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Experimental Investigation of Stretchability and Bendability Characterization of AISI 1020 Steel

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Abstract

In this study formability of AISI 1020 steel sheet with different thicknesses was investigated by limiting dome height test at room temperature. The influence of thickness on the stretchability, bendability characteristics and dome height for AISI 1020 steel sheets had been identified from experimental data. Increase in the thickness enhanced stretchability, bendability characteristics and dome height values. Results of experiments indicate that AISI 1020 steel sheets can be used to product components with manufacturing processes based on bending and stretching.

Keywords: Stretchability, Bendability, Formability, Dome height test

AISI 1020 Çeliğinin Gerilebilirlik ve Eğilebilirlik Özelliklerinin Deneysel Olarak İncelenmesi

Öz

Bu çalışmada, farklı kalınlıklardaki AISI 1020 çelik sacın şekil verilebilirliği, oda sıcaklığında tepe yüksekliği testi kullanılarak araştırılmıştır. AISI 1020 çelik levhalarda kalınlığın; gerilebilirlik, eğilebilirlik karakteristikleri ve tepe yüksekliği üzerindeki etkileri deneysel verilerden tespit edilmiştir. Sac kalınlığındaki artış gerilebilirlik, eğilebilirlik karakteristikleri ve tepe yüksekliği değerleri üzerinde olumlu etki göstermiştir. Deney sonuçları, AISI 1020 çelik sacların gerdirme ve eğme esaslı imalat yöntemlerinde kullanılabileceğini göstermektedir.

Anahtar Kelimeler: Gerilebilirlik, Eğilebilirlik, Şekillendirilebilirlik, Tepe yüksekliği testi

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1. INTRODUCTION

Sheet metal formability is of great technological and economic interest. Formability is defined as the ability of the sheet metal to undergo the desired shape change without necking and tearing [1,2]. It is well known that metallic materials have different failure mechanisms during formability. Therefore it is essential to test these materials under various stress and strain states, such as 1) stretching, 2) bending, 3) stretch bending, 4) deep drawing and 5) flanging. Figure 1 shows stampings with different stress states [3].

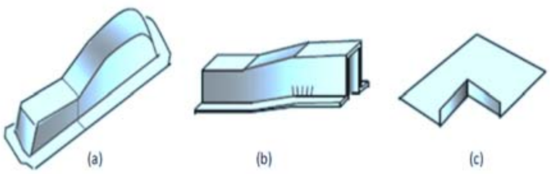


Figure 1. Shapes with different stress states: a) significant stretching, b) moderate stretching and bending, c) high hole expansion and tight bending [3]

Most sheet steels used in automotive and other manufacturing applications requires high ductility, strength and elasticity modulus [4-6]. Mechanical and chemical properties of sheet metal materials such as ultimate tensile strength, yield strength or hardness are not sufficient to account for their formability. Therefore new test methods are needed to identify formability limits to use the sheet metal materials effectively in manufacturing process. In recent years, among the new studies in which the sheet metal formability limits are determined, Forming Limit Diagram (FLD) test has been of concern. Theoretical and experimental FLD methods have been proposed by numerous researchers since 60's [6-14]. Forming Limit Diagrams (FLDs) consist of curves (forming limit curves) plotted in the plane of principal strains. Each curve identifies limit strains when a particular combination of material and process parameters is applied. Stretchability and bendability of sheet metal is usually characterized by the forming limit diagram of the material. However, experimental determination of FLDs is associated with many difficulties.

There are many tests such as the limiting dome height (LDH) test, Swift cup test, Erichsen test and bend test, hydraulic bulge tests of formability for sheet materials. LDH test is a formability test designed for the sheet metal industry. It tests in or near plane strain. The limiting dome height test simulates the common failure strain states in sheet metal forming processes [2,15].

LDH test can be used for determination of the stretchability and bendability in the industrial applications. The height of the dome at maximum load (near failure) can be used as a measure of stretchability. Stretchability is the increase in length-of-line without fracture. Stretchability is measured by the dome height to dome diameter ratio. Higher this ratio indicates better stretchability. Bendability is often measured by the dome radius to sheet thickness ratio. Smaller this ratio indicates better bendability [3].

In this study the effect thickness on formability had been investigated using LDH test results. Formability of AISI 1020 sheet metal with different thickness had been identified using stretchability, bendability characteristics and dome height parameters obtained from LDH test results.

2. EXPERIMENTAL STUDY

Applications in industry require materials presenting both high strength and formability. In the present work, the stretchability and bendability characteristics and dome height parameter had been used to evaluate the formability of AISI 1020 low carbon steel sheet which is widely used in industry, especially in automotive industry. The chemical composition and mechanical properties of the studied material is given in Table 1.

Table 1. Chemical and mechanical properties of AISI 1020 steel

Chemical compositions (%)	C	Mn	P	S
	0.18-0.23	0.30-0.60	0.040 max	0.050 max
Mechanical properties	Tensile strength 380-420 (MPa)	Yield strength 165-205(MPa)	Elongation (%) 15-25	Hardness 100-120 (HB)

The influence of thickness on the stretchability, bendability characteristics and dome height for AISI 1020 steel sheets had been investigated. In the experimental study LDH tests were performed on steel sheets that have thicknesses of 0.5 mm,1 mm, 1.2 mm, 1.5 mm and 2 mm. Specimens were cut in dimensions of 200x200 mm and located into the die and punch system. Figure 2 shows test setup test equipment of LDH test and upper and bottom images of tested/deformed sample. The experimental studies were performed at the room temperature using a hydraulic press with a capacity of 60 kN. The speed of the spherical tip was selected as constant during the experiments. A spherical punch is used to deform the sheet while a lock fixture clamp prevents material flowing from outside to inside the die as seen in Figure 2. Measured maximum height of dome (H), dome radius (r) and diameter of dome (d) after failure had been given in Table 2 to asses stretchability and bendability.

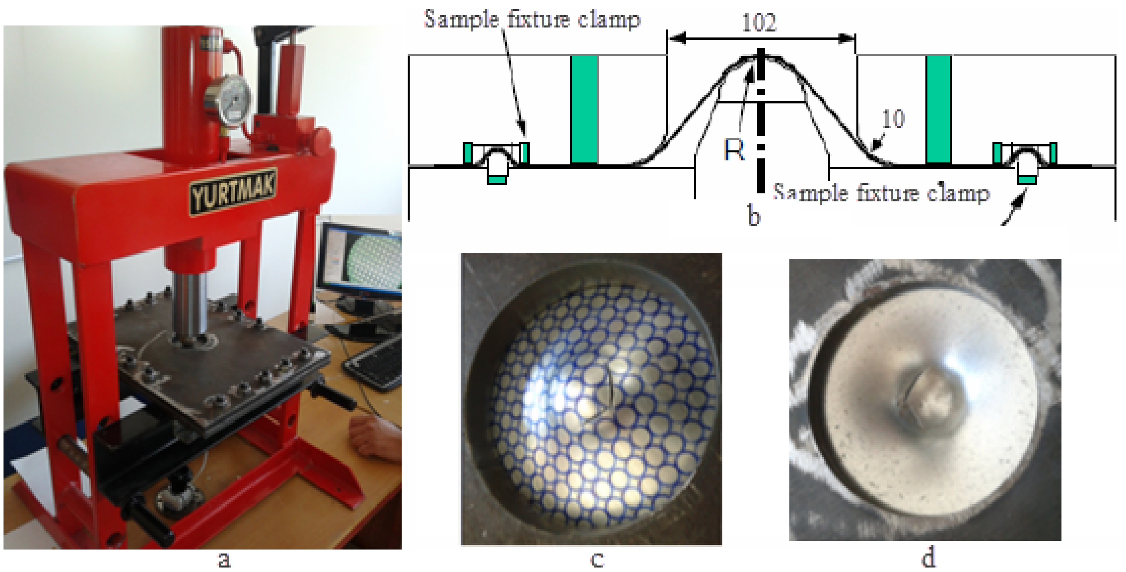
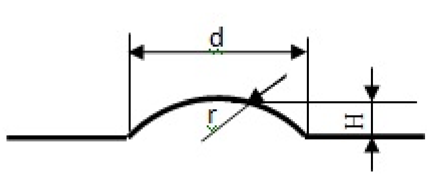


Figure 2. LDH test setup used in experiments. a) Hydraulic press, b) Schematic diagram of tool set up for LDH, Sample Upper (c) and bottom (d) Photograph after LDH test for AISI 1020 steel sheet

Table 2. Experimental results of LDH tests for different thickness of AISI 1020 steel

t (mm)	H (mm)	d (mm)	R (mm)	H/d	r/t
0.5	10	40	20	0.250	40
1	11.1	41.6	20.8	0.266	20.8
1.2	12.4	44.2	22.1	0.280	18.4
1.5	13.4	45	22.5	0.297	15
2	16.7	47	23.5	0.355	11.75



3. RESULTS AND DISCUSSION

In LDH tests the material is forced with a punch having a spherical tip as seen in Figure 2 until it is torn in. Formable sheets are required to be have a certain height of the dome depending on the thickness of the material.

In our study AISI 1020 low carbon steel sheet which is widely used in automotive industry. The most formable sheets are required to be have a certain height of the dome depending on the thickness of material.

The height of the dome at maximum load (near failure) is used as a measure of stretchability. Stretchability is the increase in length-of-line without fracture. To evaluate it, limiting dome height is commonly used. Stretchability, which is defined as H/d and bendability, which is defined as R/t was computed by using experimental data given in Table 2. Figures 3 and 4 give stretchability and bendability characteristics of AISI 1020 steel sheet with different thickness, respectively. Higher H/d ratio implies better stretchability. Increasing values of thickness enhanced stretchability of the material as seen in Figure 3. Increasing the thickness of the sheet from 0.5 mm to 2 mm increased the stretchability 42%. In their study Li and Wu stated that increasing thickness of the metallic materials reduces fatigue strength and fatigue endurance limit [16].

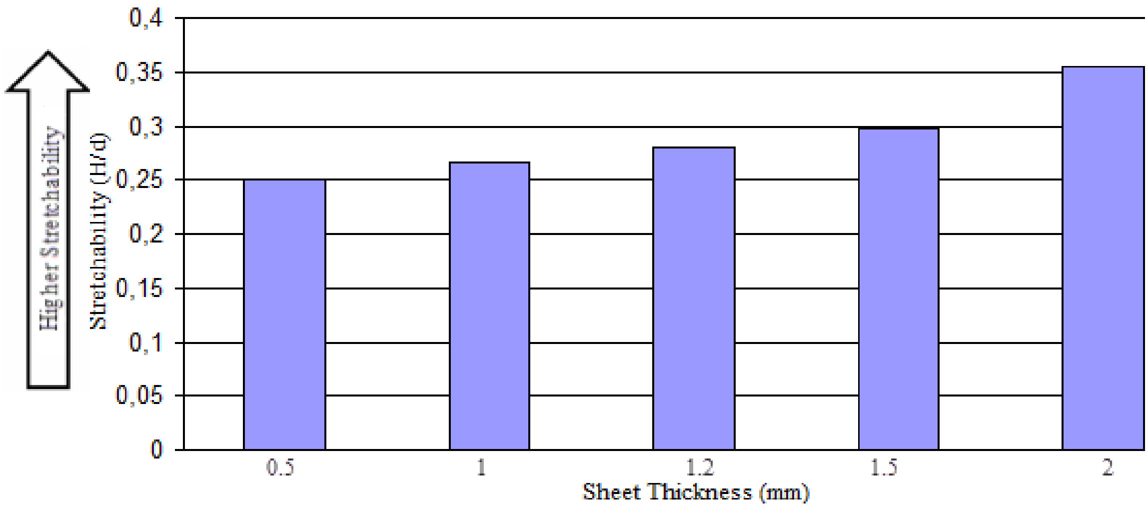


Figure 3. Stretchability of AISI 1020 steel with different thickness

Smaller r/t ratio implies better bendability. As seen in Figure 4 increasing values of thickness enhanced bendability of the material.

Increasing the thickness of the sheet from 0.5 mm to 2 mm increased the bendability 70.6%. As seen in Figure 5 increasing values of thickness enhanced the dome height of the material. Increasing the thickness of the sheet from 0.5 mm to 2 mm increased dome height 67%. The higher value of the height of the dome means the ductility of the material. Same formability results had been found from stretchability, bendability and dome height for the studied material.

There is accordance between the results data of stretchability, bendability and dome height for studied materials. This accordance also confirms the validity of the study. Results of experiments indicate that AISI 1020 steel sheets can be used to product components with manufacturing processes based on bending and stretching.

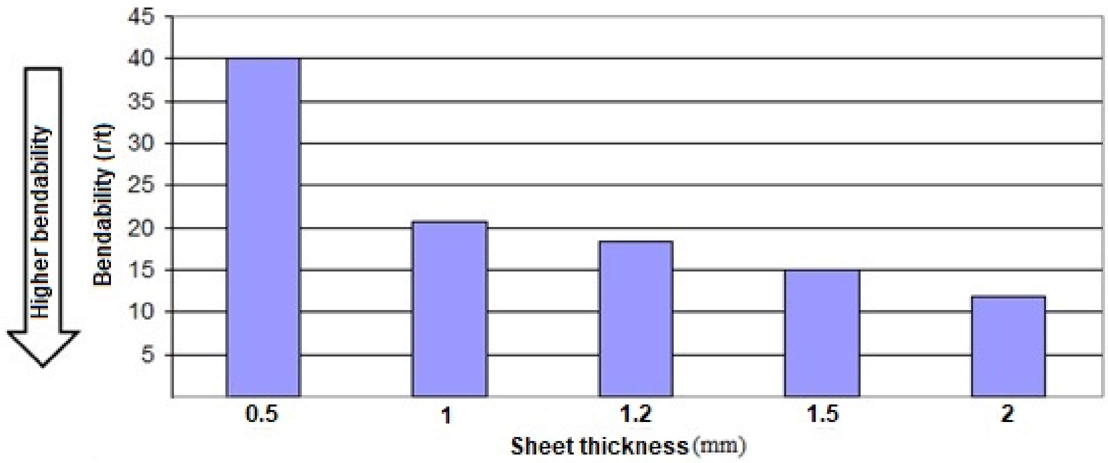


Figure 4. Bendability of AISI 1020 steel with different thickness

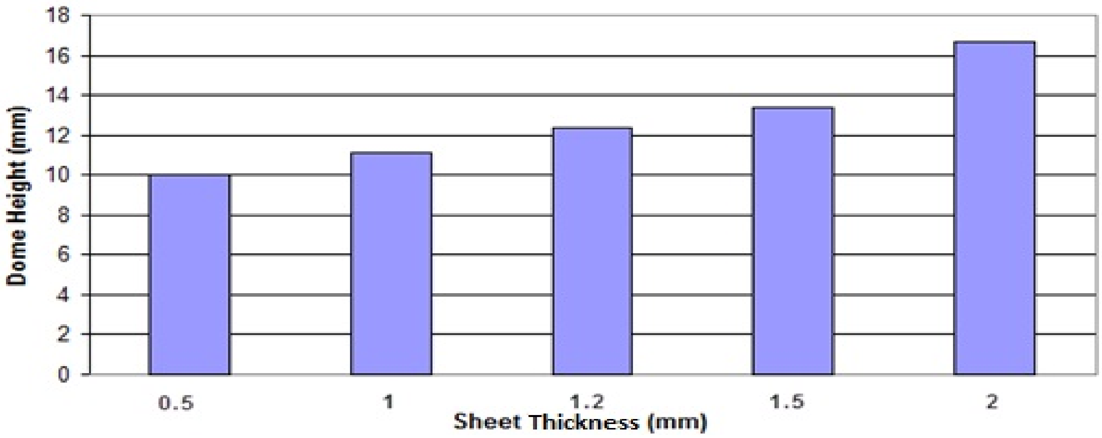


Figure 5. Comparison of dome height of AISI 1020 steel with different thickness

4. CONCLUSIONS

Formability of AISI 1020 steel sheets was investigated by LDH test at room temperature. Effect of sheet thickness on stretchability, bendability characteristics and dome height were discussed. The results are concluded as follows:

The thickness of the ductile materials affects the strecthability, bendability characteristics and dome height.

Increasing values of thickness from 0.5 to 2 mm enhances stretchability and bendability 42% and 70.6%, respectively of the AISI 1020. Higher dome height to dome diameter ratio indicates better stretchability. Increase in the thickness from 0.5 mm to 2 mm results in 67% increase in the dome height.
Smaller dome radius to sheet thickness ratio implies better bendability.
There is accordance between the results data of stretchability, bendability and dome height for studied material.

Stretchability, bendability and dome height properties can be used for evaluation of formability of metallic sheet materials.

AISI 1020 steel sheets can be used to product components with manufacturing processes based on bending and stretching.

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