Collective behavior and spacing of necks in ductile plates subjected to dynamic biaxial loading

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Dynamic necking of a sheet metal is a major issue in high speed forming processes, leading to unacceptable thinning and even failure if fully developed, and in the dynamic behavior of metallic structural elements of small thickness used for energy absorption purposes. This process is frequently related to the collective development of localization bands resulting in a necking pattern which depends on the sheet properties and the loading conditions.

Within this context, in this work we investigate the emergence of multiple necking patterns in metallic plates subjected to dynamic biaxial loading. For that task we have used a linear stability analysis and finite element calculations. The linear stability analysis is derived within a 2D framework and includes specific features to account for inertia and stress multiaxiality effects inside the necking. Two different finite element models are built: (1) a unitary cell model in which the localization is favoured by a sinusoidal geometrical perturbation and (2) a plate with constant cross section which allows to assess the collective behavior of multiple necks. A wide spectrum of loading paths which range from uniaxial tension to (almost) biaxial stretching has been explored.

The effects of loading path, loading rate, thermal coupling and geometric imperfections on the stability of the deformation process and on the distance between necking bands are examined. We have shown that the neck spacing increases with the ratio of strains and decreases with the loading rate and the temperature rise. Moreover, we have demonstrated that, if inertia plays a dominant role in the loading process, the influence of geometrical imperfections in the necking inception is substantially reduced and the necking pattern shows a deterministic nature. The deterministic nature is directly connected to the emergence of a critical wavelength which characterizes the neck spacing at high strain rates. This critical wavelength increases (i.e. the neck spacing increases) and becomes less prevailing (i.e. the necking pattern becomes less uniform) as the ratio of strains increases. This is a key outcome of our investigation that, from the authors' knowledge, has not been previously reported in the literature.