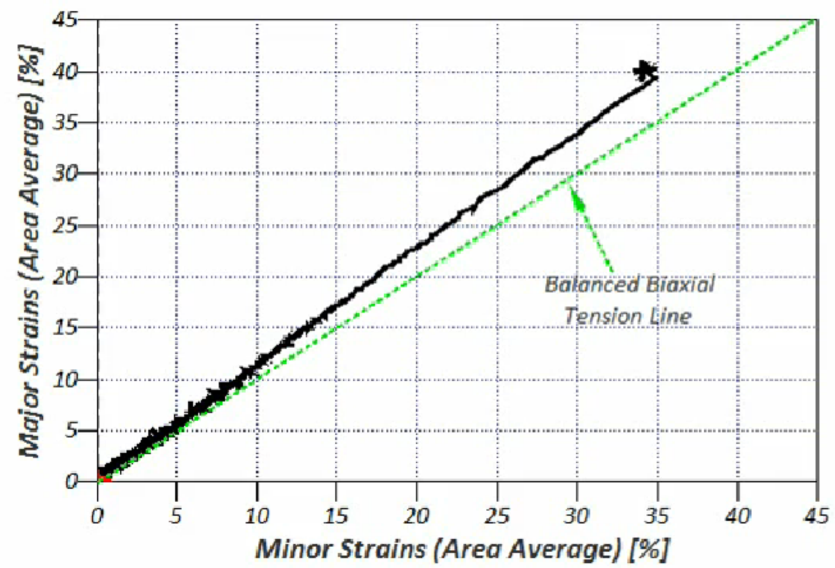
Bulge Stress/Strain Curves



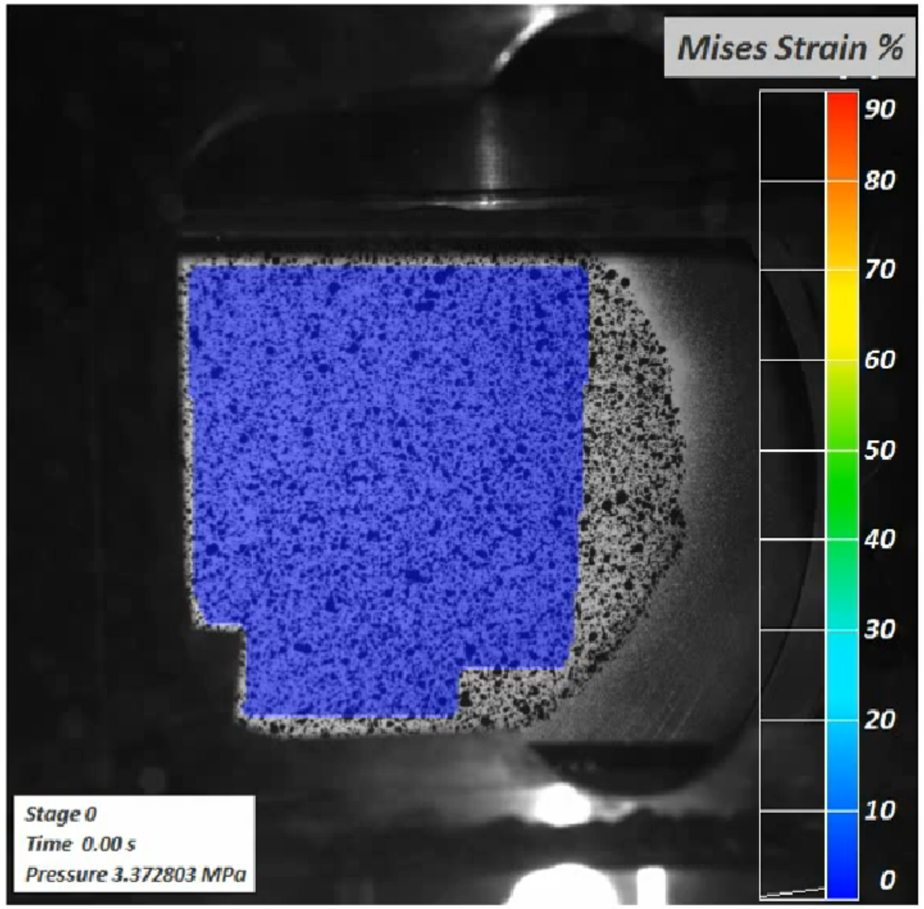
Results

Sample DIC Video _ Sample-6 (1)





M12_BBT(PB)-200C-TD6
0.035 MPa/s



Other

Attachments

Attachments to this report:

- *Excel files containing all the raw data and DIC extracted measurements (time, pressure, strains, stresses …), as well as plots, for all the performed tests.*
- *Detailed DIC video (one DIC sample video per tested material showing the evolution of surface strains, effective stress/strain curve and the strain path during the test).*

Other:

- *NA*

Thank you!