

Forming Limit Diagrams of Ground St14 Steel Sheets with Different Thicknesses

Ramin Hashemi
University of Tehran

Amir Ghazanfari
Sharif Univ of Technology

Karen Abrinia
Tehran Univ

Ahmad Assempour
Sharif Univ of Technology

ABSTRACT

The influence of sheet thickness on sheet metal forming limits is a controversial issue; while some investigations indicate the considerable influence of thickness on forming limit diagrams (FLDs), others suggest that it is of negligible importance. In the present work, it has been demonstrated that if the thickness-reduction process is chosen so as not to alter the micro structure of the material, the forming limits do not change with variations of thickness. A material which has extensive usage in sheet metal forming processes of automotive industry (St14) has been provided. The initial thickness of the sheet is 1.5mm and using grinding process (which does not alter the microstructure) the initial thickness is reduced to different thicknesses, namely 1 and 0.5mm. Afterwards, the FLDs for all three thicknesses were determined using standard test methods. The FLDs for specimens which were ground to various thicknesses differ slightly. This small difference is attributed to bending effects resulted from curvature of the punch. Thus, the results strongly support the conclusion that the absolute value of thickness has no influence on forming limits of St14 steel sheet.

CITATION: Hashemi, R., Ghazanfari, A., Abrinia, K. and Assempour, A., "Forming Limit Diagrams of Ground St14 Steel Sheets with Different Thicknesses," *SAE Int. J. Mater. Manf.* 5(1):2012, doi:10.4271/2012-01-0018.

INTRODUCTION

In all processes involving sheet metal forming, the major concerns of the designer are to avoid wrinkling and necking of the sheet. Until 1960s, the only reliable test of formability was whether or not the formed product was free of fractures and through-thickness necks [1]. To preclude necking, one must know the limiting strains or stresses that result in necking; consequently several theoretical and experimental researches have been carried out in order to predict diagrams indicating these limit strains or stresses, namely forming limit diagrams (FLDs) and forming limit stress diagrams (FLSDs).

The concept of FLD was introduced by Keeler and Backhofen in 1964 [2] for biaxial stretching ($\epsilon_1 > 0$; $\epsilon_2 > 0$). Four years later, Goodwin [3] extended the curve for tension-compression domain ($\epsilon_1 > 0$; $\epsilon_2 < 0$). They sketched circular

mesh on the surface of a sheet and drew it up to the fracture point for various stress ratios. After the deep drawing process, circles changed shape to ellipses and by measuring the major and minor axes of the ellipses nearest to fracture point, limiting strains were obtained and the FLD was plotted.

Since 1960s, various experimental methods have been proposed to determine the FLDs. A summary of the most common techniques is as follows:

Uniaxial tensile test method, which is probably the easiest method, uses a general purpose testing machine to obtain the left hand side of the curve. Hydraulic bulge test could be employed to acquire the right hand side in the absence of friction with the aid of elliptical dies with various geometries. Hecker's test method [4] is capable of producing the biaxial stretching region with only one punch and one type of sample

by varying the friction regime. Marciniak [5] used a flat-bottom hollow punch to acquire the positive domain of the curve by changing the shape of the punches. The most important advantage of this method is that the crack initiates in a planar surface. Nakazima's test method [6] involves deforming rectangular samples on a hemispherical punch. Both sides of the diagram are covered by employing various friction conditions and specimen geometries. Despite its drawbacks, this technique is probably the most prevailing way of determination of FLDs.

Numerous experimental and theoretical investigations have been performed in order to discover the effect of various parameters on FLDs (e.g. strain path, lubrication, temperature, strain rate, material constants and sheet thickness). Among all effectual parameters, the influence of thickness on sheet metal forming limits is the most controversial issue; while some investigations indicate the considerable influence of thickness on FLDs and enumerate some reasons for that, others suggest that it is of negligible importance. For instance, Keeler and Brazier [7] proposed that there is a linear relationship between thickness and the major strain in plane strain state that results in necking. On the other hand, Barata da Rocha et al. [8] and other researchers obtained the FLDs of sheets with different thicknesses and claimed that "the sheet thickness does not affect in a noteworthy mode the forming limits".

The aim of the present work is to reach a conclusion on this point and elucidate the controversies. In this study, an experimental procedure has been carried out to prove that the influence of sheet thickness on forming limits is due to variations of microstructure resulted from thickness reduction processes; i.e. it has been shown that if the reduction process is chosen so as not to alter the micro structure of the material, the forming limits do not change with variations of thickness.

EXPERIMENTAL WORK

MATERIAL AND PROCESS

A low-carbon drawing quality steel, St14, which has extensive usage in the sheet metal forming industry, was chosen. The chemical composition of the material is presented in Table 1. The initial thickness of the sheet was 1.5mm. The grinding process was used to reduce the thickness of the sheet to 1mm and 0.5mm. Thus, there were three various sample types.

Table 1. Chemical composition of St14.

Material	C (%)	Mn (%)	P (%)	S (%)
St14	0.08	0.40	0.030	0.030

Grinding is a subset of cutting in which each grain of abrasive functions as a microscopic single-point cutting edge (although of high negative rake angle), and shears a tiny chip. In this experiment, a surface grinding machine is employed. Surface grinding uses a rotating abrasive wheel to smooth the flat surface of metallic or nonmetallic materials. The surface

grinder is composed of an abrasive wheel, an electromagnetic work-holding device known as a chuck and a reciprocating table (see Fig. 1). The process reduces the thickness in a gradual manner with a slow rate which does not alter the microstructure notably.



Figure 1. The grinding machine.

FORMABILITY TESTS

In order to measure the formability of the sheets, the out-of-plane Nakazima test [6] was performed. This test involves two stages: fixing the sample using circular die rings as the blank-holder, and stretching the sample using a hemispherical punch with a diameter of 51mm. A 60-ton hydraulic press was employed to provide the required force. The test setup is shown in Fig. 2.



Figure 2. Test setup.