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Experimental Investigation on Forming Limit Diagram of Mild Carbon Steel Sheet

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Abstract

The sheet metal forming process is the process of deforming the sheet metal into a desired shape without fracture or excessive localized necking. Variables in sheet metal forming process can be discussed together with formability and test methods. There are many defects occurring during sheet metal forming processes, such as cracking, wrinkling, local necking, buckling etc. The strain measurement in a deformed sheet metal is necessary for measurement comparison. As the thickness of sheet metal is very small as compare to other dimensions of the sheet metal, the sheet metal operation is usually considered as a plane stress problem. The Forming Limit Diagram (FLD) was also determined from surface strain measurement. The FLD is the graph between major strain (e1) and minor strain (e2). The Forming Limit Curve (FLC) or the Forming Limit Diagram (FLD) is useful concept for characterizing the formability of sheet metal, which reflects the maximum principal strains that can be sustained by sheet materials prior to the onset of localized necking. Generally there are three methods to establish FLD i.e. theoretical, numerical and experimental. In this paper experimental method is used to develop FLD. For experimental determination of FLD of Mild Carbon steel sheet Limit Dome Height testing is used according to the American Society of Testing Material (ASTM) as published in ASTM E 2218-02. In this paper the procedure of grid marking, punch stretching and strain measurement is used. For punch stretching operation the set up of spherical die and punch has developed on the hydraulic Universal Testing Machine (UTM). The material used for the die and punch is High Carbon High Chromium Steel (HCHCr). For printing the grids on sheet material chemical etching method is used. In this grid making process grids of 5 mm diameter circles printed. For trial experiment the sheet metal sample is stretched at the force of 23 KN. The deformed circles were converted into ellipse and from that deformed ellipse major and minor strains are to be calculated. After that the FLD will give the two different regions of safe and failure zone.

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Keywords: Forming Limit Diagram, Forming Limit Curve, Universal Testing Machine, and Limit Dome Height.

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1. Introduction

Sheet metal forming process is method of transforming sheet metal into required shape without fracture. In recent years some numerical methods are used for modeling the sheet metal processes. However several finite-element packages are also available for analysis of sheet metal forming processes. As each software gives different results it is important to verify finite results with experimental results. Surface strain measurements are important in case of sheet metal process due to thickness being very small as compared to other dimensions of sheet metal. Forming Limit Diagram also determined by using Surface strain measurement. FLD's can be constructed by using experiments of hemispherical punch-stretch tests and Marciniak cup tests. These experimental methods require intensive efforts and time. Some analytical methods are used to improve efficiency of FLDs. However failure cannot be estimated by analytical methods. A forming limit diagram (FLD) is a graph which depicts the major strains (e1) for all values of the minor strain (e2) at the onset of localized necking. However, because of scattering in the measured necking strains, a narrow band is normally utilized for necking evaluation [1-2].

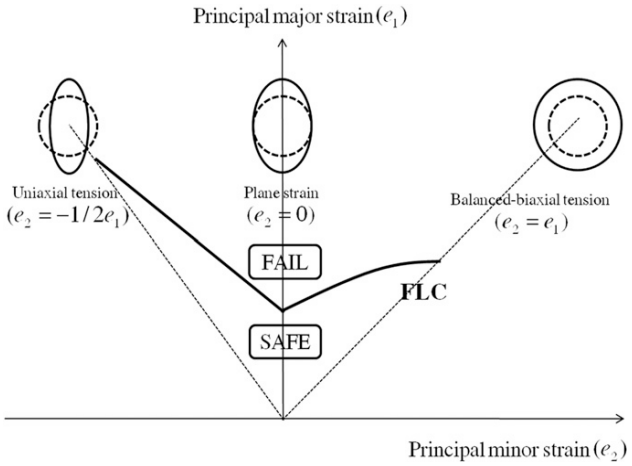

Fig. 1.1 Forming Limit Diagram [3].

FLD is shown in Fig. 1.1 which is divided into two regions separated by a curve, the forming limit curve (FLC). The region below the FLC corresponds to safe strain states whereas that above the FLC represents failure strain states. Even though the strain states of the sheet metal forming processes are complex, FLDs are often constructed using tensile and biaxial stretch tests. As the use of FLD in sheet metal forming industry increases different experimental methods were proposed. Among them ASTM standard test is mostly used. In this test hemispherical punch is used to stretch material on which grids are printed. After stretching operation the grids deformed. Using the deformation of these grids major and minor strains are calculated and graph between major and minor strains is formed [3].

2. Literature Review

V Talyan et. al. [4] studied the formability of Ferritic and Austenitic stainless steel by using tensile Test and Limiting Dome Height test. Result shows that Ferritic steel deform as same as Plain Carbon steel where as Martensite is formed in Austenitic steel due to various strain rate and temperature.

T. Pepelnjak and K. Kuzman [5] has developed Forming Limit Diagram by using Marciniak testing procedure simulated with the FEM program ABAQUS on Galvanized steel, Plain Carbon steel, Al-Alloys and Ti-Alloys with different thickness. Result shows the corelation between experimental and numerical analysis.

Gleiton Luiz Damoulis et. al. [6] used the FLD for the analysis of different forming processes in industries. Before tool production process simulation is the effective method. FLD is used as the method of designing tool for the forming processes for different materials.