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Influence of friction on strain distribution in Nakazima formability test for circular specimen

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Abstract

This paper presents experimental and numerical investigations of the influence of friction on sheet deformation in Nakazima type formability tests. Numerical simulations have been performed using the authors own explicit dynamic finite element program. Strain distribution obtained in numerical analyses has been compared with experimental data. Location of fracture was of major interest in this work. The studies confirmed that the fracture location near the center of the specimen as required by the standards can be obtained for low values of the friction coefficient. With the increase of the friction coefficient the fracture is displaced further from the center.

1. Introduction

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, 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. Zero friction would allow us to obtain fracture at the center of specimen with nearly strain path at fracture point. 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 for circular specimen and study numerically effect of change of friction on strain distribution and failure location in a sheet specimen.

Numerical simulations have been performed assuming the data corresponding to own laboratory tests.

2. Experimental and numerical studies

Nakazima type formability tests have been carried out for the steel grade HC380LA 1.5 mm thick. *Figure 1* shows the geometry of the tools used in the tests. The tests have been performed for circular specimens with diameter of 160 mm. Different tribological conditions: (i) without any lubricant, (ii) graphite lubrication, (iii) polymer foil, and (iv) Teflon foil introduced between the tools and sheet, have been investigated.

Circular specimens with fractures after the testing are presented in *figure 2*, In the almost frictionless case with the Teflon foil (*figure 2d*), the fracture is obtained nearly at the center of the blank, while in the other cases with higher friction the fracture is displaced from the center by a certain distance, the largest displacement is observed for no lubrication conditions. Friction coefficients corresponding to each of the cases have been identified in numerical simulations.

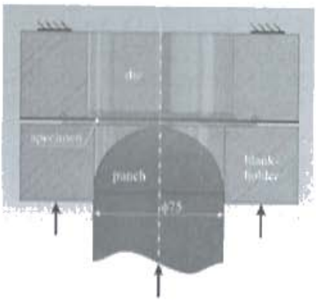
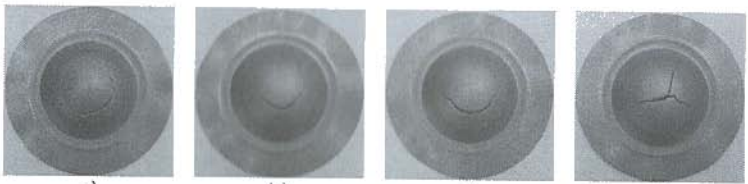


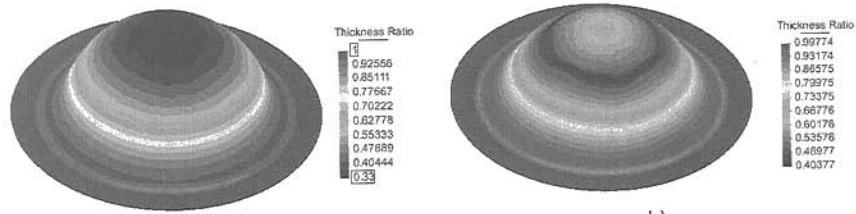
Figure 1: Schematic representation of tools and specimens for formability tests.



a) b) c) d)

Figure 2: Fractured circular specimen from steel grade HC380LA after Nakazima test for different tribological conditions:
(a) without a lubricant, (b) a polymer film, (c) graphite, (d) Teflon

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.



a) b)

Figure 3: Simulated distribution of sheet thickness in the stamped circular specimen: (a) zero friction, (b) friction coefficient 0.15

Figure 3 shows simulated distributions of the normalized thickness for the punch stroke of 38 mm for zero and non-zero friction conditions. In the frictionless case (*figure 3a*) maximum thinning, indicating a possible fracture, is obtained at the center of the blank, while in the case with non-zero friction the area of diffused necking is displaced from the center by a certain distance.

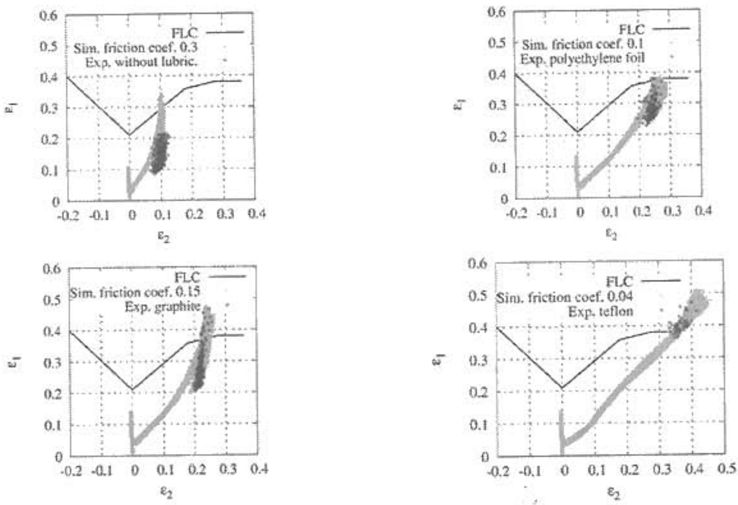


Figure 4: Comparison of strain distribution in circular specimen obtained numerically and experimentally under different tribological conditions.

Friction coefficients for each of the investigated cases have been estimated by matching the numerical and experimental strain distributions in the forming limit diagrams (*figure 4*). The effect of friction on the strain path is shown in *figure 5* showing the strain path for the point with maximum thinning. With the increase of friction strain path deflects toward the plain strain from equibiaxial strain state. This result agrees with experimental results obtained by Graf and Hosford [4] and by Ozturk and Lee [5].

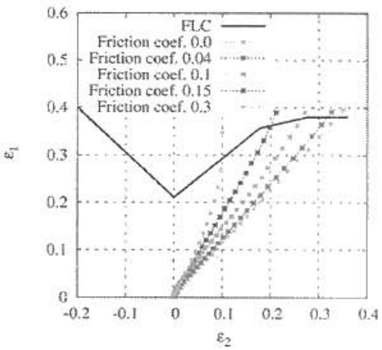


Figure 5: Strain path obtained numerically for different friction conditions.

3. Conclusions

Numerical simulations have shown that specimen deformation in Nakazima type formability tests strongly depends on friction between the punch and sheet. Friction influences the strain path and location of fracture. Location of fracture close to the center of the specimen as required by the standards can be achieved only for low values of the friction coefficient. With the increase of the friction coefficient the fracture is displaced further from the center. Friction coefficient can be determined by fitting numerical strain distribution to that observed in experiments.

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