# Forming limit diagrams for sheet deformation processes

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## Introduction

Forming limit diagrams (FLD's) offer a convenient and useful tool in sheet products manufacturing analysis. They show the critical combinations of major strain and minor strain in the sheet surface at the onset of necking failure (Fig. 1).

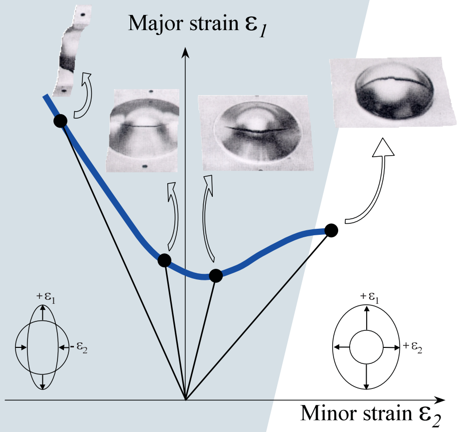


**Fig.1** *An example of an FLD for uniform deformation.*

Formability in the context of multiple phase operations strongly depends of the deformation history and therefore demands an investigation of every particular case. This makes the experimental determination of FLD's unappreciative expensive and causes the necessity to develop an accurate and efficient theoretical method for formability prediction.

The aim is to develop a numerical method to predict forming limit diagrams for FCC metal sheets.

## Method

To induce the occurrence of strain instability in uniform deformation processes initial textural inhomogeneities are used; no additional artificial imperfections have to be introduced. Biaxial stretching of a sheet material configuration has been simulated using the finite element method in plane stress conditions. For the description of the material behaviour at integration point level time-dependent crystal plasticity units with Taylor interaction model have been used. The limit strain was established from a maximum of power criterion.

## Results

Proportional loading of a metal sheet with an initially random distribution of the crystal lattice orientations has been computationally analysed for different uniform strain paths. The RVE consists of 8 by 8 elements and every integration point deals with 10 monocrystals.

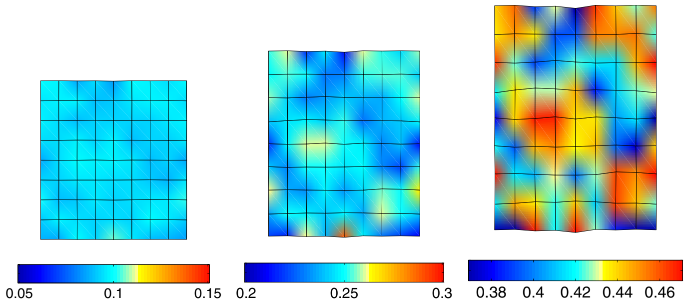


**Fig.2** *Evolution of the second strain field invariant,* $\varepsilon_2 = 0$.

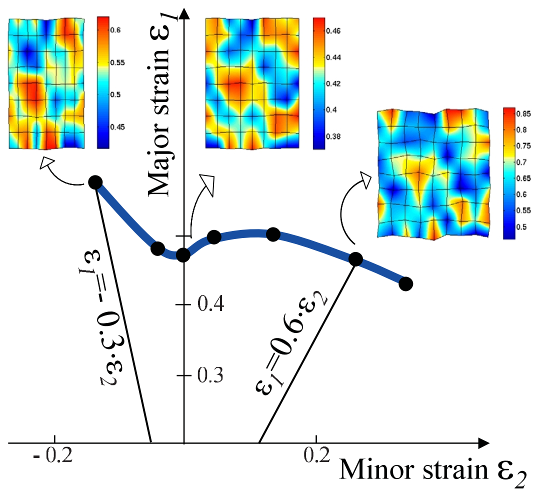


**Fig.3** *Calculated FLD and strain localization patterns.*

## Conclusions

- The results prove the capability of the method to predict strain localization.
- The obtained forming limit diagrams agree qualitatively with experimental data.
- The localization criterion should be improved for a better agreement with experimental observation.




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