EXPERIMENTAL ANALYSIS AND MECHANICAL BEHAVIOR OF LEAD

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Introduction.

Lead attracts large attention for its possible application in civil engineering, for example in dampers or in lead rubber bearings; however, its mechanical properties are still not well known.

In this study, the experimental uniaxial behavior of lead is presented considering large strain (more than 10%), the strain rate dependency, the effect of voids in the material and the necking after the peak of the stress. After the analysis of the experimental data by the image processing technique, a constitutive model for this material is introduced.

Material tests.

Experiments on lead are conducted under monotonic loading condition in order to understand the energy absorption property, the rate dependency and the softening in large strain. In these tests, different velocities of displacement are taken into consideration (effect of the strain rate).

During the testing, pictures of the lead specimen are taken using three cameras: one in the back, one in the front and one at the top of the sample. The time step considered between two following pictures is decided on the basis of the testing velocity.

Image processing analysis.

Since lead is characterized by localized deformation, the common strain gauge cannot be used to measure the displacement and the image processing technique is applied to trace the deformation field on the surface of the specimen. This method is improved, with respect to the previous study[2)], regarding the way to define the material points (i.e.: using the accurate shape of the specimen). Besides, new deformation modes are considered, as concerning the deformation of the templates, and the displacement field is calculated by an iterative method.

The analysis of the experimental data is performed at first in 2D, considering the pictures of the specimen, which are taken during the test; then the three displacement fields are combined to get the 3D behavior. Finally, the experimental stress-strain relation for different velocities is obtained considering two cross sections in the specimen as shown in fig.2.

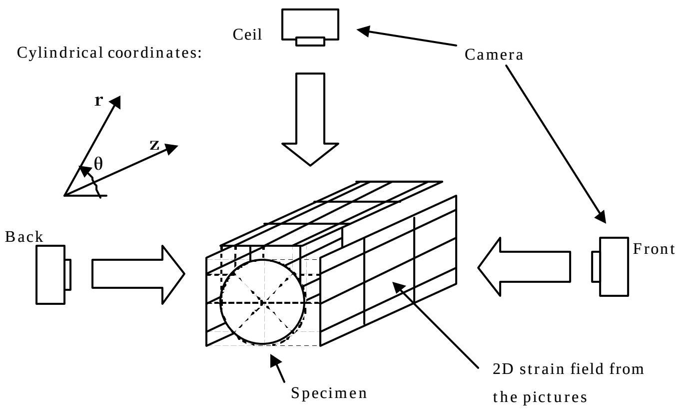

Fig.1 Combination of the 2D displacement field in 3D.

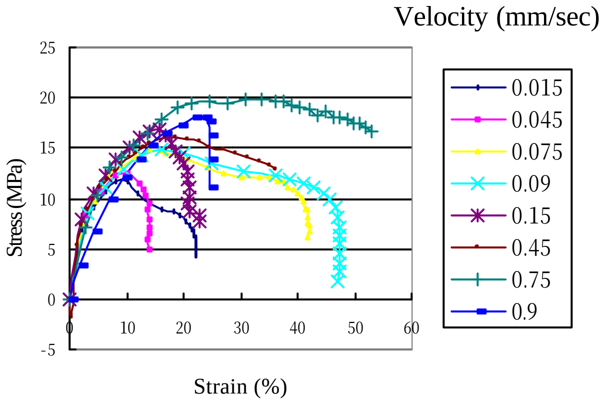

Fig.2 Experimental behavior for different velocities.

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Constitutive model for lead.

Based on the experimental data measured by the image analysis, a constitutive model for lead is proposed, that is an extension of the visco-plastic type of the Gurson model[1]. This is originally used to describe the nucleation and the growth of voids in the material. The extensions are introduced on the basis of the observed experimental behavior that shows, in terms of stress-strain relation, a very small elastic range, a peak in the stress, and a typical post-peak behavior. Therefore, a third order polynomial function is added to the power law that is used in the original Gurson model to express the strain hardening function *g* and a critical value e_c for the strain is assumed:

$\bar{\varepsilon} < \varepsilon_c$

$$g1 = \left(1 + \frac{\bar{\varepsilon}}{\varepsilon_0}\right)^n + c_1\bar{\varepsilon}^3 + c_2\bar{\varepsilon}^2 + c_1\bar{\varepsilon} + c_4$$

$\bar{\varepsilon} > \varepsilon_c$

$$g2 = p\left(\frac{\bar{\varepsilon} - \varepsilon_c}{\varepsilon_0} + q\right)^r$$

In the above equations, 10 parameters are considered: n, c_1 , c_2 , c_3 , c_4, p, q, n, r, e_0 .
The second extension is related to the overstress function that takes the form of the Chaboche visco-plastic model:

$$\dot{\bar{\varepsilon}} = \dot{\varepsilon}_0\left[\frac{\sigma_F}{c(\tilde{D})\sigma_0} - (1 - b + b * g)\right]^{1/m} .$$

After the identification of the parameters (for the overstress function: b, c, m, s_0 , e_0), the experimental results are reproduced by the proposed model as concerning the peak of the stress and the necking behavior, while in the elastic part there is a discrepancy between experimental results and simulation caused by the lack of data in this range.

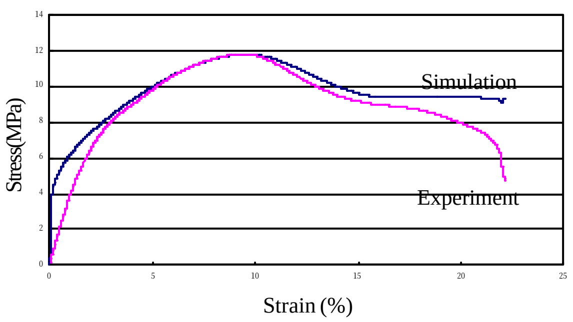

Fig. 3: Test at 0.015 mm/sec.

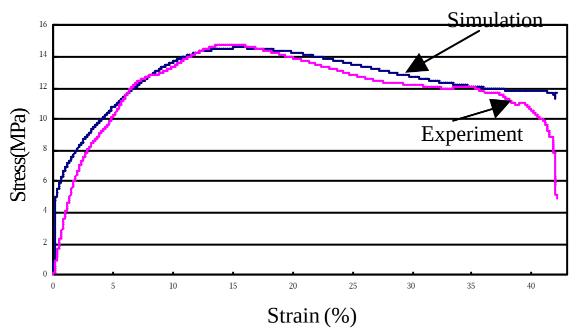

Fig. 4: Test at 0.075 mm/sec.

Conclusion

This study shows a constitutive model to describe the mechanical behavior of lead in uni-axial monotonic loading. This model is based on the Gurson model with a new strain hardening function and a new overstress function. The experimental results are reproduced by the analysis as concerning the peak of the stress and the necking behavior.

Acknowledgement

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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.