High precision strain and displacement control by FBG and DIC

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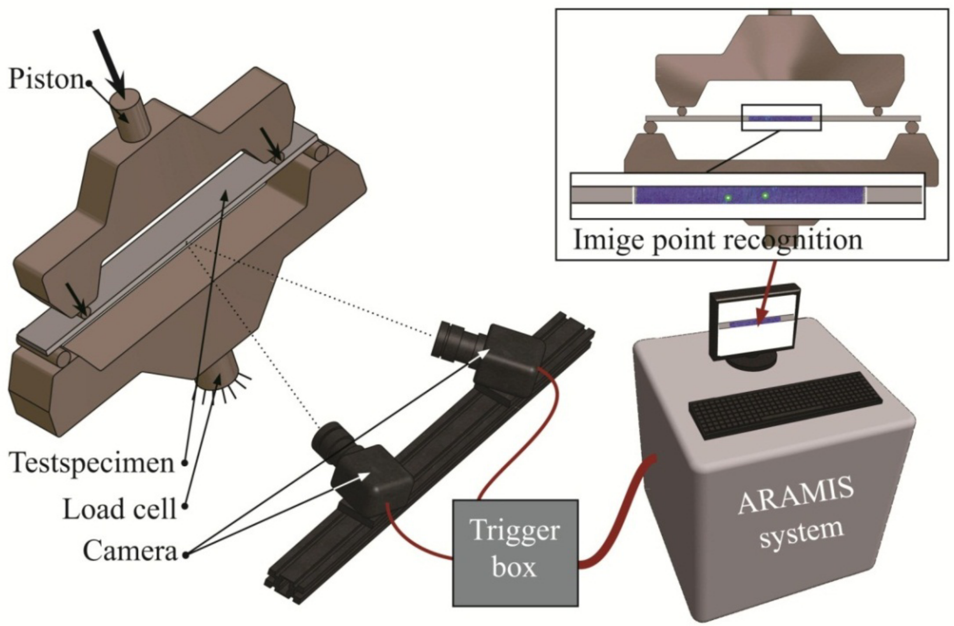
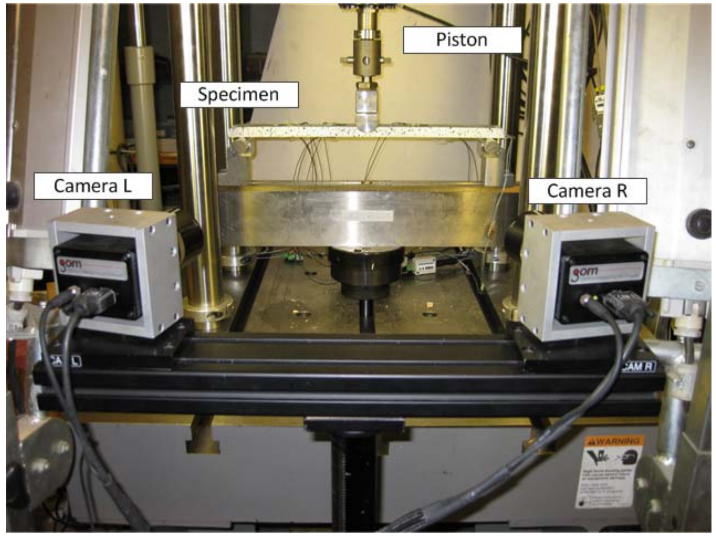
Objective

- Structural testing is commonly operated by displacement or force gauges positioned in the pistons of the test machine.
- A force/displacement is prescribed the test specimen and a piston moves accordingly.
- This is adequate when testing specimens in simple and rigid test rigs where influence of the test rig's deformation is insignificant.
- When using compliant test rigs or test rigs with joints and bearings the compliance can have high influence on the results.
- It was desired to control tests by gauges positioned directly on the test specimen

Digital Image Correlation (DIC) Technique



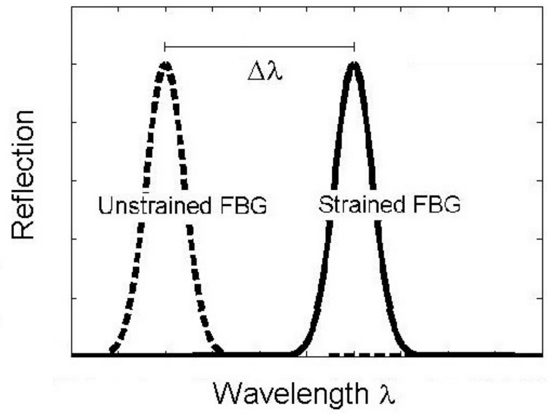


- Stereo DIC determines strains and deformations of a surface based on images acquired from a surface. This enables full field measurements
- Each camera image is divided into measurement points.
- The motions of the measurement points on the image are related to displacements by a calibration object with known dimensions.

Fibre Bragg Grating (FBG) Technique

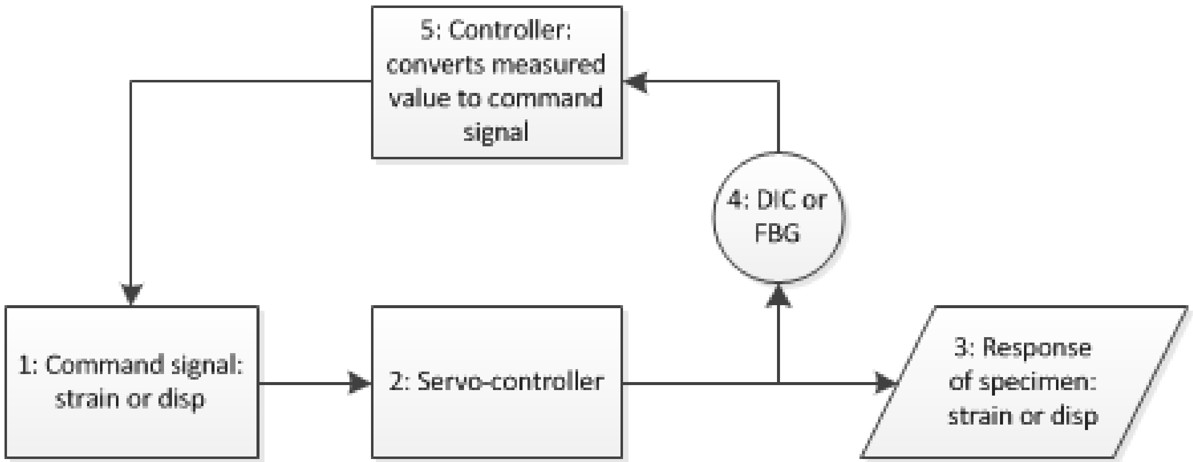
- An FBG sensor is a grating in a optical fibre
- Light is emitted through the fibre and the FBG sensor reflects light of a given wavelength.
- If the sensor is subjected to strain the wavelength of the reflected light is shifted.
- The strain is then calculated:

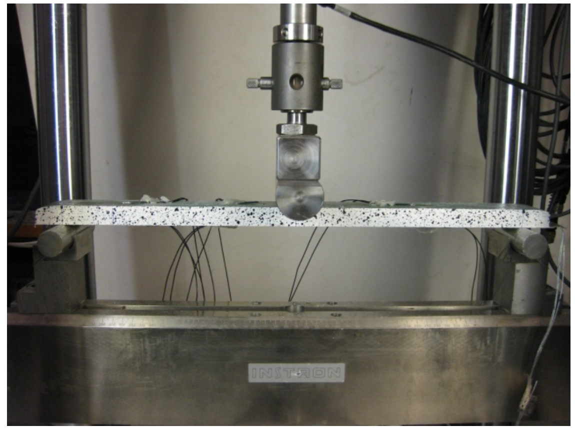
$$\frac{\Delta\lambda}{\lambda_0} = \varepsilon k_\varepsilon + k_t \Delta T$$



- Optical fibres with FBGs can be embedded into structures e.g. composites, concrete etc.
- Thereby measure strain inside structures.
- E.g. residual strains developed during manufacturing.

Control Loop

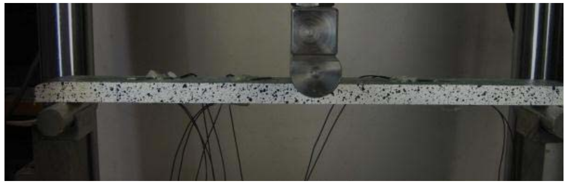


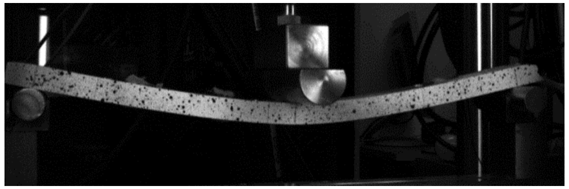


1. The control program is given the desired displacement/strain input.
2. A servo controller, which operates the piston, receives the command signal.
3. The deformation is obtained.
4. The DIC and FBG systems measure strains and displacements of the specimen.
5. The control program evaluates the displacements/strains and checks if they are within the error tolerance.

If not, a new command signal is sent to the servo controller.

Results





- Fibre Bragg Grating Control
  Specimen applied strain of 2800µm/m
  259µm/m → 50µm/m, without and with FBG control
  9.25% → 1.79% error (compared to total strain)

- Digital Image Correlation Control
  Specimen applied displacement of 5.87mm
  0.126mm → 0.01mm, without and with DIC control
  2.15% → 0.179% error (compared to total displacement)

If the method is used on more compliant test rigs, the benefits will presumably improve, since the difference between the deformation of the piston and the specimen is larger.

The method is sought to be used for control of test rigs where specimens with more complex geometry is tested and several actuators might be used.

The control method could be used to control a test in more degrees-of-freedom