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P096

NUMERICAL INVESTIGATION OF INFLUENCE OF FRICTION ON STRAIN DISTRIBUTION AND FORMING LIMIT CURVE IN NAKAZIMA FORMABILITY TEST

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1. Introduction

This paper presents numerical investigations of the influence of friction in the contact between sheet and a punch on sheet deformation in Nakazima type formability tests. The Nakazima test [1] is one of the most commonly used tests to study experimentally formability of metal sheets. It consists in stretching of a sheet specimen by means of a hemispherical punch until occurrence of fracture.

Friction, affecting strain paths in a tested specimen, is usually undesired phenomenon in formability tests, therefore different measures are taken to reduce friction. In the Nakazima tests, either oil, grease or polymer foils should be used as lubricant systems [1]. Tribological conditions should be adjusted so that fracture occurs within a distance less than 15% of the punch diameter away from the apex of the dome. The failure location is very sensitive to friction. Even small increase of friction displaces the location of fracture [2].

The aim of this study has been to numerically identify frictional conditions in a selected case of the Nakazima test and study numerically effect of change of friction on forming limit curve (FLC). Numerical simulations have been performed assuming the data corresponding to own laboratory tests carried out for the steel grade HC380LA 1.5 mm thick.

2. Numerical investigation of influence of friction on strain distribution and FLC

Numerical analyses have been performed using the authors' own computer explicit dynamic finite element program. Sheet was discretized with a linear shell triangular elements BST [3]. The material has been considered assuming the Hill'48 model. The tools have been modelled as rigid bodies whose surfaces has been discretized with triangular facets. Frictional contact between the tool and sheet has been treated using the Coulomb model of friction. Deformation process has been analyzed under prescribed motion of the punch. Strain distribution obtained in numerical simulations for circular specimens and various friction conditions are compared with experimental results on the forming limit diagram in Fig. 1. A good agreement between numerical predictions and experimental data can be easily seen.

Influence of friction on forming limits has been studied numerically using specimens with different width which allows us to receive the full range of conditions needed to build a FLC. The results in the form of numerically determined FLC along with strain paths are shown in Fig. 2. The fracture localization was obtained by post-processing time histories of major and minor strains and their first and second derivatives. A peak of the major strain acceleration in the failure zone determined the onset of localized fracture. With the increase of friction strain path deflects toward the plain strain from equibiaxial and uniaxial tension strain state. The increase in friction causes the narrowing of the area of possible deformations of the material.

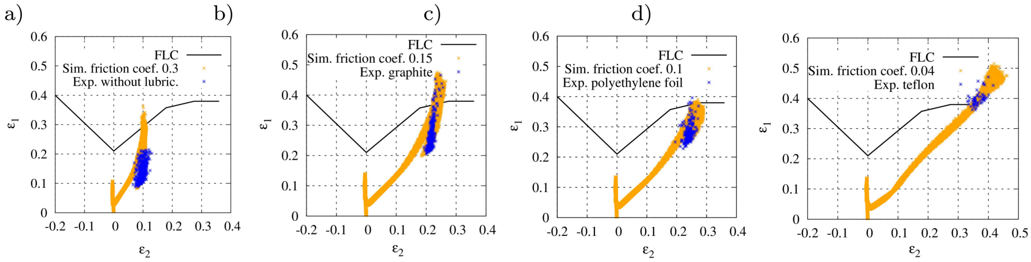

Fig. 1. Strain path in circular specimen obtained numerically in bulging test under different friction conditions: a) without a lubricant, b) graphite, c) a polymer film, d) Teflon.

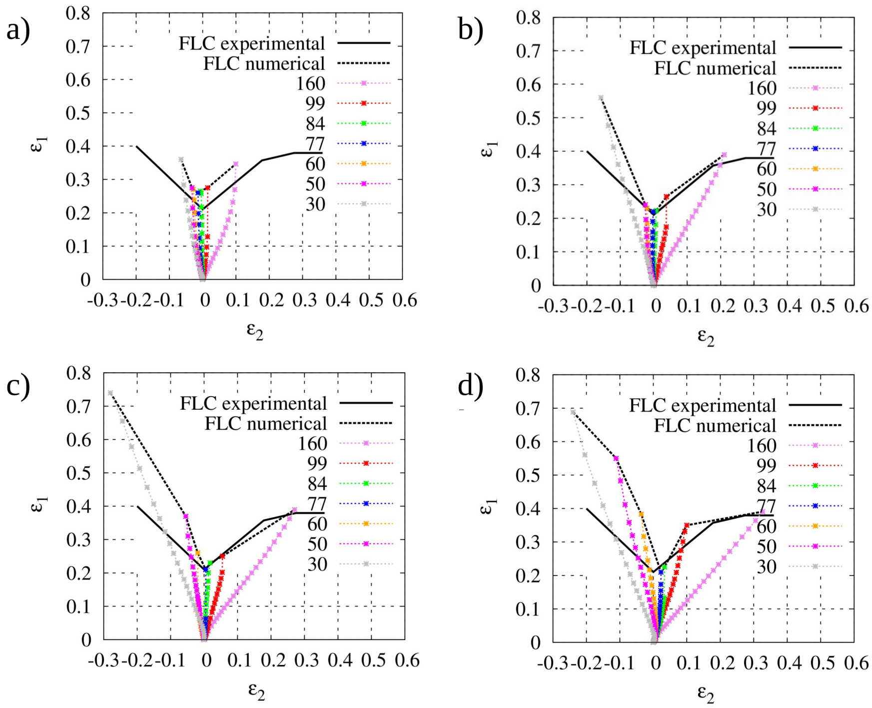

Fig. 2. Comparison of strain distribution in circular specimen obtained numerically and experimentally in bulging test under different tribological conditions: a) without a lubricant, b) graphite, c) a polymer film, d) Teflon.

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