# NUMERICAL STUDIES OF FORMABILITY OF PRE-STRETCHED STEEL SHEET

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This paper presents results of numerical simulation of formability tests carried out for a pre-stretched steel sheet. Numerical modelling has been verified using experimental results. The tests consisted in stretching of the specimens of different widths over the hemispherical punch. The specimens were cut from the 1 mm thick DC04 steel blank in the as-received state and after pre-stretching by 13% along the rolling direction. The specimens were orientated parallel and perpendicularly to the rolling and pre-strain direction.

The experimental forming limit curves (FLC) were determined for the as-received and pre-deformed blank. FLCs provide a failure criterion in the forming limit diagrams (FLD) used for the estimation of the metal sheet formability. The known drawback of the strain based forming limit curves (FLC) is their dependence on strain paths [1], [2].

The aim of this study is to develop a numerical model allowing us to simulate complex deformation paths of the material subjected to a preliminary stretching, and then bulging tests performed to determine the FLC. Numerical analyses have been performed using the authors own computer explicit dynamic finite element program [3].

Numerical simulation consisted of the following subsequent stages: uniaxial stretching of the sheet, unloading and stress relaxation, cutting a specimen out of the pre-stretched sheet and bulging a specimen with a hemispherical punch. The onset of strain localization in the specimen was determined by post-processing time histories of major and minor strains and their first and second derivatives in accordance with the methodology presented in [4]. This procedure allows us to locate the inflection point in the major strain rate curve associated with the localization. The final shape of the specimens with thickness distribution are shown in Figure 1 together with fractured specimens. A good agreement between simulation and experiment in the failure location can be seen.

The experimental FLC for the as-received and pre-stretched steel blanks are shown in Figure 2. The FLD is built taking the rolling direction as the $y$ axis and the transverse direction as the $x$ axis. The effect of pre-stretching is visible in Figure 2 in the changed form and shift of the forming limit curve for the pre-stretched blanks in comparison to the as received FLC. The major and minor principal strains near the failure zone obtained for the two specimens analysed were compared in Figure 2 with the experimental FLC for the pre-stretched blank and experimental principal strains measured at fractured zones in the respective specimens. We can notice that the strains in the failure zone predicted

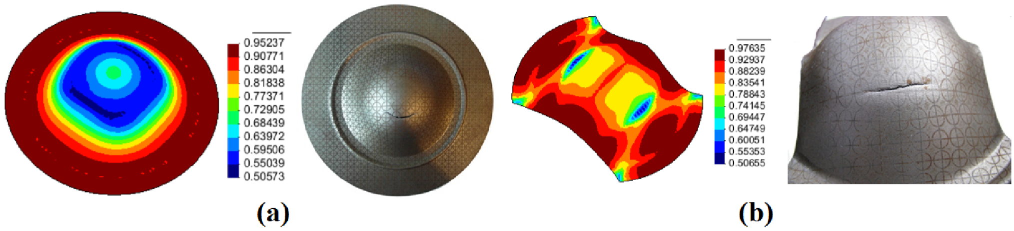


**Figure 1.** Comparison of numerical and experimental results – deformed specimens with thickness distribution and fractured specimens after test: (a) circular specimen, (b) 77 mm wide specimen

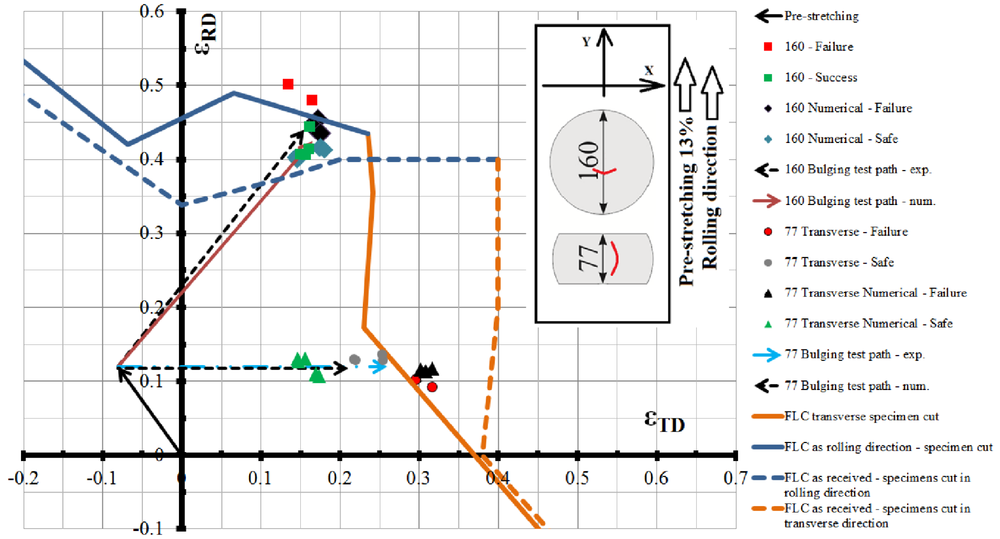


**Figure 2.** Strain paths and principal strains in the failure zones –numerical and experimental results.

by numerical simulation are in a good agreement with experimental data. Some discrepancies can be attributed to size dependency of strain localization in the finite element models as well as inaccuracy of strain measurements in experimental tests. Figure 2 also shows schematically complete strain paths for the material in failure zones in both specimens.

Comparison of numerical and experimental results obtained in formability tests performed for the pre-stretched blanks confirms validity of the developed numerical model. The model can be used in further theoretical studies. It can be applied to study the effect of different strain paths on the FLC. Different strain paths can be obtained easily in the model.

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