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Residual Stress Analysis of Severe Plastic Deformed Materials using the Finite Element Method and the Neutron Diffraction Method

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1. Introduction

Severe plastic deformation (SPD) is one of the most promising top-down techniques, moving towards industrialization to fabricate bulk ultrafine grain materials. The strain distribution and deformation behavior during the ECAP (equal channel angular pressing), influenced by tool angles, friction and material behavior, was studied through experimental and numerical analyses.

The residual stress of work piece which was straight before ECAP produces many serious problems in the next processing e.g. input of the work piece for the next ECAP.

The bent work piece needs additional straightening or surface polishing even if the amount of bending is small, and residual stress need to be released before service applications. Residual stress, particularly tensile residual stress can be a very important factor in affecting the reliability and integrity of working parts.

The formation of tensile residual stress may result in initiation of fatigue cracks, stress corrosion cracking, or other types of fracture. Hence, residual stress and resulting bending need to be controlled during ECAP. Thus, in current study the bending behavior and the residual stress of the work piece in ECAP are analyzed through experimental and finite element analyses by considering the effects of material, geometric, and processing parameters individually. The stress states in the ECAP processed work piece were measured by the non-destructive way using neutron diffraction.

Efforts were made to suggest the alternate routes to reduce the residual stress and bending of work piece in ECAP.

2. Methods and Results

2-1 Sample produce

The ECAP(Equal channel angular pressing) process is a promising method that involves large shear plastic deformation in a deforming layer of a work piece by moving through a die containing two intersecting channels of identical cross-sections that meet at a predetermined angle. And this processing's sample material is pure Cu, sample size is a suarepillar (6mm* 6mm* 60mm). ECAP process perform at room temperature, in ram velocity 1mm/sec and once time.

2-2 Finite Element Method analysis

In a rectangular work piece with the width of *W* and Length of *L*, the thickness direction is perpendicular to the width and length directions, so that the strain along the thickness direction is zero, i.e. plane strain condition Prevails. That is, the deformation during the ECAP process of rectangular specimens becomes two dimensional. Therefore, isothermal two-dimensional Plane-strain FEM simulations of the ECAP process have been carried out using the commercial rigid-plastic finite element code, Abaqus. According to the Experimental and the theoretical analyses, the isothermal condition can be fulfilled at low pressing speed. In the simulations, the simple model die has the geometry of 15 (width)× 1 (thickness)× 120 (length) mm3, _=90° and _=90°. Although the deformation behaviors during ECAP varies with the corner angle and the channel angle , one set of =90° and was taken as a prototype of high corner angle.
Fig. 1 shows the initial finite element mesh system for the plastic deformation analysis of ECAP. The work piece material used in the calculations was Cu, which exhibits strain rate sensitivity of flow stress and strain hardening behaviors.

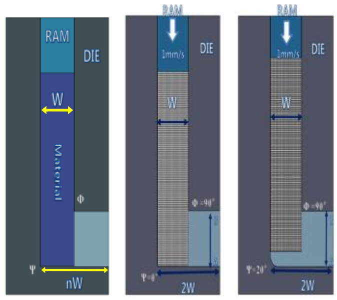

Fig. 1

2-3 Measurement by Neutron scattering

The basic measurement is a determination of lattice spacing, d_h, for the (hkl) plane of the crustal via Bragg's law , $\mathbf{2d_h \sin\theta_h = \lambda}$ where λ is the known neutron wavelength and $\mathbf{2d_h}$ is the angle of diffraction. The elastic train, ε , is given by ε = (d-d$_0$) / d$_0$ where d$_0$ is an appropriate stress-free lattice spacing. The relation between the principal residual stresses,

$$\sigma^n = E/1+\nu\ [\varepsilon^n + (\nu/1-2\ \nu)(\ \varepsilon_1\ + \varepsilon_2\ + \varepsilon_3\ )]$$

Where n=1,2,3 stads for the principle component and E and ν are diffraction elastic constants for the planes of interest. The diffraction Young's modulus E is the ratio of an applied macroscopic stress to the strain measured by diffraction on the subset of grains whose plane normal (hkl) lie along the scattering vector. Fig.2 is showed position praphing and measurement data.

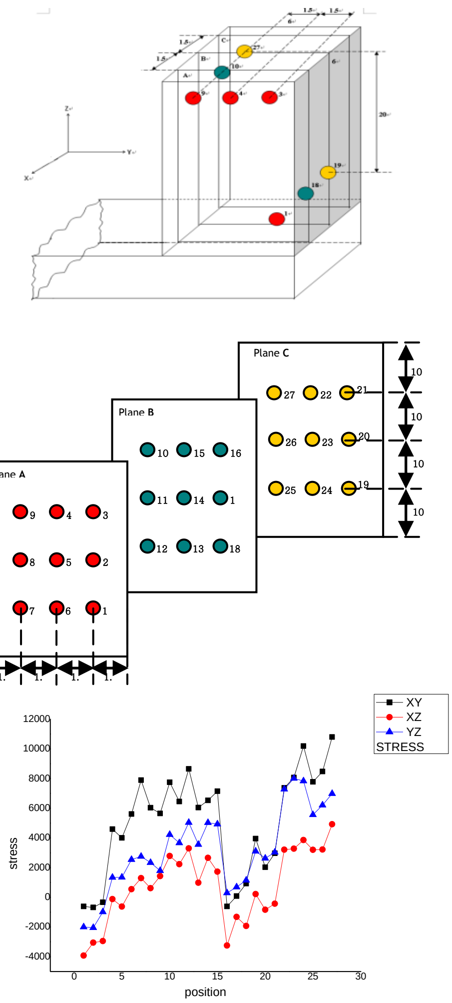

Fig2.

3. Conclusions

This experiment use pure copper(Cu) sample, ECAP process perform at room temperature and get residual stress data by neutron diffraction method, so we compared measure data with Finite Element Method data. In accordance with we could know that;

1) Each of after processing sample ' s plan (top-middle-bottom) measurement data is similar stress trend.

2) After ECAP processing sample cause Curved situation (Banana situation). Because sample that pushed by die can get loose by turned state.

3) ECAP processing calculation data is showed as similar as FEM data. Especially we can verify economical efficiency and a propriety by considered FEM calculating method.

REFERENCES

[1] H.S. Kim, Finite element analysis of equal channel angular pressing using a round corner die, Mater. Sci. Eng. A315 (1-2) (2001) 122– 128.

[2] Y.H. Chung, J.W. Park, K.H. Lee, An Analysis of Accumulated Deformation in the Equal Channel Angular Rolling (ECAR) Process, Metal. Mater. Inter. 12 (4) (2006) 289– 293.

[3] T.M.Holden, J.H.Root, R.H.Holt, M.Hayashi Neutron-diffraction measurements of stress, Physica B213&214 (1995)793-796

[4] T.M.Holden, R.A.Holt, G.Dolling, B.M.Powell and J.E.Winegar, Metall. Trans. 19A(1988)2207

[5] T.M.Holden, R.A.Holt, J.Neutron Research, vol.5,pp241-264