Estimation of process parameters of hydrostatic extrusion by means of FE modelling

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Abstract

Hydrostatic extrusion is a severe plastic deformation process which allows to produce bulk nanostructural metals. Aim of this work is to build and calibrate thermo-mechanical model of this process, which takes into account the heat generation. Main output parameter is the value of hydrostatic pressure necessary to extrude billet of given dimensions and mechanical properties through the reduction channel. The results have been also used to analyze similarities and differences between single and multi-pass processing.

Keywords: hydroextrusion, nano-metals, numerical analysis

1. Introduction

Reduction of the material grain size results in improvement of the strength, according to Hall-Petch equation, which predicts a linear depependece of yield stress on the inverse of square root of the average grain diameter. One of the so-called severe plastic deformation processes which leads to grain refinement up to nanometer scale is hydrostatic extrusion. In this process a billet is pushed through a channel of the reduced diameter under the action of hydrostatic pressure of surrounding fluid medium. Main advantage of this process is high strain rate, which prevents dynamic recrystallization. Also, it is characterized by friction between billet and the channel being reduced to minimum.

Hydrostatic extrusion has been used successfully to produce nanostructured samples of a wide range of metals and alloys, such as aluminium, titanium, copper, and steel. Basic parameters of the process are: (a) initial diameter of the billet, (b) diameter of the die and (c) extrusion pressure.

2. Model description

FE code of Ansys v12 was used to develop FE model of HE, which takes into account the following phenomena:

- Critical value of the extrusion pressure which initiates the process
- The friction
- Strain hardening of the material
- Heat generation

To account for these phenomena and to evaluate the influence of material properties on the process parameters, an axisymmetric parametric model has been developed. This model assumes multilinear kinematic hardening (Besseling model) to simulate plastic behaviour of deformed specimens, including the Bauschinger effect [1]. The model assumed also the dependence of the properties on the material temperature, which increased during the extrusion due to the conversion of mechanical work on heat.

The temperature changes during plastic deformation and their effect subjected to hydroextrusion process was evaluated in terms of the yielding heat factor k, described by the following relationship:

$$k = \frac{\dot{q}}{\sigma \cdot \frac{d\varepsilon_{pl}}{d\tau}},$$

with $\dot{q}$ standing for the heat flux $\left[\frac{W}{m^3}\right]$, σ meaning the stress $[Pa]$, $\frac{d\varepsilon_{pl}}{d\tau}$ - plastic strain rate $\left[s^{-1}\right]$.

3. Results

The simulations in each case resulted in numerical estimate of process parameters, including the pressure, angle of die, and friction. In order to calibrate the FE model, experimental data from HE processing of stainless steel and aluminum alloys were used. The results of computations provide radial distribution of plastic deformations which can be used to estimate the grain refinement of extruded specimens (Fig.1).

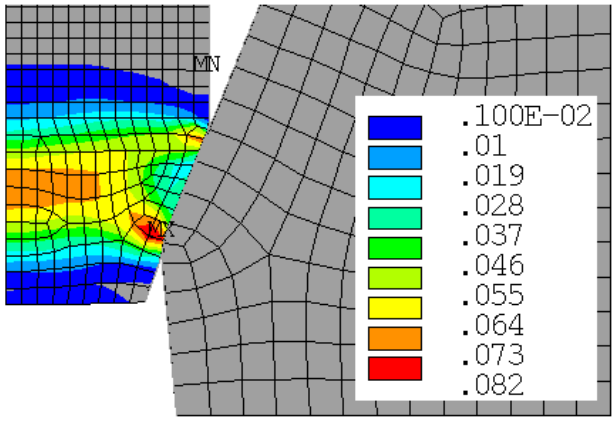

Fig. 1 An example of the plastic strain distribution generated by a single-pass extrusion

References

[1] ANSYS® Academic Research, Release 11.0, Help System, ANSYS, Inc