



On the Calibration of Optical Full-field Strain Measurement Systems

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Objectives

- To design, produce and test a measurement standard (reference material) suitable for the calibration of full-field optical techniques and instrumentation for strain measurement.
- To devise an appropriate calibration procedure (method of use) to be used with the RM.



Approach

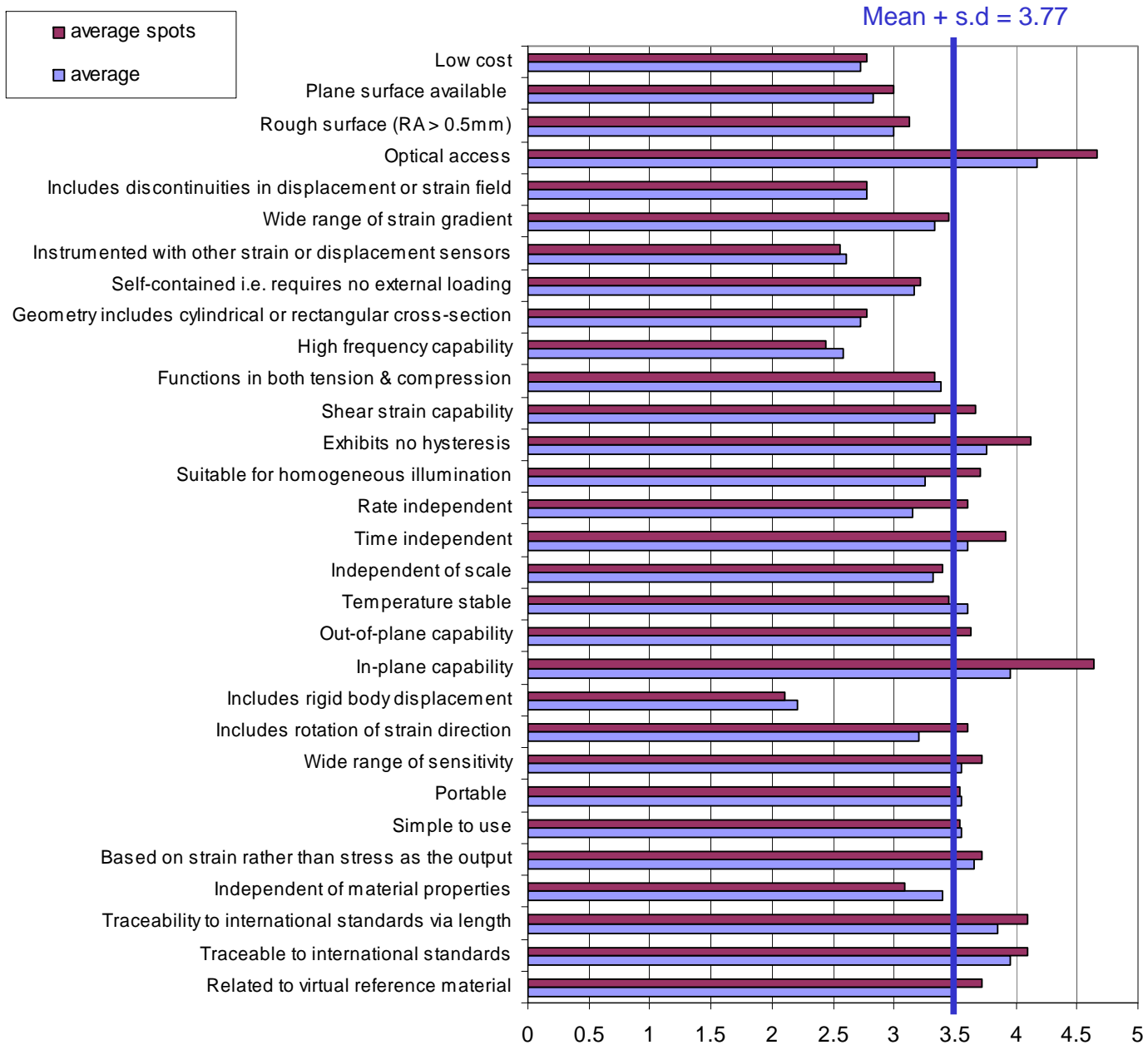
Rational Decision Making

1. Select and apply weighting to a list of desirable attributes*
- Identify any essential attributes.
2. Propose a set of candidate designs and evaluate them against the essential and desirable attributes.
3. Select preferred candidate designs and proceed with development and testing.
4. Evaluate performance and implement further refinements.
5. Approval and acceptance, publication of specifications.

* - Optical Division of the Society for Experimental Mechanics
- Int. Conf. on Advanced Techniques for EM, Nagoya, Japan (ATEM 03)



Attributes



Easy optical access

Exhibits no hysteresis

In-plane capability

Traceability to int. standards via length



Candidate selection

Candidates from brain-storming

1. Brazilian disc
2. Brazilian diamond
3. ~~Airbag/bladder~~
4. Diaphragm
5. Cantilever beam
6. 4pt/3pt bend beam
7. Tensile plate with hole
8. Curved tie-bar
9. Disc in diametral tension
10. ~~S-shaped plate (pure shear)~~
11. ~~Shape memory alloy specimen~~
12. T-shaped plate in 3pt bend
13. ~~Cylinder with thin, inflated spherical end~~
14. Notched specimens (ASTM)
15. ~~Refractive index change/glass specimen~~
16. Displacement control of rotating disc/ tilting plate

Attribute evaluation too daunting!

Classification

	ESPI	PEA	IC	Moiré	TSA
i. Compression geometries	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
ii. Diaphragm	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
iii. Bending beams	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
iv. Tension geometries	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

- Four point bend → *Cal*
- Brazilian disc → *ST*
- Contact-pair → *ST*

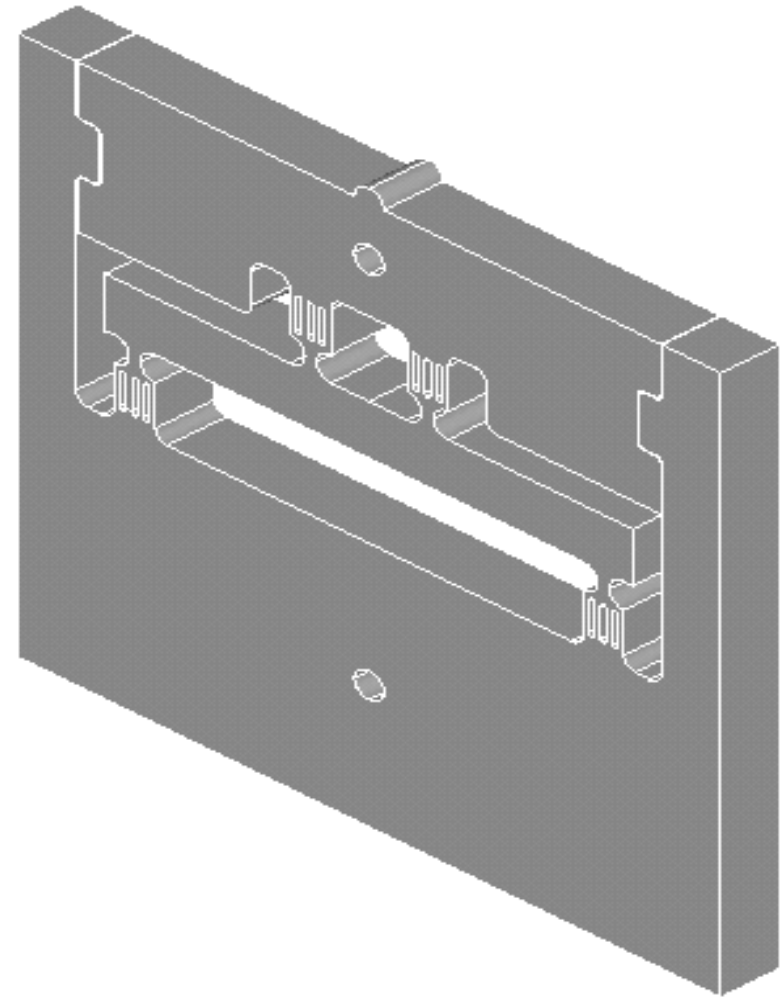
Upgrade attribute #23:
Self-contained reference material



Monolithic Design

Features

- External loading interface
 - Tension & compression
- Self-aligning
 - Symmetry about loading axis
- Constant thickness
 - Ease of manufacture
- Elastic deformation
 - No plasticity in joints
 - Plane sections remain plane
- Displacement controlled
 - Traceable to length standard
 - Strain independent of stiffness

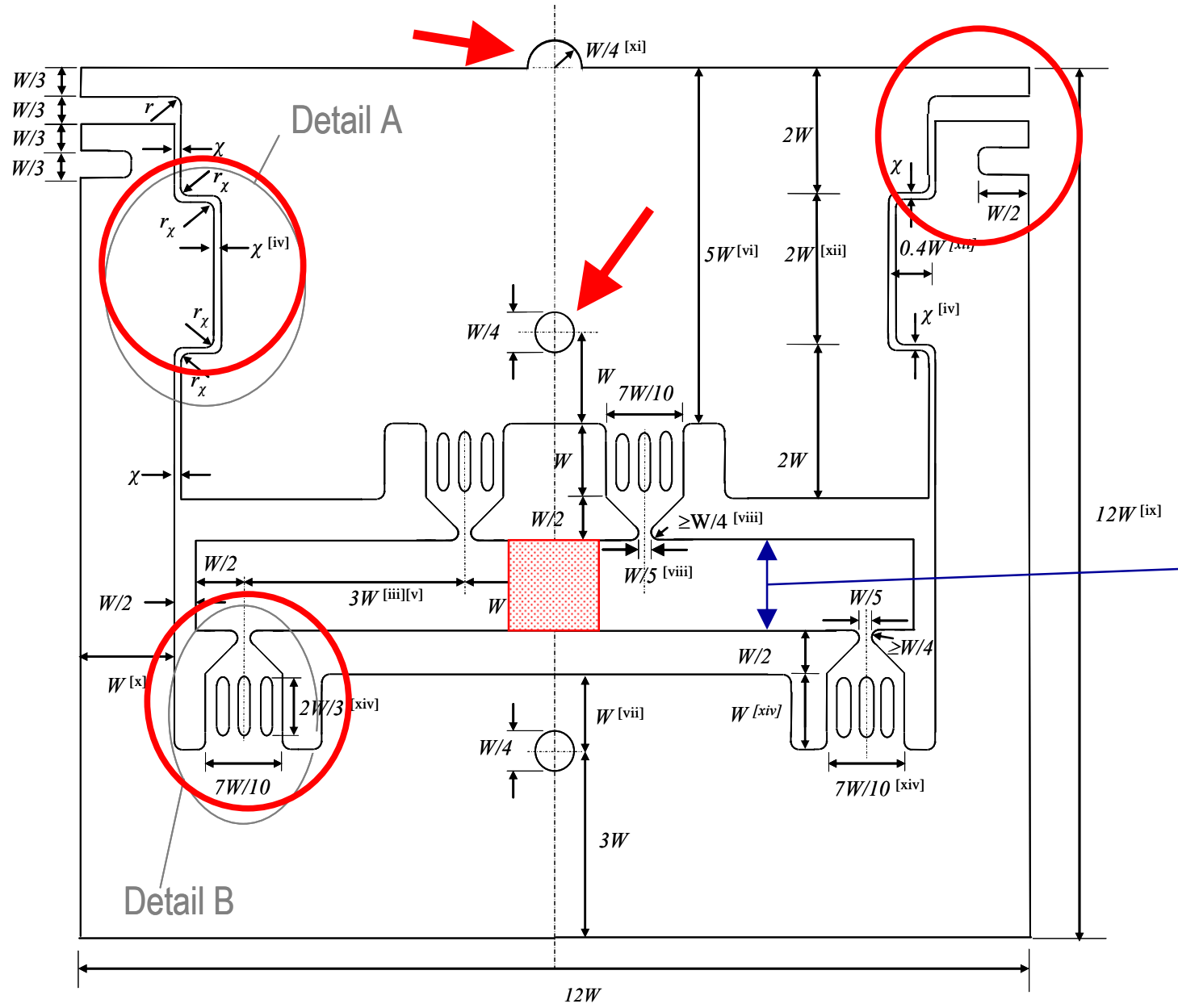




Parametric Design



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W
Beam width

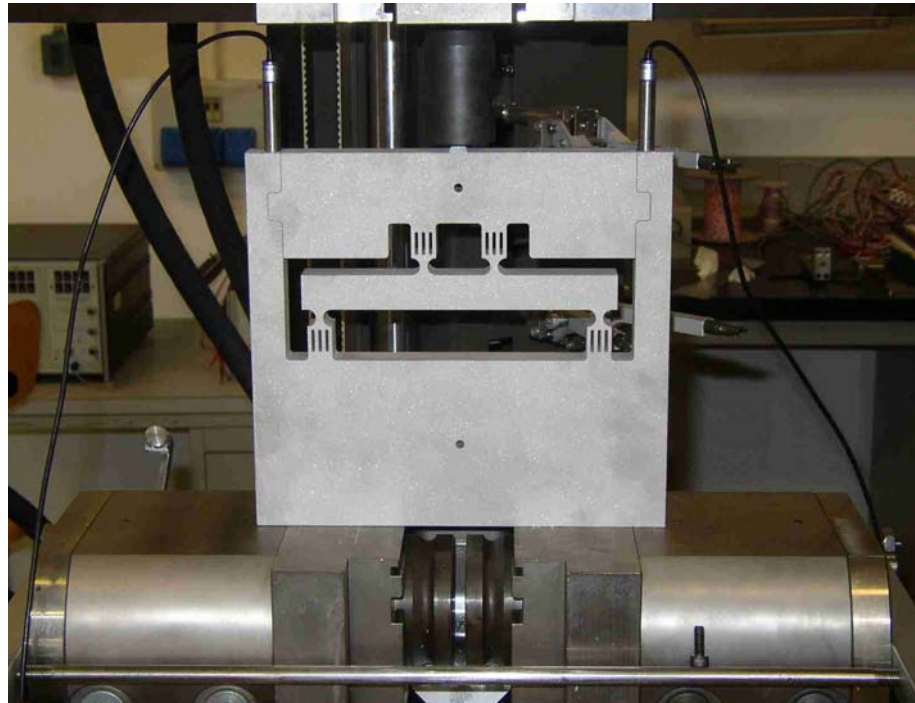


Calibration

Comparison with analytical solution

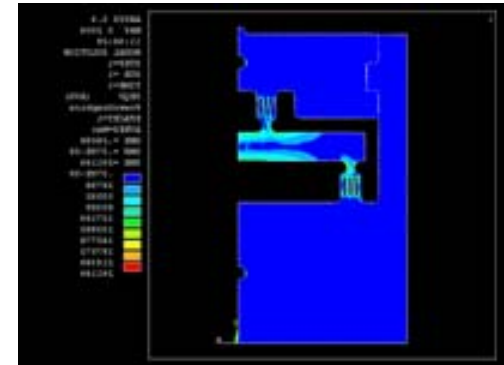
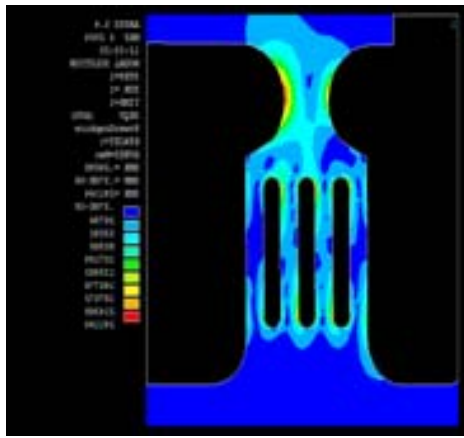
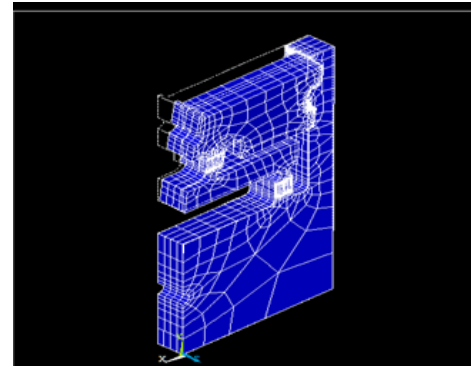
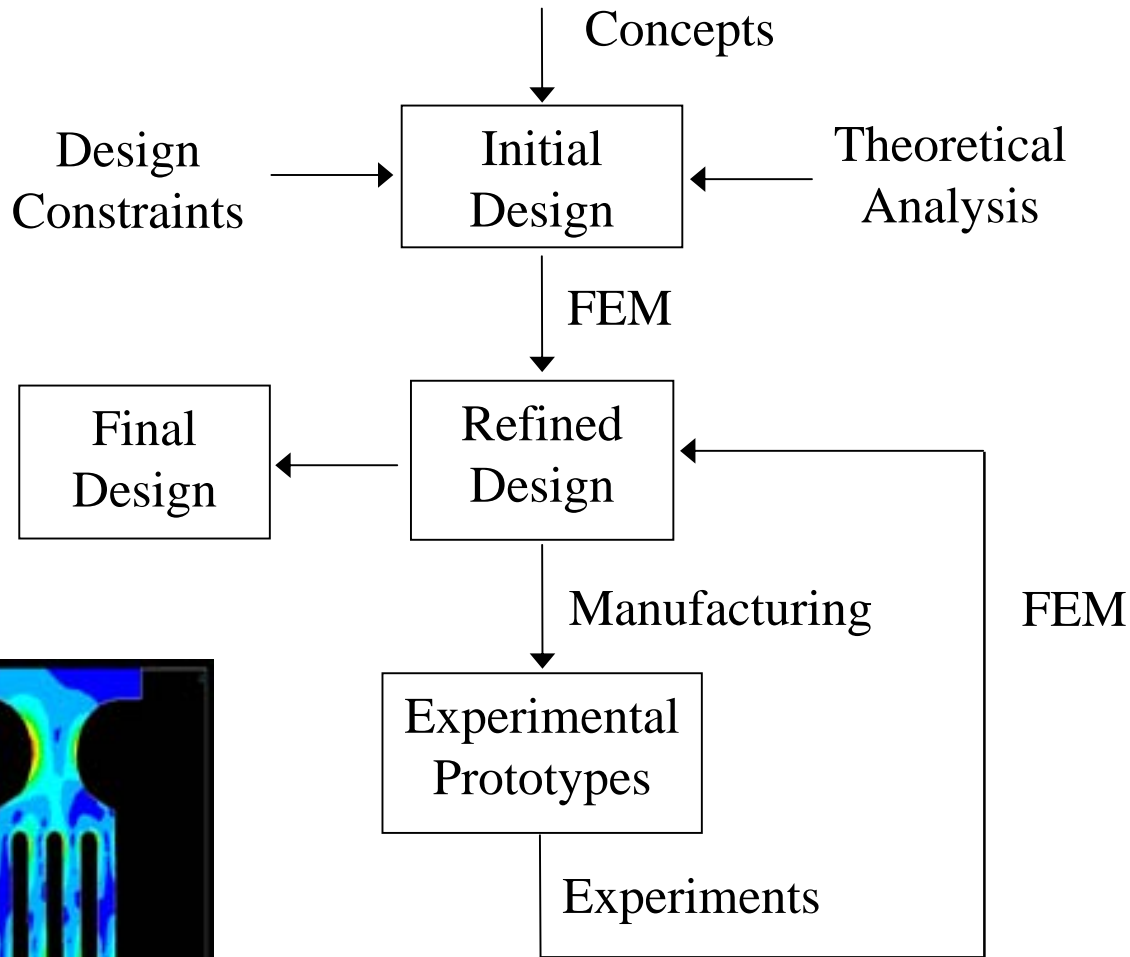
$$\varepsilon_{xx} = \frac{y\bar{v}}{6W^2} \quad \varepsilon_{yy} = \frac{y\bar{v} \nu}{6W^2} \quad \varepsilon_{xy} = 0$$

First prototype





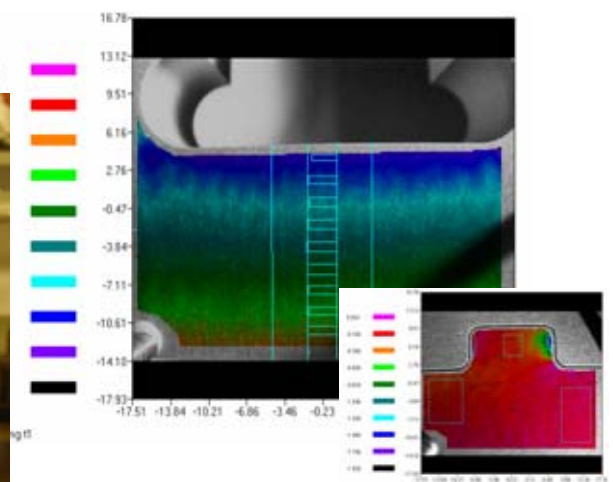
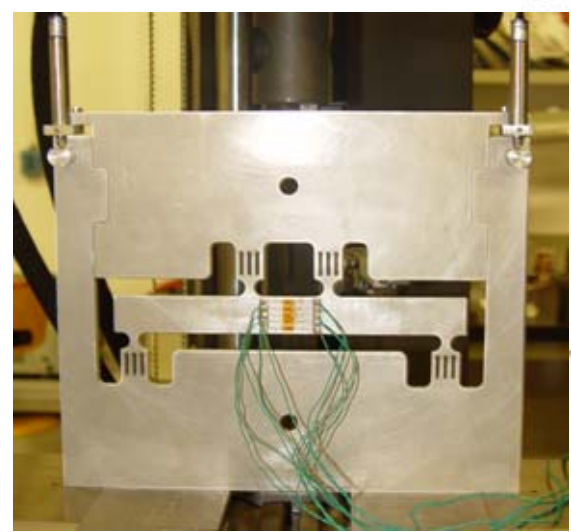
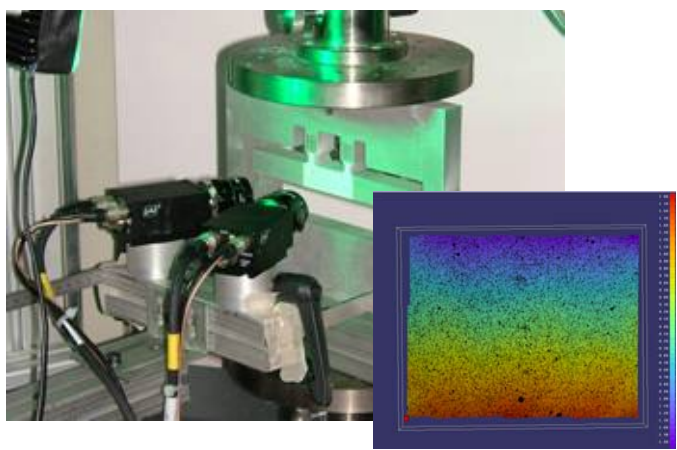
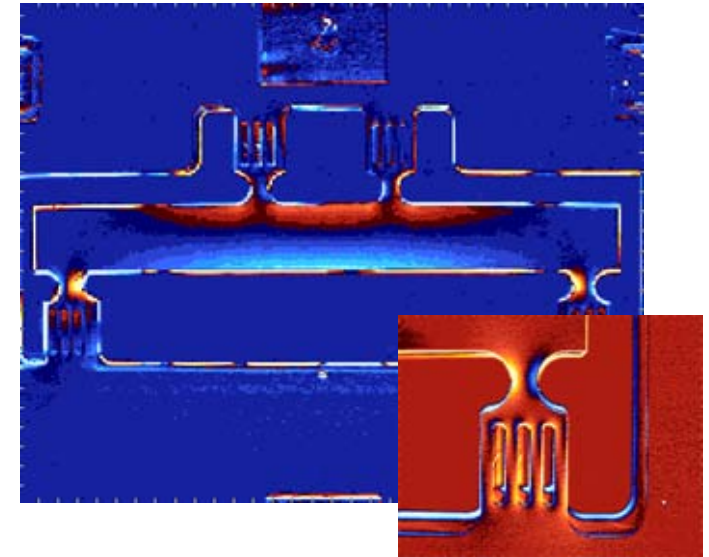
Design Process





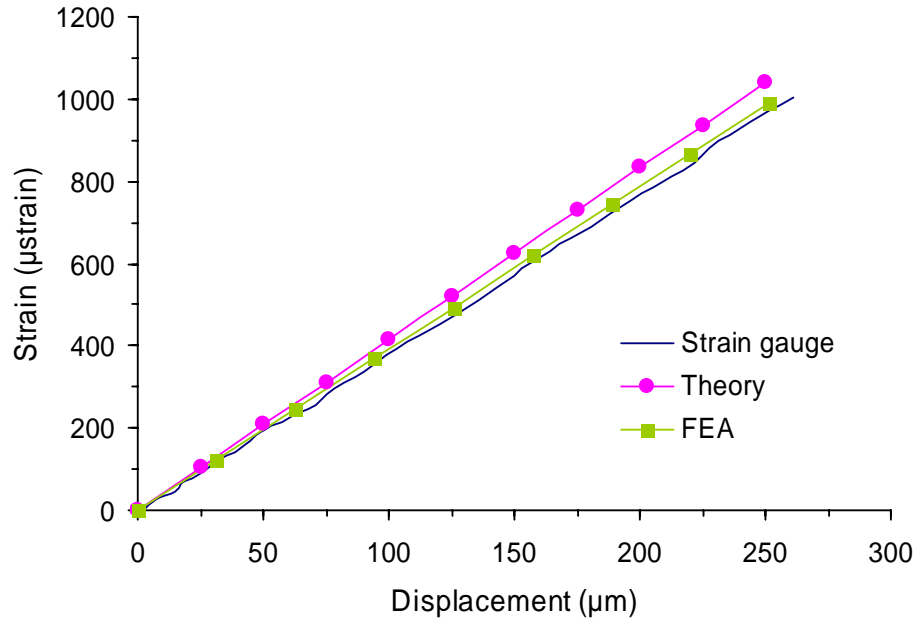
Experimental Methods

- LVDTs and strain gauges
- Thermoelastic stress analysis
- Electronic Speckle Pattern Interferometry (ESPI)
- Digital Image Correlation
- Grating Interferometry
- Photoelasticity



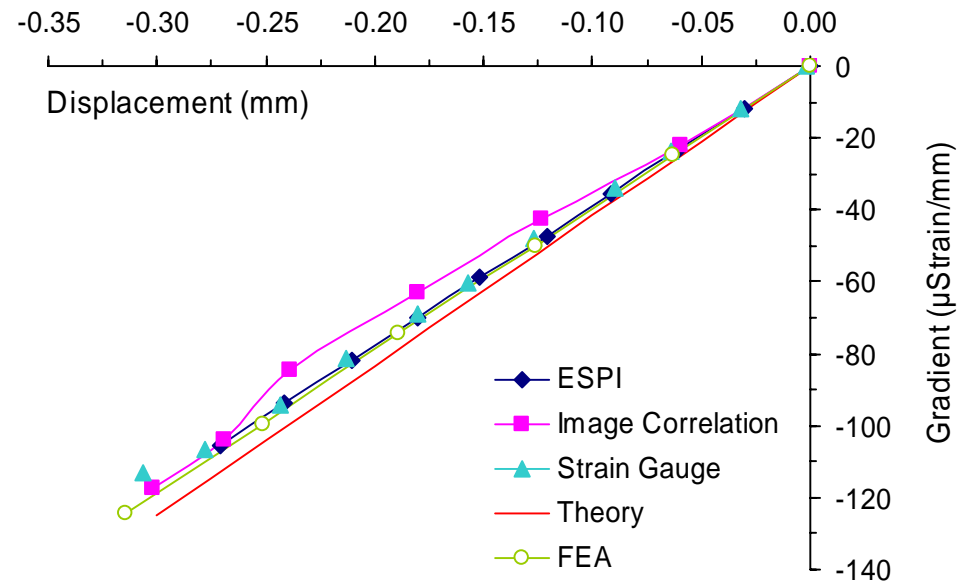


Results



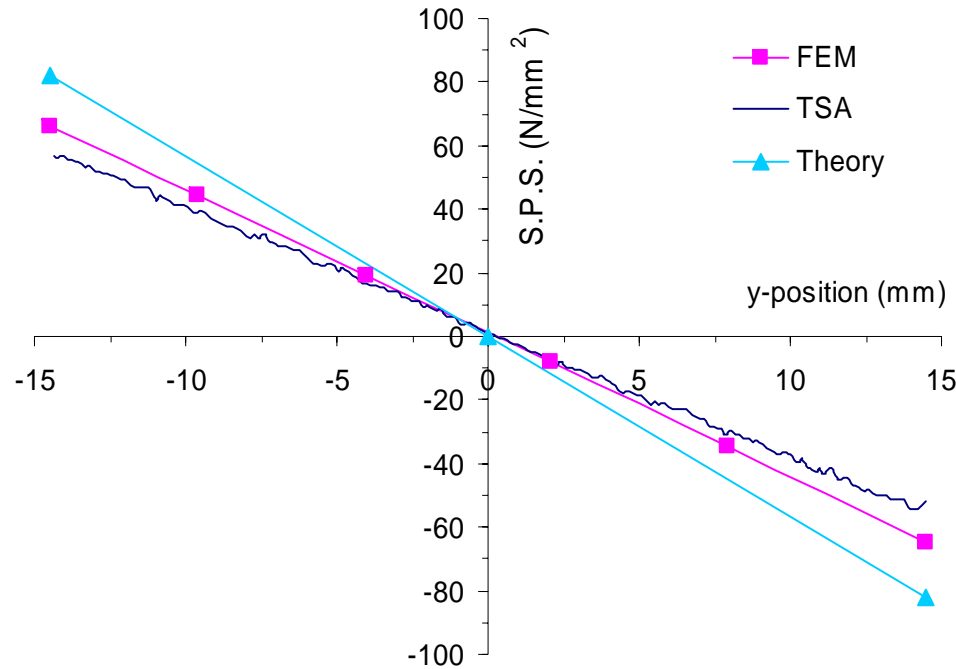
➤ Strain verses applied displacement

➤ Strain gradient verses applied displacement



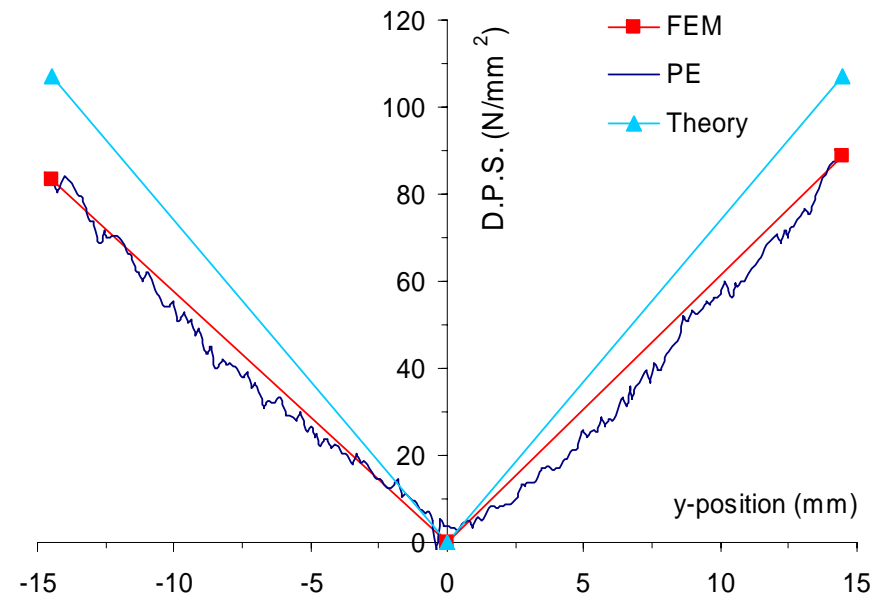


Results



➤ Sum of Prin. Stresses
verses y-position

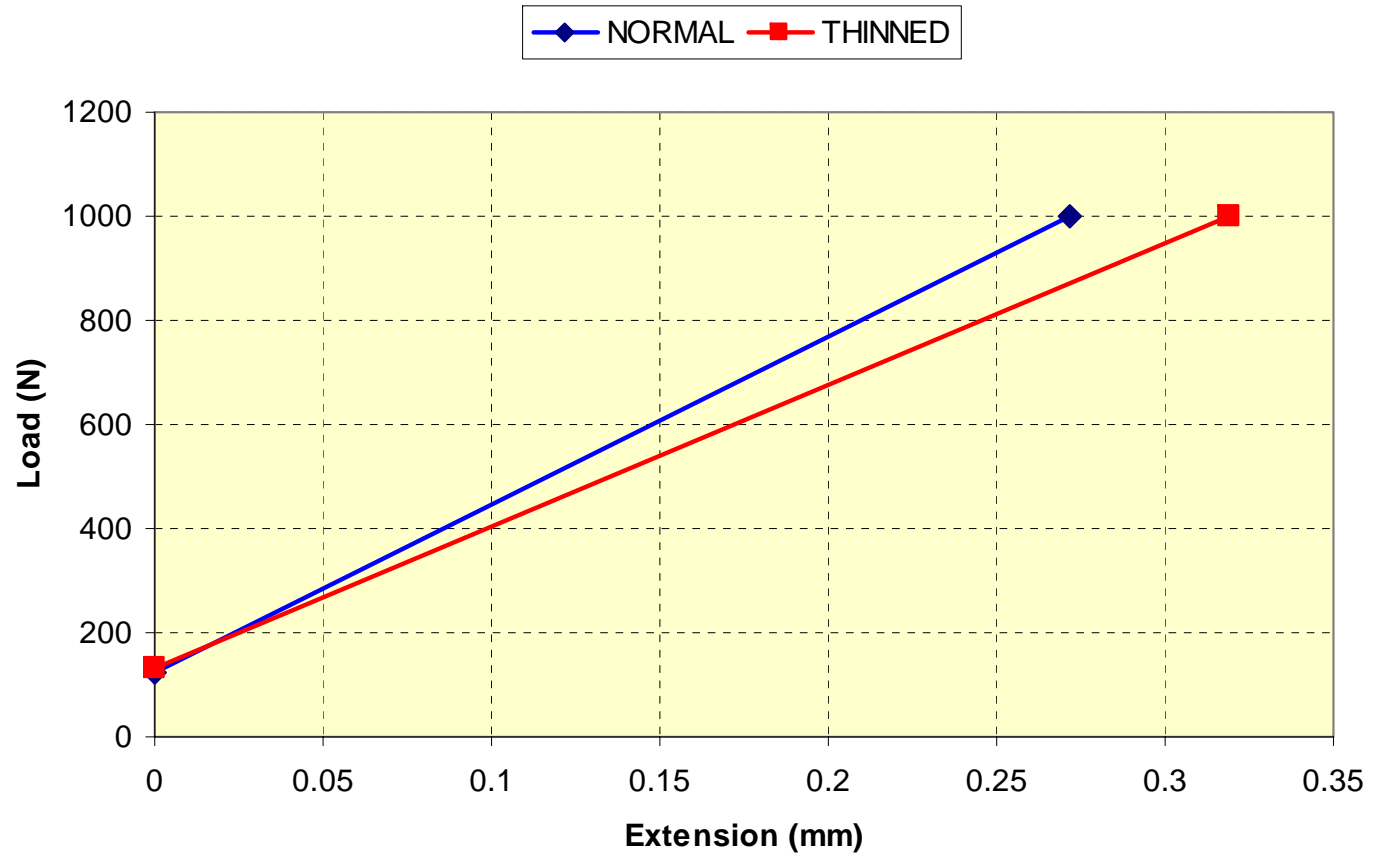
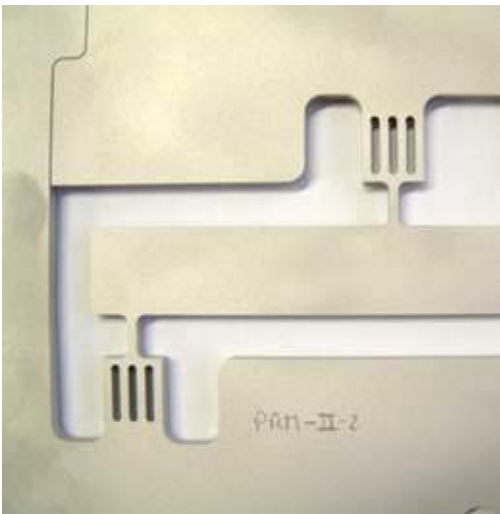
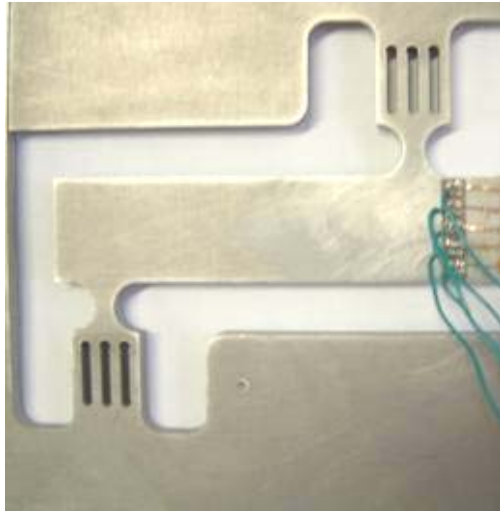
➤ Diff. of Prin. Stresses
verses y-position





Design refinements

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Reduction in beam constraint



Methodology for use

1. Preparation and set-up.
2. Acquire strain field for prescribed field in gauge zone.
3. Repeat the above at five levels of displacement loading defined by nominally equal increments between 10% and 90% of the maximum load.
4. Report differences (d) and uncertainties (s^2).

$$\bar{d} = \frac{1}{N} \sum_{i,j=1}^N d(i, j)$$

$$s^2(d) = \frac{1}{N} \sum_{i,j=1}^N (d(i, j) - \bar{d})^2$$



Conclusions

- A novel measurement standard/RM based on a **parametric** design of a **monolithic 4-point bend test** has been developed (scalable, reproducible, reliable, cheap).
- First prototypes of measurement standard produced and tested using 5 optical methods and LVDT/SGs, in 5 different labs, different sizes and materials.
- Performance of RM very promising in terms of repeatability, inter-lab reproducibility and ease of use.
- Calibration procedure (method of use) will be refined in the coming months and published at year-end.



Thank you!



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SPOTS ►

www.opticalstrain.org