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## METHOD TO EXTRACT STRESS-STRAIN FUNCTIONS FROM PURE TORSION OR PURE BENDING EXPERIMENTAL TESTS

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**Abstract:** A mathematical methodology has been developed to extract stress-strain relations from pure torsion tests. This method has also been developed to extract the compression stress-strain relation from uniaxial and pure bending experimental tests. The extraction method has been experimentally tested on pure copper wire specimens; the extracted stress-strain relations proved to be fully satisfactory, validating thus the proposed method.

### 1. Introduction

Stress-strain relations are usually experimentally identified during pure traction, pure compression or pure shear tests. Each of these tests presents its own experimental challenges. For example, buckling prevents reaching a wide range of compression stress on slender specimens: identifying the compression stress-strain relation on a satisfying range is difficult in this case. Yet, it has been observed that a higher compression stress range can be reached locally by simply applying pure bending load to these slender specimens thanks to the experimental setup developed in [1]. The measured experimental data (*i.e.* the bending moment versus curvature) contains information about the stress-strain compression relation; the aim of this work is to develop a method to successfully extract this information from experimental results. The proposed method has also been straightforwardly adapted to identify shear stress-shear strain relations from pure torsion test. In this abstract, only the latter is described for concision and simplicity sake.

### 2. Method and Results

During a torsion test, the applied and measured torque can be written:

$$\overline{M_o^{tors}} = \iint_S r \sigma_{r\theta}(\gamma) dS \overline{u_z} \quad \text{Equ. (1)}$$

where  $\sigma_{r\theta}(\gamma)$  is the searched shear stress-shear strain relation,  $\gamma = \frac{\theta r}{L}$  is the shear strain field,  $dS$  is an elementary surface of the specimen section  $S$ ,  $\overline{u_z}$  is a unity vector normal to section, and  $r$  is the distance between a point  $M$  and the specimen center.  $L$  is the specimen length and  $\theta$  is the specimen second extremity rotation relatively to the first extremity .

The shear stress-shear strain relation  $\sigma_{r\theta}(\gamma)$  is searched as a linear combination of  $n$  cubic splines  $S_k$ ,  $k \in [1; n]$  written :

$$\sigma_{r\theta}(\gamma) = \sum_{k=1}^n q_k S_k \quad \text{Equ. (2)}$$

where  $q_k$ ,  $k \in [1; n]$  represents the  $n$  unknown to be identified. These unknowns  $q_k$  are searched so as to minimize the function  $\phi^{tors}$  defined in the least mean square sense using every experimental measures  $\overline{M_o^{tors}}(t_i)$ ,  $i \in [1; p]$  . This function can be written :

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$$\phi^{tors}(q_k) = \sum_{i=1}^p \left( \overrightarrow{M_o^{tors}}(t_i) - \iint_S \sum_{k=1}^n q_k r S_k dS \overrightarrow{u_z} \right)^2 \quad \text{Equ. (3)}$$

The same method can be applied to identify the compressive stress-strain relation from pure bending experimental results provided the tensile stress-strain relation has been previously measured.

The experimental input data are presented figure 1. The identified results for 9 splines in torsion and 5 splines in flexion are presented figure 2.

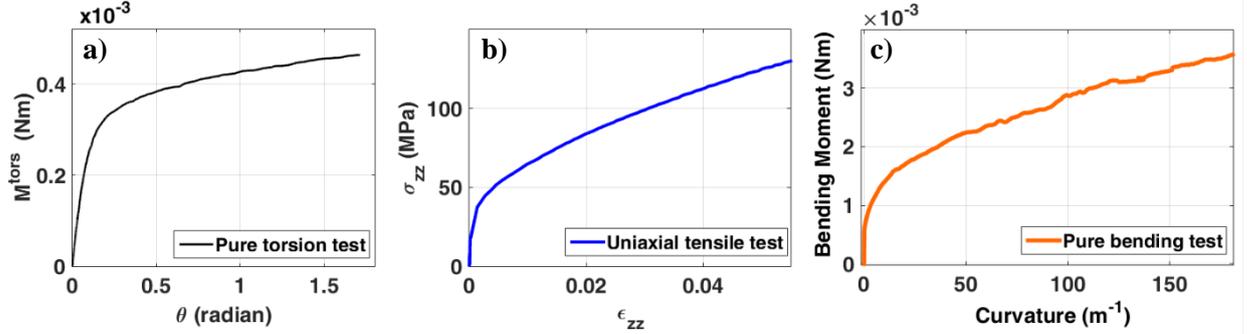


Figure 1. Input experimental data on pure copper wire ( $\phi=0.6\text{mm}$ ) (a) Pure torsion test results, (b) Pure uniaxial tensile test results, (c) Pure bending test results.

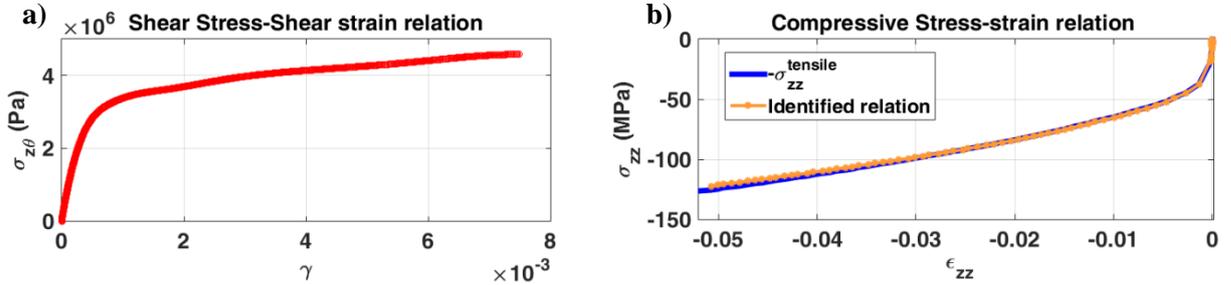


Figure 2. Identified results (a) shear stress-shear strain relation  $\sigma_{r\theta}(\gamma)$  identified using the pure torsion test results, (b) compressive stress-strain relation  $\sigma_{zz}(\epsilon_{zz})$  identified using both the pure bending and tensile test results.

### 3. Conclusions

**Shear stress-shear strain relation  $\sigma_{r\theta}(\gamma)$ :** for validation purpose, the identified shear stress-shear strain relation has been plotted in the Von Mises space (not presented here) and overlaps with the experimental tensile test results: the results are fully satisfactory.

**Compressive stress-strain relation  $\sigma_{zz}(\epsilon_{zz})$ :** the identified compression stress-strain relation is symmetrical to the tensile stress-strain relation, which was the expected result [2]. Further method validation will be presented on numerical tests along with an analyze of the noise impact on the identification.

### References

- [1] G. Antherieu, N.Connesson, D.Favier, P. Mozer, Y.Payan (2015), Principle and Experimental Validation of a new Apparatus Allowing Large Deformation in Pure Bending: Application to thin Wire, *Exp. Mech.* DOI: 10.1007/s11340-015-0102-5
- [2] R. Sandström, J. Hallgren, G. Burman. (2009) Stress strain flow curves for Cu-OFP, R-09-14, URL: [www.skb.se](http://www.skb.se).