Identification of the "Non-standard" Deformation Behaviour of European Beech and Norway Spruce during the Compression Loading

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INTRODUCTION

When the wood is **compressed parallel to grain**, the strain field exhibits three zones: **a) two damage zones** ($d_{1;\,2}$) located near the compression plates and **b) one middle zone** (*m*) located between them. Such strain field heterogeneity is commonly described with help of an analytical model of sample as a **series of three springs**.

The decrease of strain as the load increases, i.e. a **negative increment of strain** in the load direction (ε_L) was examined. It is hypothesized that, the negative ε_L increment stems from the **expansion** of the middle **stiffer spring** in a series of three springs allowed by the **failure** of the two springs representing the **"less stiff"** damage zones.

MATERIAL & METHODS

The clear special orthotropic blocks with a **cross section 20 × 20 mm²** and different lengths (**h = 30, 40, 50 and 60 mm**) from **European beech** (*Fagus sylvatica*, L.) and **Norway spruce** (*Picea abies*, L. Karst.) were cut. A basic matt white thin paint overlaid by a pigmented black paint was sprayed on the samples' side to be captured.

The **loading** parallel to the grain was carried out by the universal testing machine **Zwick Z050/TH 3A**. A point-wise ε_L data were obtained by the **"clip-on" extensometers** (Fig. 1).

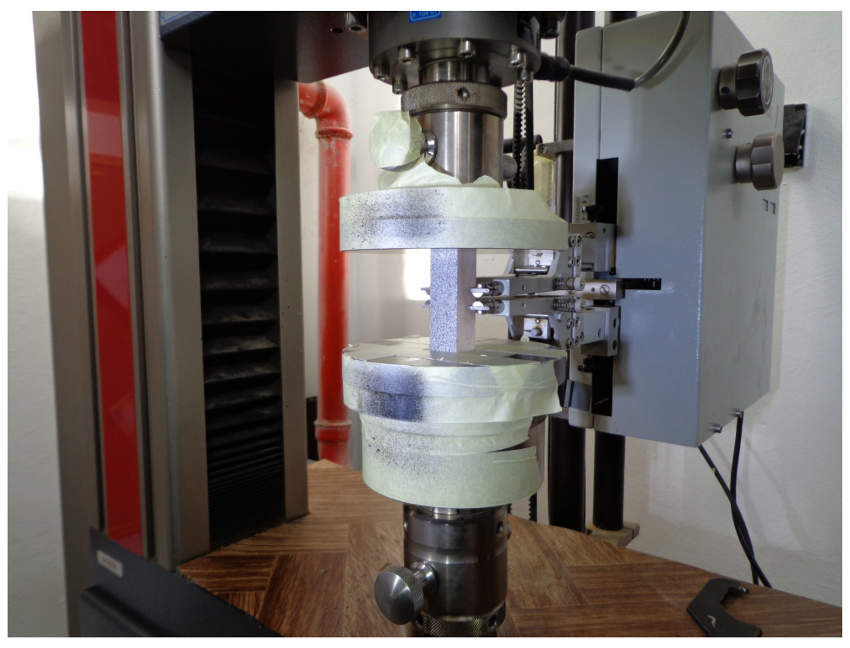

Figure 1: "Clip-on" extensometers

A **full-field strain** data were collected by the **stereovision** optical system (Fig. 2). An area of interest (AOI) covered a whole patterned samples' surface and a resulting scale was **12.5 px mm⁻¹**. A data **acquisition** rate was **4 Hz**. The strains were calculated using Lagrange notation in **Vic-3D** v. 2012 (Correlated Solutions).

A **subset** size of **25 × 25 pixels** and subset **step** of **5 pixels** were chosen based on the pre-study examining the ratio between the density of the computed points and the efficiency of recognition the speckle pattern.

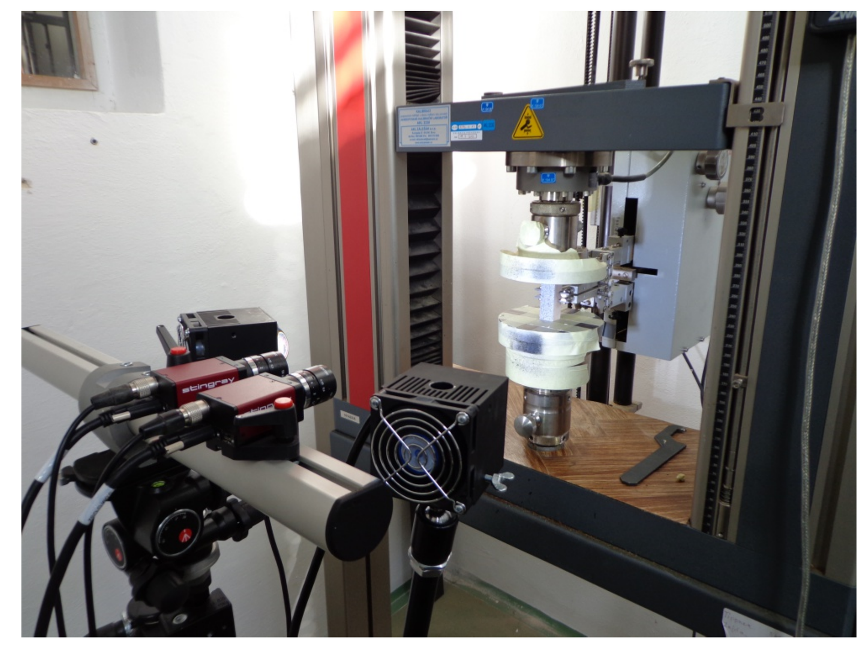

Figure 2: The stereovision system

RESULTS & DISCUSSION

Strain field characterization

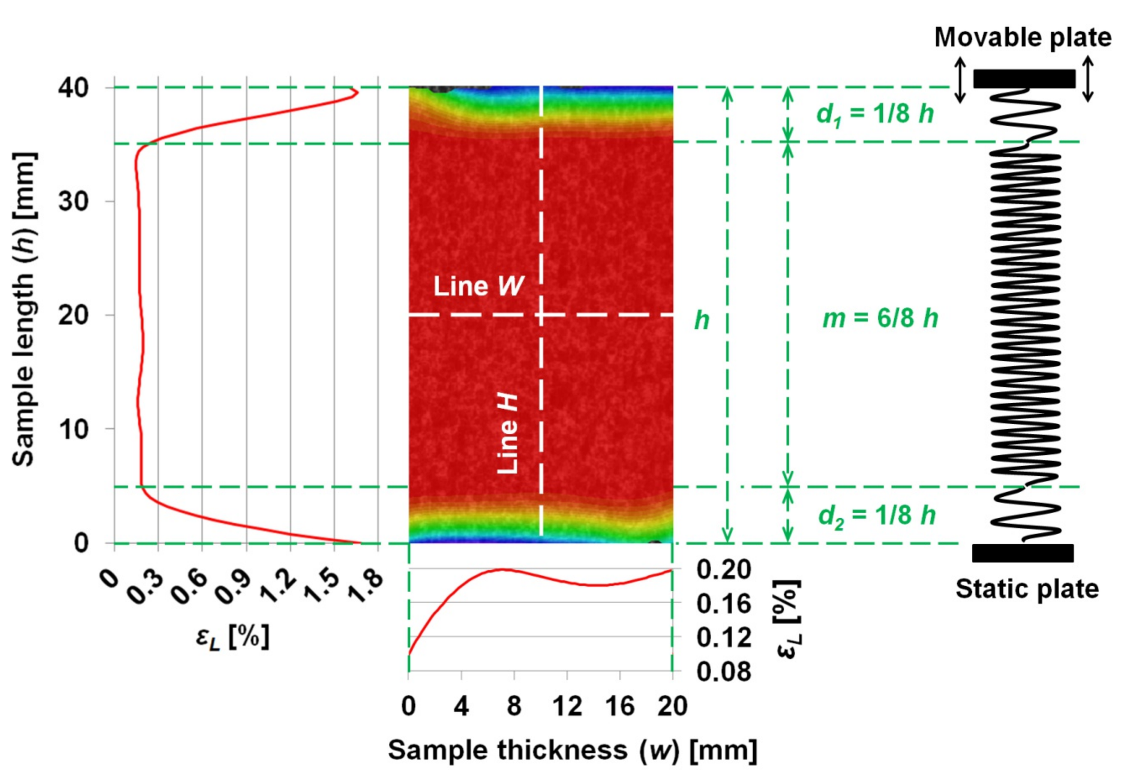

Figure 3: Typical deformation field of strain in the loading direction (ε_L) and its vertical and horizontal profiles at the $F_{50\%}$ of Norway spruce (20 × 20 × 40 mm³) during compression parallel to grain

The **length** of zone ***m*** increased as a **function of *h*** (Fig. 4). The real length of zones $d_{1;\,2}$ varied by about 4 - 5 mm for all *h* and both spruce and beech as well. The relative **constant length** of zones $\boldsymbol{d_{1;\,2}}$ was reflected in their decreasing proportion of *h* with an increasing *h*.

The substantial changes occurred in the range of **plastic deformations**. For a few samples, the **expansion** of zone ***m*** was indirectly confirmed by the successive **disappearance** of one or both zones $\boldsymbol{d_{1;\,2}}$ from the ε_L plots (Fig. 4 – right) due to compression and consequent stiffening of them.

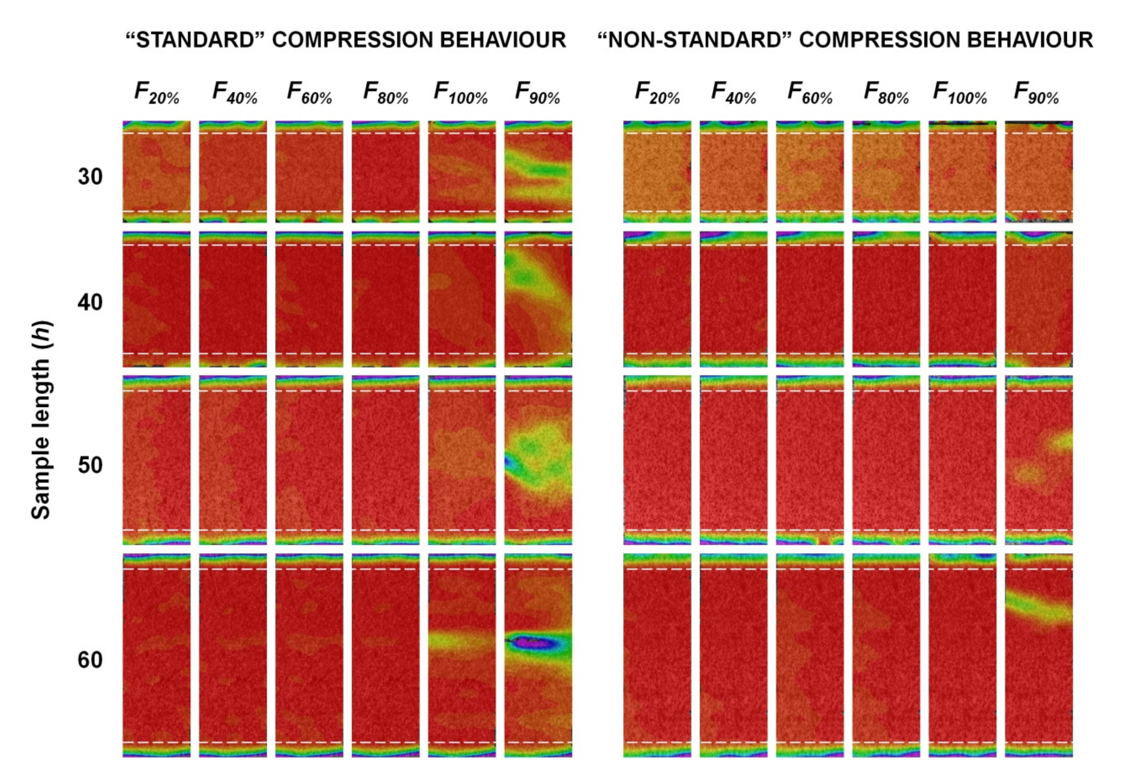

Figure 4: Deformation sub-regions consisting of strain in the loading direction (ε_L) during "standard" and "non-standard" compression behaviour.

Negative ε_L phenomenon investigated by various methods

"Clip on" extensometer

The movement of the isolated points from each other causing the **negative $\boldsymbol{\varepsilon_L}$** phenomenon can be successfully **detected** by the **"clip-on" extensometer** (Fig. 5).

The **crosshead** also mechanically tracked isolated points but located on the sample contact surfaces that moved throughout the compression test only relative to each other. The $\boldsymbol{\varepsilon_L}$ calculated **by DIC** and used for creating the stress-strain curves are **averaged**, and therefore **cannot capture** the **negative $\boldsymbol{\varepsilon_L}$** phenomenon as well.

Velocity analysis

The negative ε_L phenomenon was also observable within the **full-field velocity data of displacements** in the loading direction.

The **maximum velocity** was observed where samples came into the **contact with** the **movable** compression **plate**. As the distance from that plate increased, the velocity decreased. However, for samples exhibiting **negative** increment of $\boldsymbol{\varepsilon_L}$ (Fig. 6), a **higher velocity** of point **no. 3 than** point **no. 2** during the short time interval was proved.

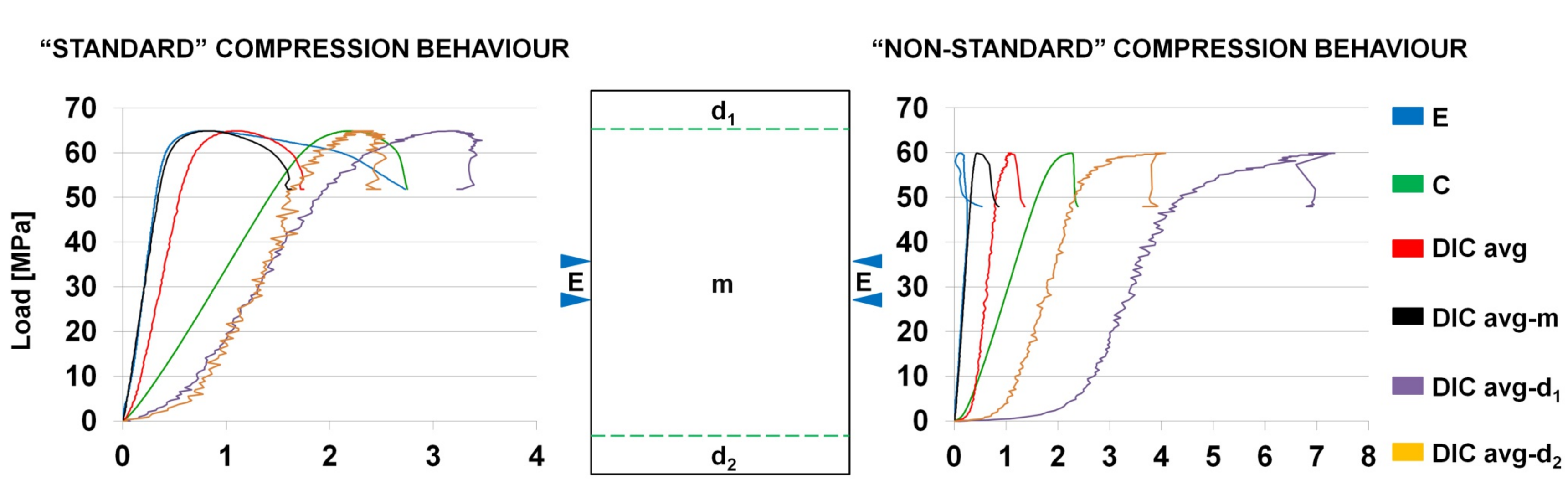

Figure 5: Stress-strain curves obtained by crosshead (C), extensometer (E), and DIC

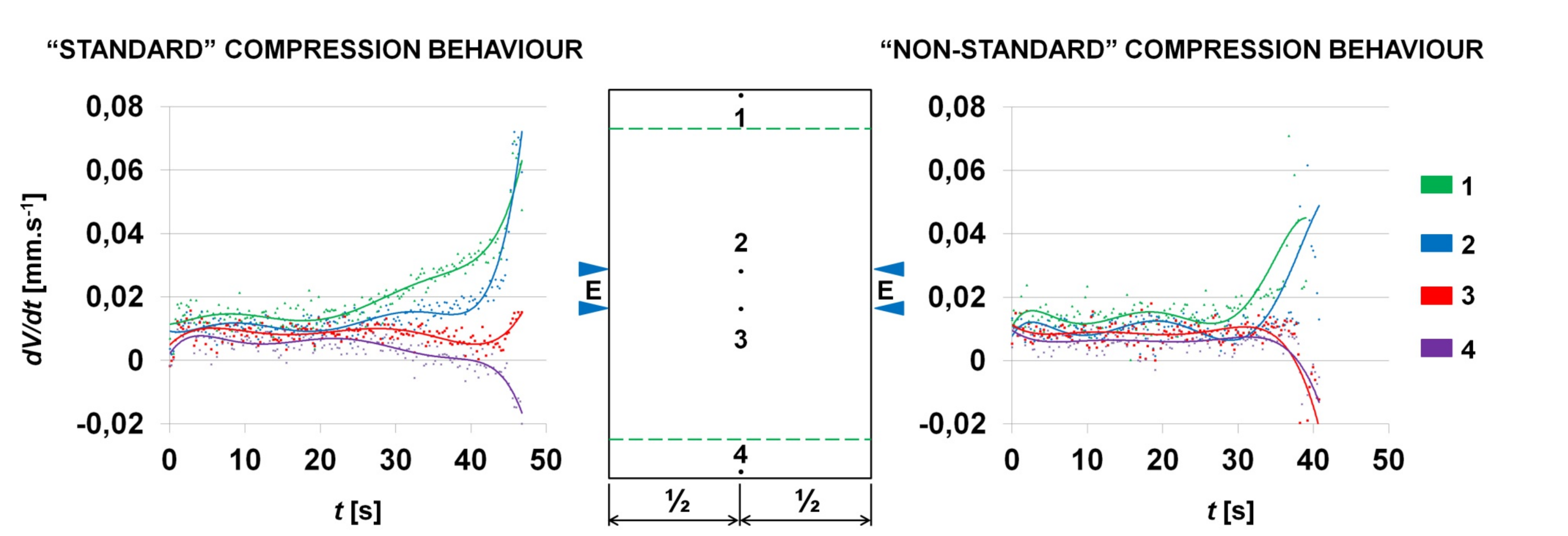

Figure 6: Development of displacement velocity (*dV/dt*) at selected points located near the compression plates (no. 1,4) and at the vertical position as the points tracked by the extensometers (no. 2,3)

CONCLUSIONS

The negative increment of strain in the loading direction during the **compression** of **Norway spruce** (*Picea abies*, L. Karst) and **European beech** (*Fagus sylvatica*, L.) **parallel to grain** was eplored.

The full-field deformation analysis revealed that the **negative increment of strain** results in an **expansion** of the **middle zone**. The findings can be **helpful for** the identification of weaknesses of standard compression tests, especially in the **choice** of the **sample length** and surface **area for** the deformation **measurement**.

ACKNOWLEDGEMENT

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