METHODOLOGY TO CHARACTERIZE FRACTURE FORMING LIMITS IN SHEET METAL

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ABSTRACT

Forming limit curve is usually utilized to predict failure by necking in conventional sheet metal forming. However in specific cases, like single point incremental forming, it was observed that fracture precedes necking. This lies outside the scope of conventional forming limit curve (FLC) and thus rises the need for the determination of the fracture forming limits. This study verifies the application of the methodology to characterize the plastic flow and fracture forming limits in sheet metal developed by Silva et al. (2008) and Isik et al. (2014) on Copper and Brass. The experimental work consisted in the realization of tensile Nakajima bulge and shear tests, in order to obtain the necking and fracture limits for the materials in study.

Keywords: forming limit curve, fracture forming limit, shear, brass, copper.

INTRODUCTION

The Forming limit diagram (FLD) is used to characterize the formability of sheet metals. This diagram depicts the relationship between major and minor strains. Fracture forming curve (FLC) in FLD, developed Keller (1968) and later Goodwin (1968), represents the maximum principle strains the sheet metal can sustain prior to the onset of localized necking. The experimental methods to the determination of the FLC are well established where the circle grid analysis and time dependent methods are the most common ones.

The formability limit by fracture has not been of interest to the sheet metal forming community because once a neck appears and spreads sideways under subsequent deformation, thinning will progress very fast under decreasing loads or pressures until the sheet cracks. Recently, it has been growing the interest to consider the onset of failure by cracking as well as by necking because under certain conditions tensile fracture can precede necking in traditional sheet metal forming processes (Embury and Duncan 1981) and in Single Point Incremental Forming (Silva et al. 2008).

Recent studies by Silva et al. (2008) and Isik et al. (2014) has showed the importance of the determination of the fracture limits, defining the fracture forming limit line (FFL) and shear fracture forming line (SFFL), being related with mode I and II of fracture mechanics, respectively. Isik et al. (2014) presented a methodology to characterize the fracture limits that includes the characterization of necking and fracture of tensile, Nakajima, bulge and shear tests in an Aluminium alloy.
RESULTS AND CONCLUSIONS

The sheet materials of this study are oxygen-free 99.5% Copper with 0.8 mm of thickness and Brass with 1 mm of thickness. The materials properties were obtained by tensile tests following the ASTM standard E8/E8M - 09.

The FLCs were determined by means of the necking strains of the tensile, Nakajima and bulge tests. The FFLs were determined by means of the fracture strains of the tensile, Nakajima and bulge tests, and the SFFLs were determined by means of the fracture strains of the shear tests. Figure 1a and Figure 1b represent the resulting FLDs including necking and fracture limits, i.e. FLC, FFL and SFFL for Copper and Brass sheet metal respectively.

![Fig. 1 - Forming limit Diagrams for: (a) Copper and (b) Brass [Necking points are represented by open markers and fracture by solid markers]](image)

This study reveals that the methodology proposed by Isik et al. (2014) can be successfully applied to characterize the fracture limits in Copper and Brass.

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