EXPERIMENTAL ANALYSIS OF LEAD MECHANICAL BEHAVIOR BY IMAGE PROCESSING

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Introduction

Lead attracts large attentions for its applications in Civil Engineering as constitutive element in base isolators. However, the mechanical properties of this material are still not well known due to a complicate experimental behavior involving large deformations, necking phenomenon, etc…. In this research, tests are performed to collect data for the development of lead constitutive model. The image processing technique is applied because the localization of deformation during experiments prevents from using strain gauges. After post-processing, the 3D displacement field is visualized and the stress-strain relation is calculated.

Mechanical Test

Uni–axial experiments on lead are performed to clarify the rate dependency, the softening in large strain, the effect of porosities and the localization of deformations. Various loading conditions are considered: monotonic tension, tension with unloading, cyclic and relaxation.

The specimen used is designed on the basis of JIS4 specification and, in relation to JIS H2105, it is composed by lead for the 99.99% while the remaining 0.01% are impurities (Cu, Ag, As, Zn, Fe, Bi and Sb+Sn).

During the setting, three analog cameras are located perpendicularly to each other at the top, in the front and in the back of the specimen. After startup, the sample is simultaneously photographed throughout the test evolution and the output from the actuator in terms of force-elongation is recorded in a computer.

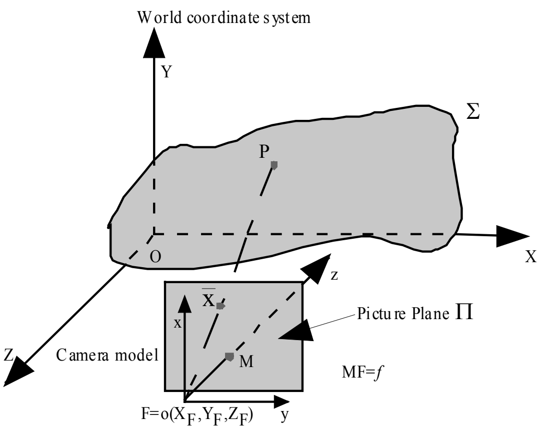

Fig.1 Perspective projection of a point.

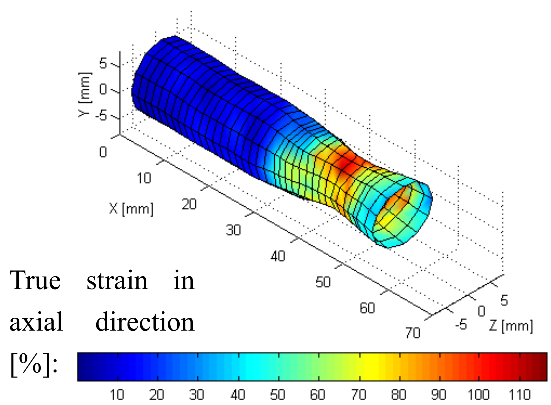

Fig.2 Post processing of the data.

Image Processing Analysis

The image processing technique is applied to analyze the sequences of image files obtained after digitalization of the experimental pictures. This enable to track the displacements in particular material points at each step of the sequence considered. The initial position of these points takes into account the perspective of the 3D object analyzed through the main concepts of epipolar geometry[1]. Fig. 1 shows the projection of a material point **P** on the picture plane (physically

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the camera film). The initial grid of material point may also consider initial imperfections of the sample (curvature or shear deformation) and the localization of deformation.

After the identification of the initial grid, the processing is performed on the basis of the template matching and by applying an iterative procedure to optimize the computational time. Besides, new deformation modes for the template are introduced to improve the matching correlation with respect to previous study[2].

The 3D situation is finally recovered from the 2D fields by combining the three experimental points of view. The result of the analysis is shown in fig. 2 where the color expresses the true strain in the axis direction.

Lead Mechanical Properties

The stress-strain relation is computed in the form of true stress (σ_{xx}) and true strain (e_{xx}) with respect to the representative volume included between each couple of successive cross sections along the specimen. The elasto-plastic properties of the material are described in fig. 3 while the monotonic behavior in large deformation is represented in fig. 4. The latter suggests rate dependency with a peak stress, increasing with the strain rate, and softening immediately after it. This weakening can be imputed to a rapid damage (porosities growth and coalescence) and it is associated to a strain localization in a part of the sample where the cross section area in some cases decreases to 25% of its initial value, equivalent to a 50% reduction in radius (compare also fig. 2).

In cyclic condition the material stabilizes after four or five cycles and it shows isotropic hardening.

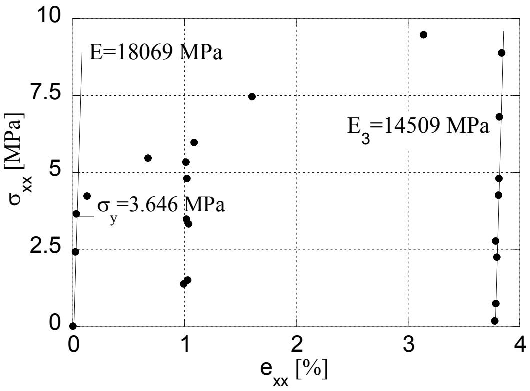

Fig. 3 Elastic properties.

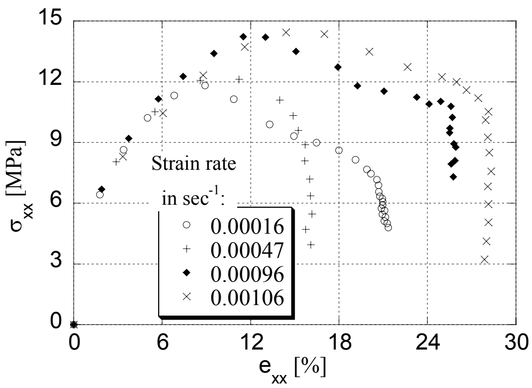

Fig. 4 Rate dependency.

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Conclusion

In this study data for the constitutive modeling of lead are collected with attention to large deformations, rate dependency and porosities effect. Besides, the image processing technique is proved to be applicable whenever a material shows localization of deformation. Therefore, the experimental approach introduced can be applied to define the detailed mechanical properties of a material in any engineering field. This method is particularly convenient in hard mechanics problem involving kinematic non-linearity, material non-linearity and rate dependency under large deformation.

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Reference

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2. H. Takegami, "Evaluation of the mechanical property of Lead by Image processing", undergraduate research paper, Department of Civil Engineering, University of Tokyo, 2000.