HIGH STRAIN RATE TENSILE TESTING - IDENTIFICATION OF DYNAMIC CONSTITUTIVE FLOW LAW USING HIGH SPEED TENSILE TEST AND TAYLOR GAS GUN

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1 Introduction

Over the last past years, numerous studies have been concentrated on dynamic mechanical properties of materials. Constitutive laws, the relation between applied forces and deformations, have also received much attention. Under large deformations and high deformation rates such as forming or machining processes, non-linear constitutive laws plays a significant role in predicting the mechanical behavior of materials. They will become more complicated if more physics are taken into account. The implementation of non-linear constitutive laws in numerical simulation requires the identification of a large number of parameters. This paper presents an inverse identification procedure of the Johnson-Cook constitutive law parameters for 2017 aluminium alloy (AlCu4MgSi) based on a new tensile test specimen.

2 Presentation

Johnson-Cook is an empirical constitutive model and is widely used in simulation of materials and structures under high strain rate. In this model, flow stress depends on the plastic strain, the strain rate and the temperature [1]. The proposed identification procedure contains two main parts: an experimental dynamic tensile test and a numerical simulation of the same test. Identification of the constitutive law parameters is done by minimizing the difference between the numerical results and the experimental ones.

High strain rate tensile testing originally designed by LGP (Laboratoire Génie de Production) is based on Taylor tests. In the Taylor technique, a rod impacts a rigid surface and a post-mortem measurement of the final shape is carried out as an evaluation of the deformation. Strain rates of over $10^4\ s^{-1}$ can be achieved in such apparatus. To conduct tensile tests, the Taylor gas gun device is used to launch a

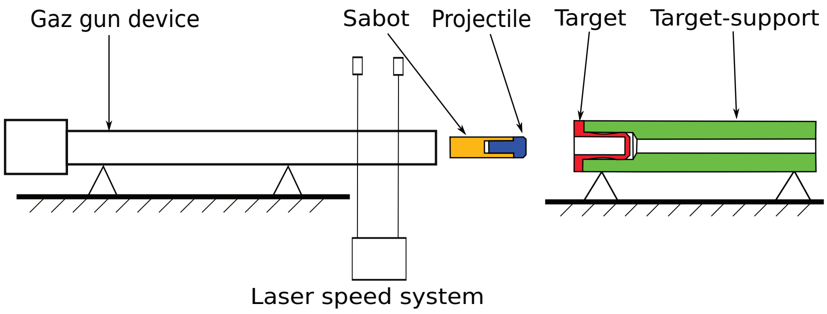

Figure 1: Layout of Taylor tensile facility using a gaz gun

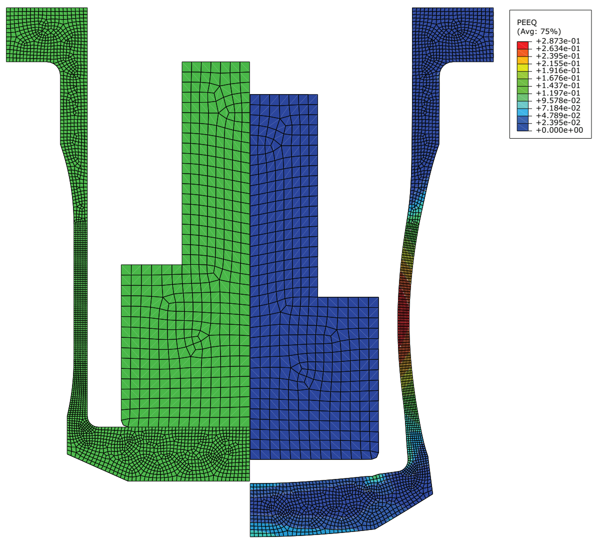

Figure 2: Two-dimensional axisymmetric tensile Finite Element Model: left is undeformed model, right is plastic strain after impact.

projectile with a weight of $30 - 50\,gr$ into a specially designed target (see Figure 1) with different impact velocities (ranging from $60\,m/s$ up to $120\,m/s$) and tensile plastic deformation occurs in the center zone of the target. In the present work, the geometries of the projectile and the target have been modified with regards to the previously proposed approach [2] and optimized in order to obtain higher strains and higher strain rates without reaching the critical state of the rupture of the specimen. A two-dimensional finite element model of the target is shown in Figure 2 (left side of figure) and an illustration of the deformed specimen showing the plastic strain contourplot is reported in Figure 2 (right side of figure) for an impact speed of $V = 90\,m/s$.

Numerical models are built thanks to the finite element software Abaqus/Explicit. The correlation between the final deformed shape of numerical models and the final deformed shape of experimental specimens is evaluated by a new identification program developed using the Python language in the LGP (the previous version was in C++). The aim of this program is to provide an appropriate set of constitutive law parameters giving a good prediction of material behavior by minimizing the difference between a selected set of experimental results and simulation responses. In the original program, the coarse and refinement researches were achieved by a sequence of the Monte-Carlo and the Levenberg-Marquardt algorithm seperately [3].

In the new version of the identification program many improvements have been developped in order to increase the robustness and the stability of the identification procedure. Adaptive filering methods to supress the numerical noise in the results have been implemented to increase the convergence rate and a numercial database of the previous results has been added in order to reduce the computing time when the same sets of parameters are generated during the optimization procedure.

3 Conclusion

An identification procedure of dynamic constitutive flow law has been developed. Using Taylor gas gun facility, high speed tensile tests are conducted to obtain experimental results. Numerical modeling is completed by the finite element software. A Python program is used to identify the values of constitutive law parameters through evaluating the difference between experimental results and numeriacal responses. The efficiency and accuracy of the identification procedure is proved by the results presented in this paper. The application of the identification procedure needs to be extended to multiple dynamic tests (compression and shear). Automatic techniques for measuring the final deformed shape of specimens remains to be improved is the present work.

References

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