Residual Stress Measurement Using Surface Strain

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Residual Stress

▶ Definition of residual stress

A stress state which exists in materials without application of an external load (including gravity) or other source of stress, such as a thermal gradient, is called a residual stress.

[I.C. Noyan, J.B. Cohen, *Residual Stresses* (1987)]

▶ Origin of residual stress

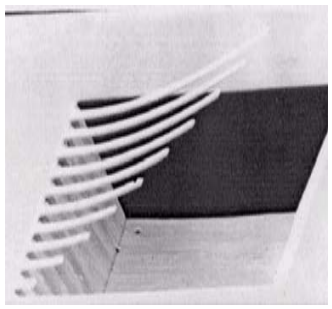
- **Plastic deformation or forming**
  - rolling, extruding, bending, forging, pressing, spinning
- **During manufacturing process**
  - welding, electrodeposition, CVD, PVD, machining
- **During heat or thermochemical treatment**
  - quenching, laser and plasma heat treatment, ion plating

→ Residual stress is one of the important factor about the fracture or failure of materials and structures.

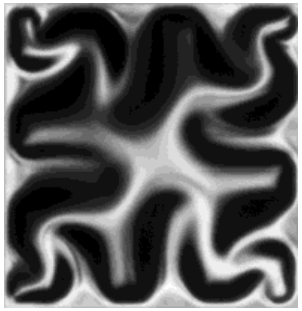
▶ Bulk material

Crack initiation

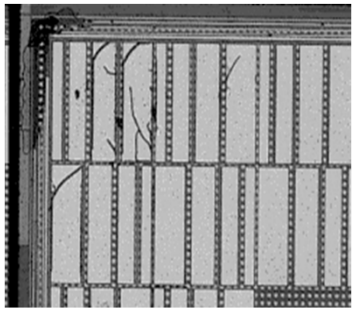
▶ Thin film



Bending

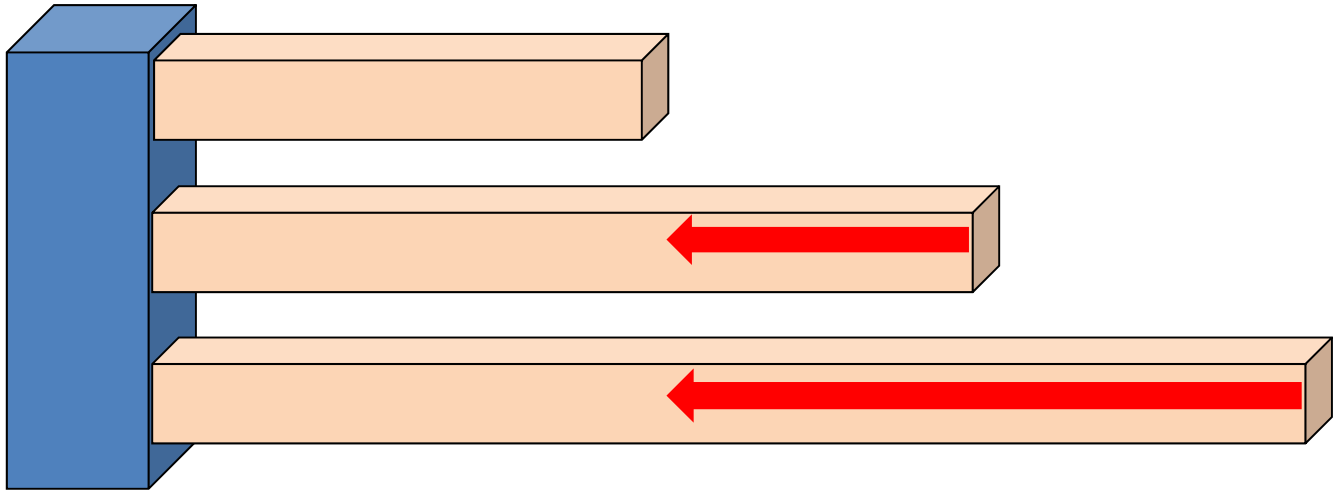


Buckling



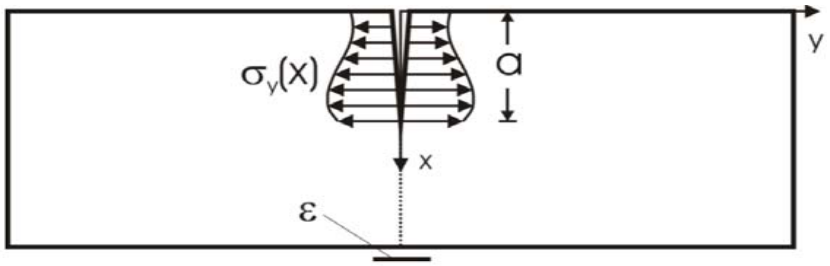
Cracking

Stress Relaxation



$$\varepsilon \propto \sigma_{res}$$

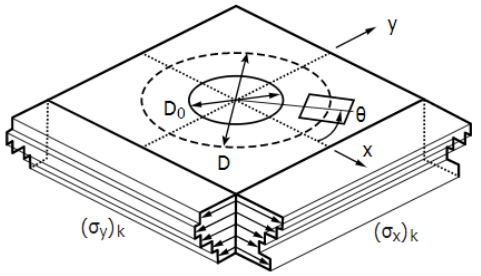
$$\sigma = E\,\varepsilon$$



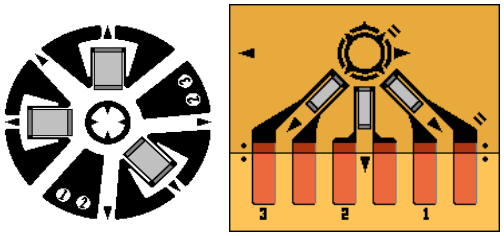
Related Technique

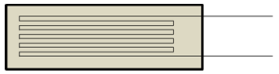
* Hole drilling
* Deep-HD
* Ring-core
* Contour
* Slitting
* Sectioning
* Layer removing

Strain Gauge Method for Evaluating Residual Stress

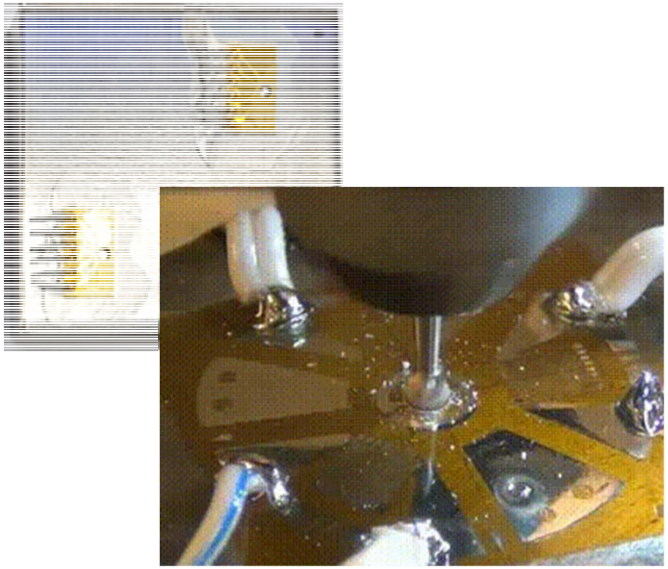


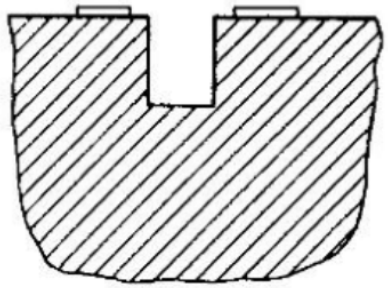
▶ Hole-Drilling Method



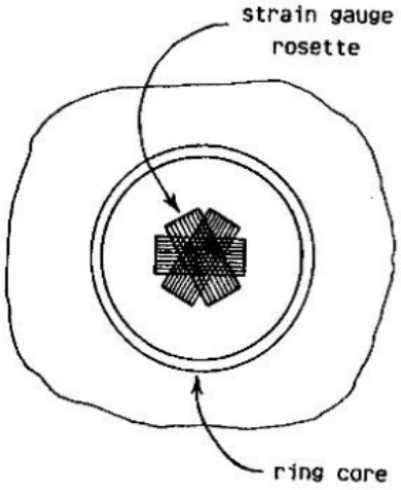


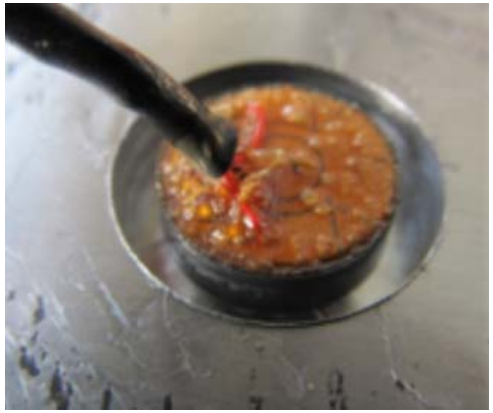
$$R = \rho \frac{L}{A}$$

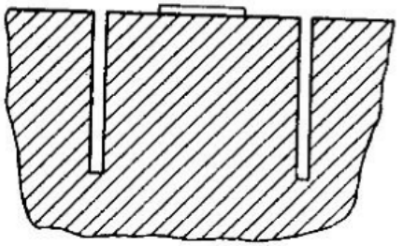




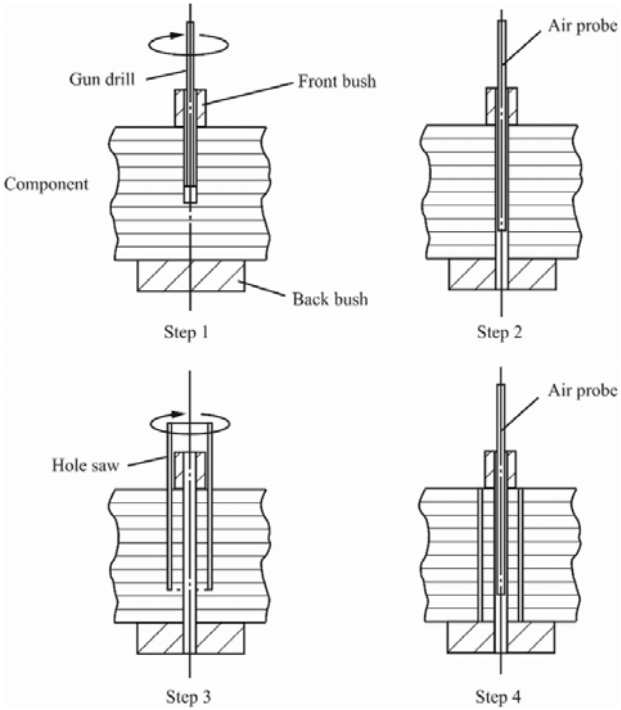
▶ Ring Core Method



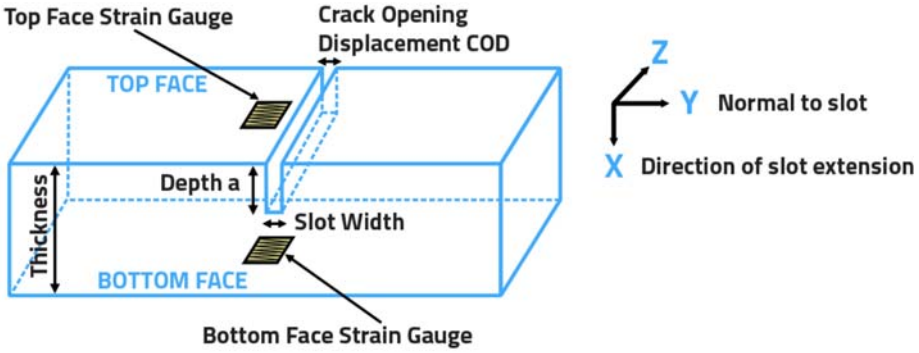




▶ Deep Hole-Drilling Method

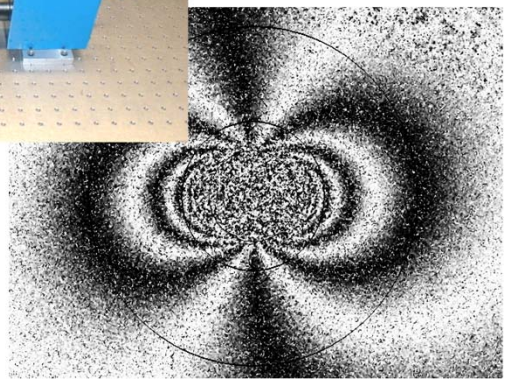


▶ Slitting Method

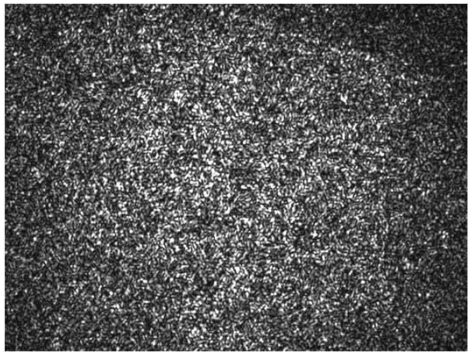


Optical Method for Evaluating Residual Stress

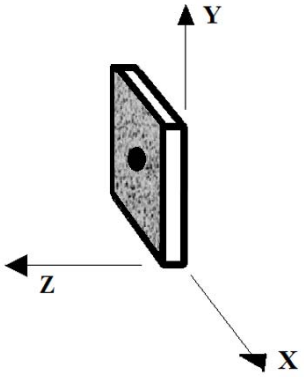
- ESPI



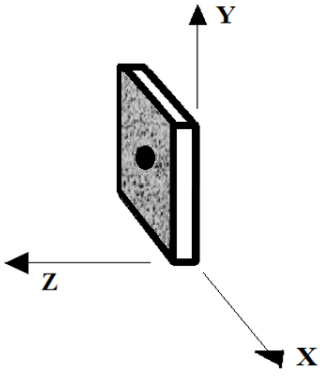
- DIC



- 2-D Technique

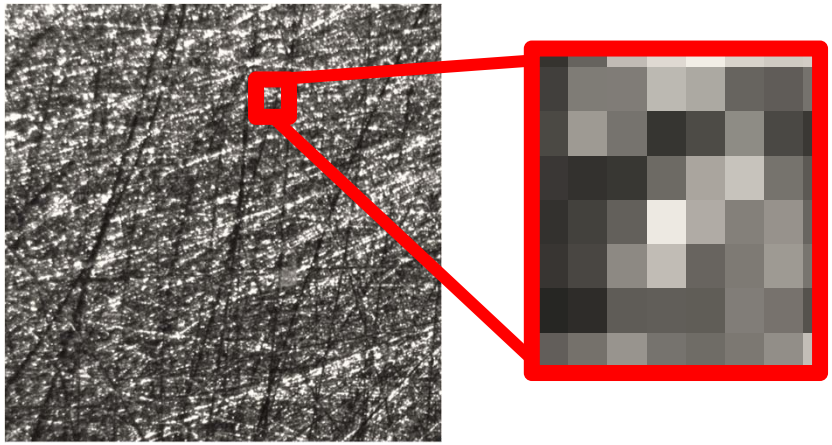


- 3-D Technique



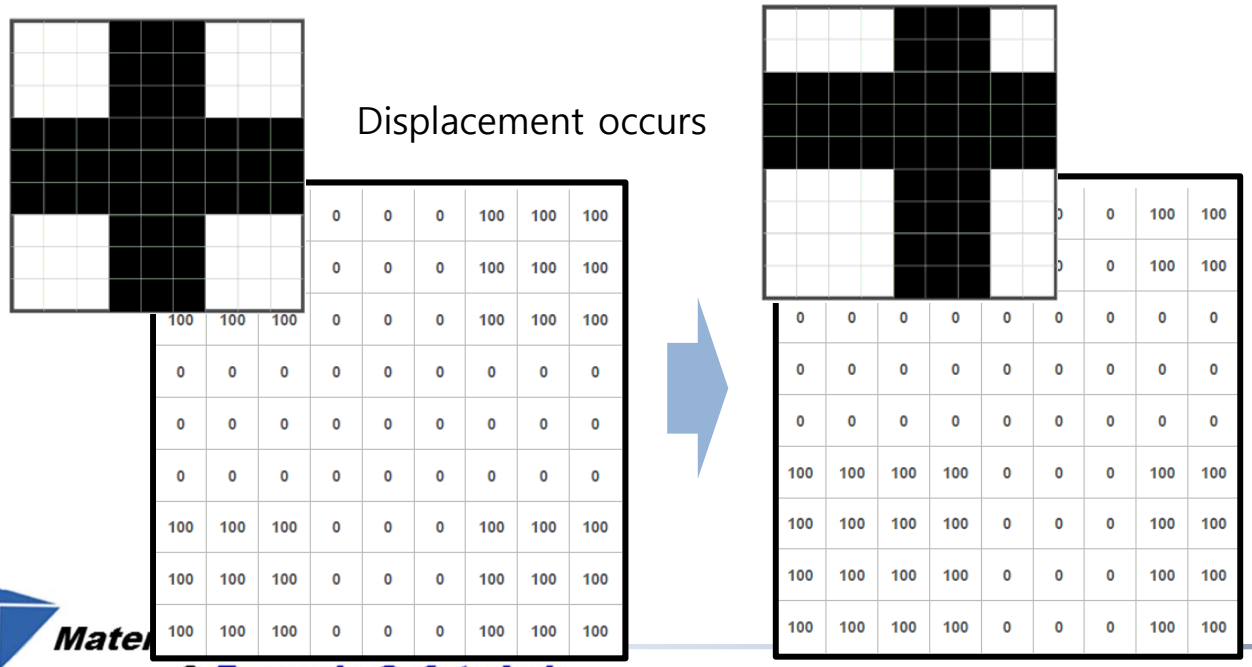
Software Computation

Input Image



Subset

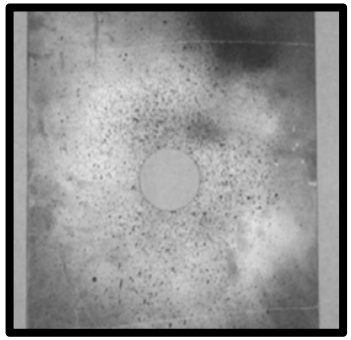
Image processing



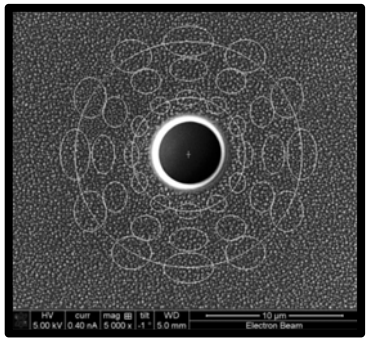
Optical Technique

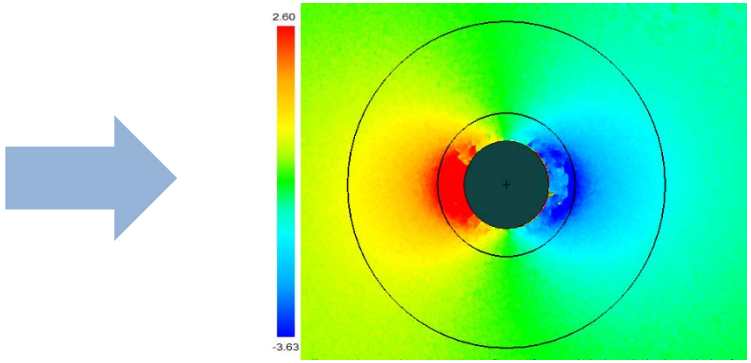
► Hole-Drilling + DIC

Macro-scale

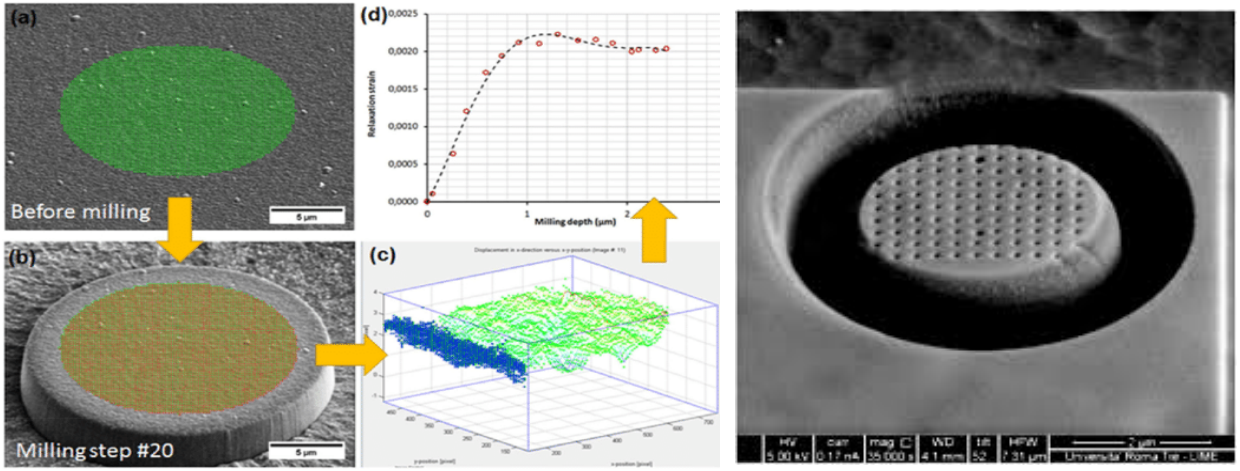


Nano-sclae





► Ring-core +DIC



$$\varepsilon \Rightarrow \sigma_{res}$$

Strain Gauge VS Optical Method

Strain Gauge Measurements	Optical Measurements
▪ Moderate equipment cost, high per-measurement cost ▪ Significant preparation and measurement time ▪ Small number of very accurate and reliable measurements ▪ Modest capabilities for data averaging and self-consistency checking ▪ Suitable for field use	▪ High equipment cost, moderate per-measurement cost ▪ Preparation and measurement time can be short ▪ Large number of moderately accurate measurements available for averaging ▪ Extensive capabilities for data averaging and self-consistency checking ▪ Suited to lab use

Anisotropy measurement

Strain Gauge

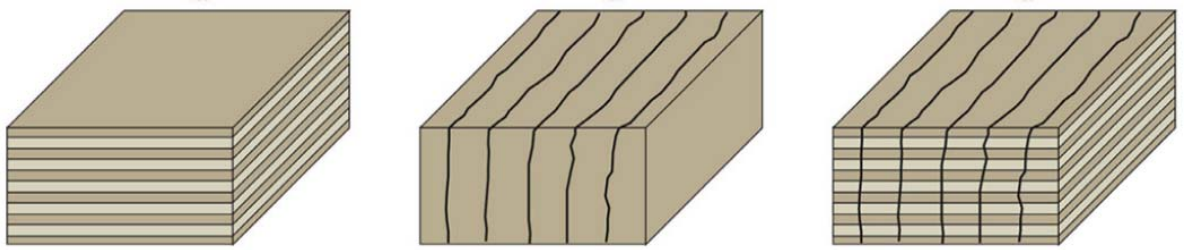
or

Digital Image Correlation

+

Indentation

Anisotropy measurement




Thank You
for Your Attention