MatchID
Metrology beyond colors

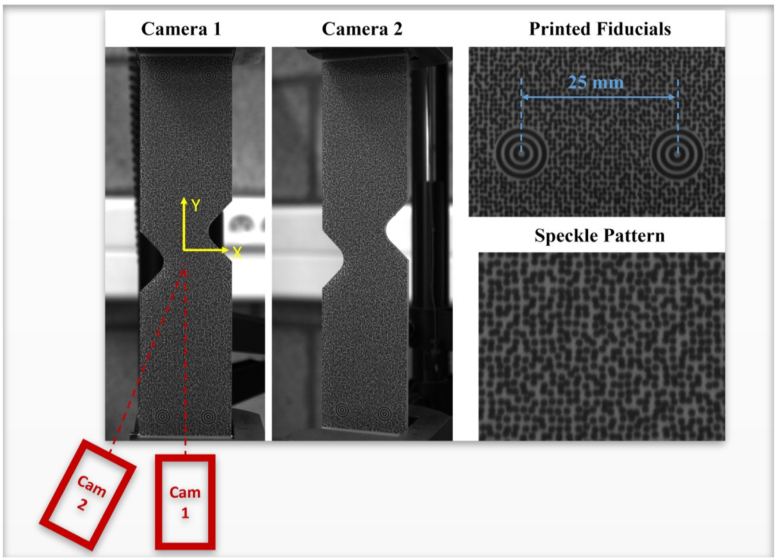
Application Note

# Ranking of constitutive model performance based on equilibrium gap indicator

## Case Description

The equilibrium gap indicator (EGI) gives a spatial indication of the extent to which the calculated stress field is statically admissible. Thus it can be used to judge the performance (or goodness of fit) of constitutive models. In this application, VFM identification was performed to identify elastoplastic and hyperelastic constitutive models. The hyperelastic models were then ranked as per their performance in terms of EGI. Two test cases were considered:

- Virtual DIC experiments performed using the MatchID FEDEF module are used to demonstrate the capability of EGI to detect material plasticity.
- Kinematic fields introduced in a notched HDPE sample are measured using DIC. Three hyperelastic constitutive models are identified using the VFM. The EGI is used to compare and rank their performance.




## Experimental Setup

- ✓ **Cameras:** 5 MPx Flir BFS-U3-51S5M-C
- ✓ **Lens:** Fujinon 25 mm
- ✓ **Acquisition speed:** 1 Hz
- ✓ **FOV:** 48 mm x 100 mm
- ✓ **Stereo angle:** 19°
- ✓ **Subset, Step:** 15, 3 Pixels
- ✓ **VSG:** 15 datapoints
- ✓ **Camera noise:** 0.7%

## Analysis

- ✓ **Type:** Stereo DIC
- ✓ **Constitutive models evaluated**
  - ⇒ Virtual experiments:
    - Elastoplasticity
- ✓ **Constitutive models ranked**
  - ⇒ Real experiments (hyperelasticity):
    - Neo-Hookean
    - Mooney-Rivlin
    - Yeoh
- ✓ **Metrics:** EGI

## Results

- ✓ **Virtual experiments:** Numerically deformed images
- ✓ **VFM:** Hyperelastic constitutive parameters
- ✓ **Model performance:** EGI maps

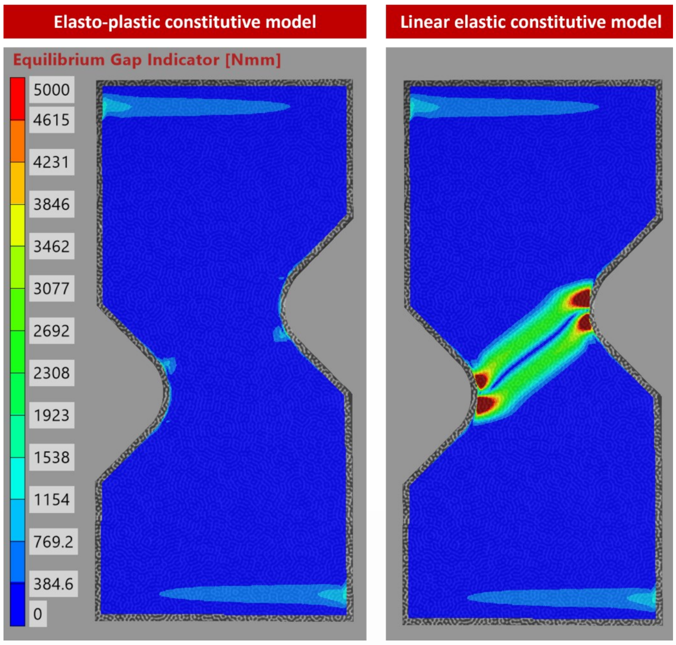
## Why MatchID

- ✓ MatchID FEDEF module to simulate DIC process
- ✓ VFM module for identifying constitutive parameters
- ✓ Reconstruction of stress fields using wide range of built-in constitutive model library
- ✓ Calculation of EGI maps

## Validation of the EGI for metal plasticity

An FE analysis was performed with an elasto-plastic constitutive model. The FEDEF module was used to synthetically deform images and virtually simulate the DIC process. Simulated kinematic fields were thus obtained.

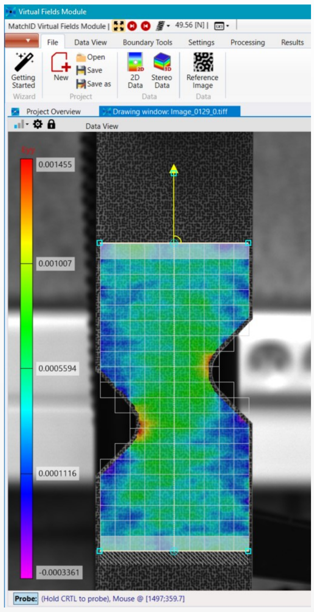
The adjacent figure (right-hand side image) illustrates how the EGI shows significant departure from the ideal value of 0 if a linear elastic constitutive model is used to reconstruct stress from the simulated strain fields. These abnormal EGI patterns mostly vanish when the correct constitutive model is used (see left-hand side image) for stress reconstruction.




## VFM identification of hyperelastic constitutive parameters

VFM identification was performed using the MatchID VFM module. The identified constitutive parameters corresponding to three increasingly complex hyperelastic models are shown in the table below. 46 load steps (images) representing a strain range of 0-8% were used for identification. A single load step in the small strain regime was used to identify the parameters of the linear elastic constitutive model. These models are available in the MatchID material model library.

| Constitutive model | Material Constants [MPa] | | |
|---|---|---|---|
| Linear elastic | $E = 863$ | $\nu = 0.49$ [-] | |
| Neo-Hookean | $C_{10} = 77.1$ | | |
| Mooney-Rivlin | $C_{10} = -2169$ | $C_{01} = 2290$ | |
| Yeoh | $C_{10} = 86.8$ | $C_{20} = -1886$ | $C_{30} = 434.2$ |




## Application of EGI: ranking of hyperelastic constitutive models

**Ranking using the EGI:**

1. Yeoh
2. Neo-Hookean
3. Linear elastic
4. Mooney-Rivlin

***It is clear that the EGI "discriminates" between the constitutive models allowing to do a quantitative comparison and ranking.***