The Effect of Load Punch in the Limits of Strain paths for (1006) Steel Sheets by using Stretch Forming

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ABSTRACT.
To control on the operation of sheet metal forming without failure, A diagram is used in which the range accepted, failure and critical deformation range are shown. This diagram is known as the Forming limit diagram. It is considered as one of the important tool to determine the formability of sheet metals. Every sheet metal has its own forming limit diagram which determines its formability, strain limit and the forming regions. In this paper, the forming limit diagrams (FLDs) were experimentally evaluated for low carbon steel sheets with different thickness (0.6, 0.75, 0.85, 1.2mm). The highest limit strain in the forming limit diagram is found in the steel sheet at thickness (1.2mm) and the lowest limits in the steel sheet at (0.6mm), this meaning that the formability improve with increase the thickness of steel sheet. The effect of load punch is higher at biaxial stretch path and the lowest at uniaxial tension path. The load punch is change with different thickness of sheet at the same path. The maximum thinning is found in the biaxial stretch path and the lowest of thinning in plane strain path for all sheets.
Keywords: Forming limit diagram, Stretch Forming, Sheet Thickness, punch load.

1. INTRODUCTION.

Forming processes are among the most important metal working operations. The industrial process of sheet-metal forming is strongly dependent on numerous interactive variables such as material behavior , lubrication, forming equipment, etc.

Forming limit diagram is a representation of the critical combination of the two principle surface strains major and minor above which localized necking instability is observed. Forming limit curve (FLC) provides excellent guidelines for adjusting material, tooling and lubrication conditions. Also it is strongly dependent on material parameters. The idea of forming limit diagrams was first introduced by Keeler [1], when he observed that the maximum local elongation was not enough to determine the possible straining rate of a sheet. He established that the plotting of the principal strains at fracture ε_1,and ε_2 on two axes of a same diagram gave a curve : the forming limit curve. This curve, first restricted on the area $\varepsilon_2 \rangle 0$, was made complete for $\varepsilon_2 \langle 0$ by Goodwin's works [2]. This curve is interesting because it divides the plane into two zones. The success area under the forming limit curve and the fail area above it, for a deep drawing operation. The criteria to reject the drawn parts is now the onset of localized necking. Keeler [3], show that measured forming limits for plane strain increase with both thickness and strain hardening exponent for steel sheet increase. Gotoh. et. al [4] study the effect of (α brass) thickness sheets (0.3, 0.6, 1.0 mm) in the limit of strain and show the limit of strain increase in the forming limit curve with increase the thickness of (α brass) sheets. The thickness effect is likely to be less significant, this is consistent with the much lower thickness effect in aluminum alloys found by Smith and Lee [5]. Narayanasamy et. al [6] studies the limit strain and strain distribution for free steel under different strain conditions and show that the limit strain increase in the forming limit diagram with increase the thickness of free steel sheets.

The aim of this work is to determine the formability of different thickness steel sheets and compare with all , and determine the load punch for different strain path (uniaxial tension path

, biaxial stretch path , plane strain path) with different sheets thickness and compare with all , and also determine the relationship between the thickness strain and the strain paths for different thickness steel sheets.

2.EXPERIMENTAL PROCEDURE.

2.1 Chemical Composition.

The chemical composition for all steel sheets are shown in **table (1)**.

2.2 Mechanical Properties.

The mechanical properties of sheets metals were obtained from tensile test **table (2)**[6], by using specimens at different angles (0°, 45°, 90°) to the rolling direction. After testing, the engineering stress-strain curve and true stress-strain curve were drawn **Fig.(1)**.
The value of strain hardening exponent (n) was determined from the slope of line in the (log coordinate of true stress strain curve) by selection two points one before ultimate stress and the other after yield point. The intersection of this line with unit strain gives the stress value that define the magnitude of strength coefficient (K) **table (3)** [6]. For anisotropy plastic property (R) The same specimens of tensile test were used with different angles and using the equation (1) and (2) to determine the plastic anisotropic ratio **table (4)** [6].

$$R = \frac{\varepsilon_w}{\varepsilon_t} \tag{1}$$

Where : ε_w is strain in the width of specimen, ε_t is strain in the thickness of specimen.

$$R' = \frac{R_o + 2R_{45} + R_{90}}{4} \tag{2}$$

2.3 Stretch Forming Equipment.

The FLDs of the sheets are determined using stretch forming tests with a hemispherical punch of (50mm) diameter and Die [7] with blank holder as shown in **Fig.(2)**. By changing the sheet width, major and minor strains were measured following varied deformation paths.

2.4 Specimens of Stretch Forming.

Using two sets of specimens in stretch forming with equal length (100mm) and having various widths with radius in one set for negative minor strain **Fig.(3)**. the specimens represent the path of strain in forming limit diagram[8].

2.5 Print the net of circle grid over surface sheet.

Using Silk Screen method to print the net of circle grid (2mm diameter) on the surface of the specimens for the purpose of strain measurements, this method is more active, chip and simple to print on the sheet surface[8].

2.6 Stretch punching of specimens and measured strain.

After print the net of circle grid, the specimens deform by using stretch forming test, the shape of circles in the net are change to ellipse shape after deformation **Fig.(4)**. Using traveling microscope to measure the major and minor diameter in ellipse or circle. The relationship (3),(4) using to measure major and minor strain.

$$\varepsilon_1 = \ln \frac{d_1}{d_0} \tag{3}$$

$$\varepsilon_2 = \ln \frac{d_2}{d_0} \tag{4}$$

We can draw forming limit curve by using Hecker method [1].

3. RESULTS AND DISCUSSION.

Fig. (5) show the experiment forming limit curve of steel with different thickness, the highest forming limit curve for steel sheet at thickness (1.2mm) and lowest curve at (0.6mm), this meaning that the effect of sheet thickness is improve limit of strain in forming limit diagram.

Fig. (6),(7) & (8) shows the relationship between the load and punch displacement with different strain path, the maximum load supplied by punch is found at biaxial stretch path (39 KN) and the lowest load at uniaxial tension (8KN), the load at plane strain path is medial between two path (24KN).

Fig. (9),(10) & (11) shows the relationship between the maximum load and sheets thickness with different strain path, and the maximum load reach with increase sheets thickness at the same strain path.

Fig. (12) show the relationship between thickness strain and strain path with different sheet thickness, the maximum thinning in the sheet at biaxial stretch path and the minimum thinning in the sheet at plane strain path.

4.CONCLUSIONS.

The forming limit diagram of the steel sheets with different thickness were determined experimentally using stretch forming. the following conclusions can be obtained.

1- The formability of the steel sheet improve with increase the thickness of steel sheet, and the steel sheet thickness (1.2mm) is higher than the all steel sheets .

2- The load punch is higher in biaxial stretch path and lowest in uniaxial tension path specially in steel sheet thickness(1.2mm) .

3- the maximum thickness strain appear in biaxial stretch path especially in steel sheet thickness(1.2mm) .

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NOTATION

$\varepsilon_1, \varepsilon_2, \varepsilon_3$	Principle strains.
n	Strain hardening exponent.
ρ	Ratio of minor strain to major strain.
α	Principle stress ratio.
K	Strength coefficient.
R'	Normal plastic anisotropic ratio.
R_1, R_0	Plastic anisotropic ratio with rolling direction.
R_2, R_{90}	Plastic anisotropic ratio transverse to rolling direction.

Table (1): chemical Composition for all steel sheets.

Material (thick.)	Mo%	Ni%	Cr%	S%	P%	Si%	Mn%	C%	Fe%
Mild steel (1.2 mm)	0.007	0.03	0.04	0.011	0.004	0.022	0.1	0.08	Rem.
Mild steel (0.85 mm)	0.000	0.016	0.06	0.021	0.006	0.025	0.11	0.082	Rem.
Mild steel (0.75 mm)	0.003	0.02	0.045	0.01	0.005	0.028	0.14	0.081	Rem.
Mild steel (0.6 mm)	0.001	0.035	0.055	0.018	0.003	0.02	0.13	0.085	Rem.

Table (2): Mechanical Properties for all sheets.

Material	Thickness (mm)	0.2%Proof stress (MPa)	Ultimate stress (MPa)	Total Elongation(%)
Mild steel	1.2	230	365	54
Mild steel	0.85	220	362	51
Mild steel	0.75	225	358	49
Mild steel	0.6	215	355	47

Table (3): Strain Hardening exponent and Strength Coefficient.

Material (thick.)	Mean of Strain Hardening exponent (n)	Mean of Strength Coefficient (K) [Mpa]
Mild steel (1.2 mm)	0.322	597
Mild steel (0.85 mm)	0.317	580
Mild steel (0.75 mm)	0.31	565
Mild steel (0.6 mm)	0.302	540

Table (4): Plastic anisotropic ratio and Normal plastic anisotropic ratio.

Material	Angle between specimens axis and rolling direction	Value of (R)	Normal plastic anisotropic ratio R'
M. Steel (1.2mm)	0°	1.532	1.295
	45°	1.152	
	90°	1.342	
M. Steel (0.85mm)	0°	1.481	1.276
	45°	1.121	
	90°	1.38	
M. Steel (0.75mm)	0°	1.511	1.308
	45°	1.18	
	90°	1.361	
M. Steel (0.6mm)	0°	1.552	1.299
	45°	1.132	
	90°	1.38	

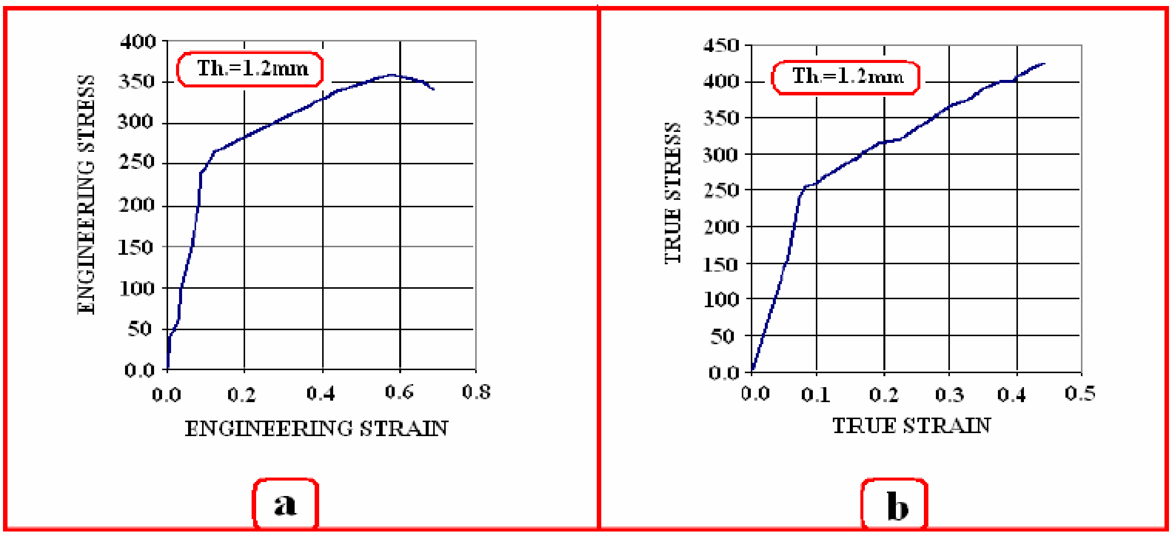
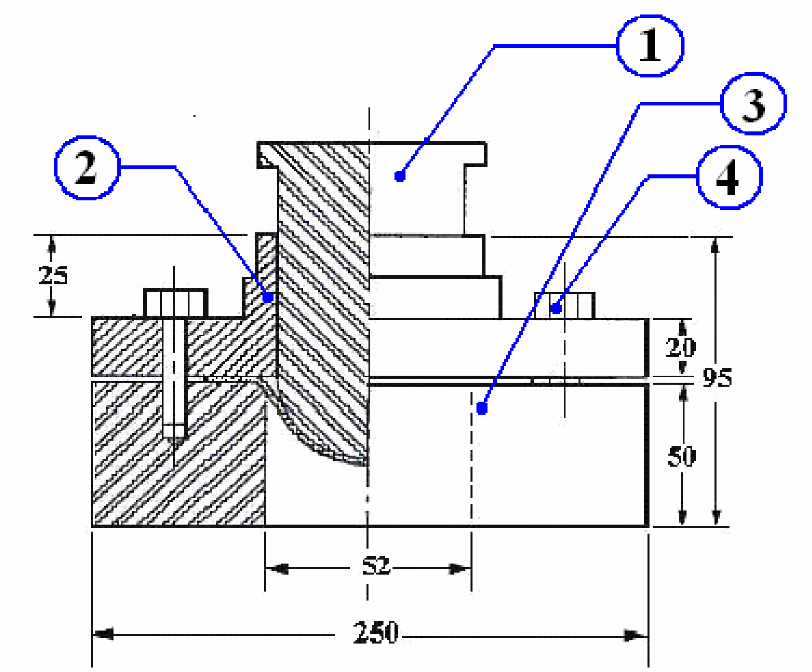


Figure (1): (a) Engineering Stress-Strain curve. **(b)**True stress-Strain curve for sheet(1.2 mm).



No.	QTY.	NAME	MAT.
1	1	PUNCH	STEEL
2	1	BLANK HOLDER	STEEL
3	1	DIE	STEEL
4	10	BOLT M17	STEEL

Figure (2): Punch , Die and Blank holder.

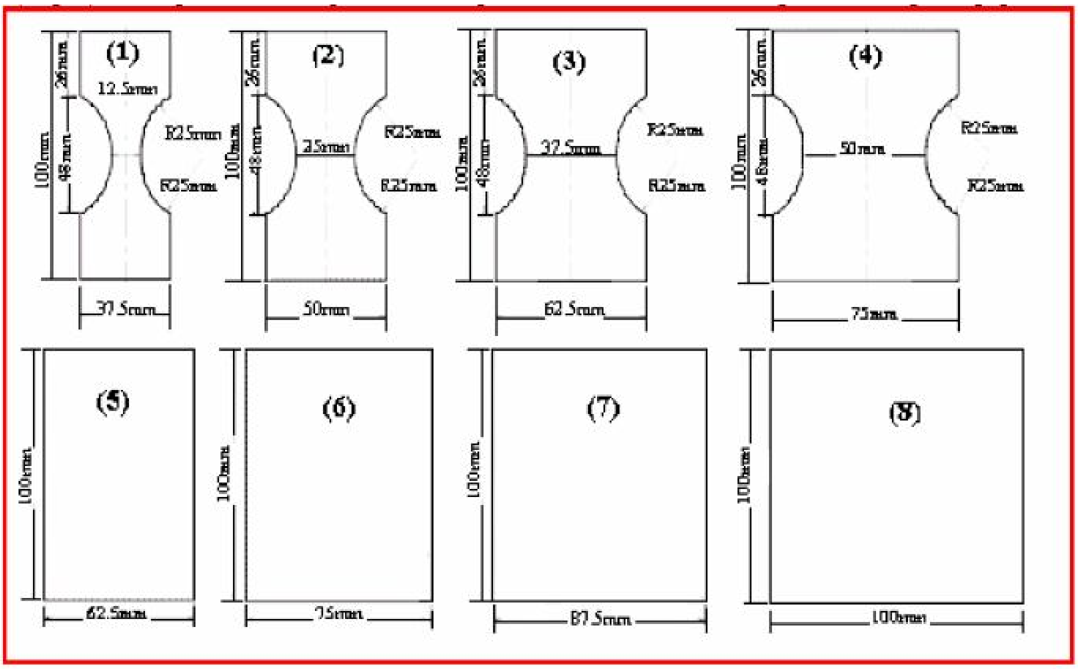


Figure (3): Shape of specimens using in stretch forming.

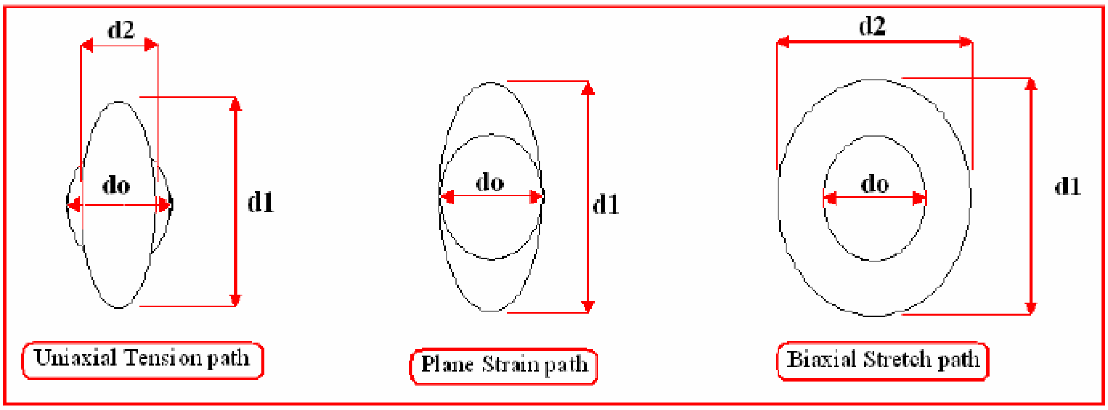


Figure (4): Printed circle before and after forming.

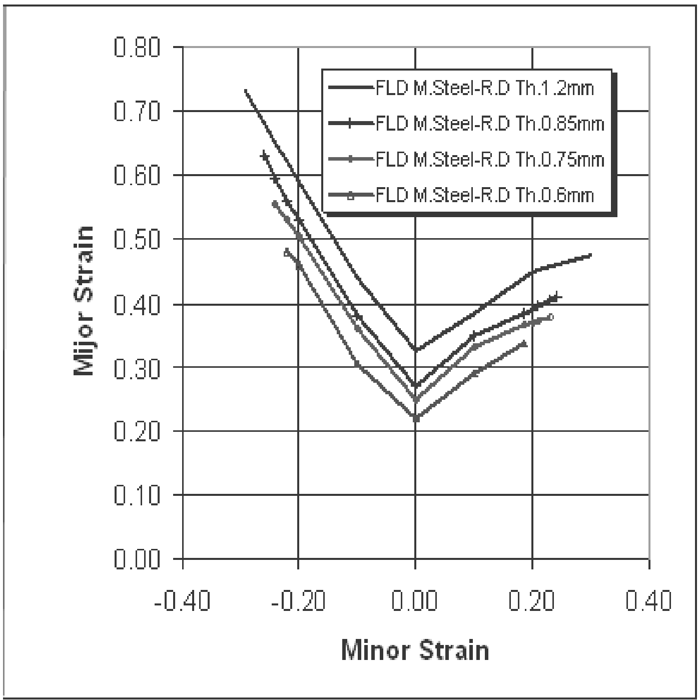


Figure (5): Forming limit curves of mild steel sheets with different thickness.

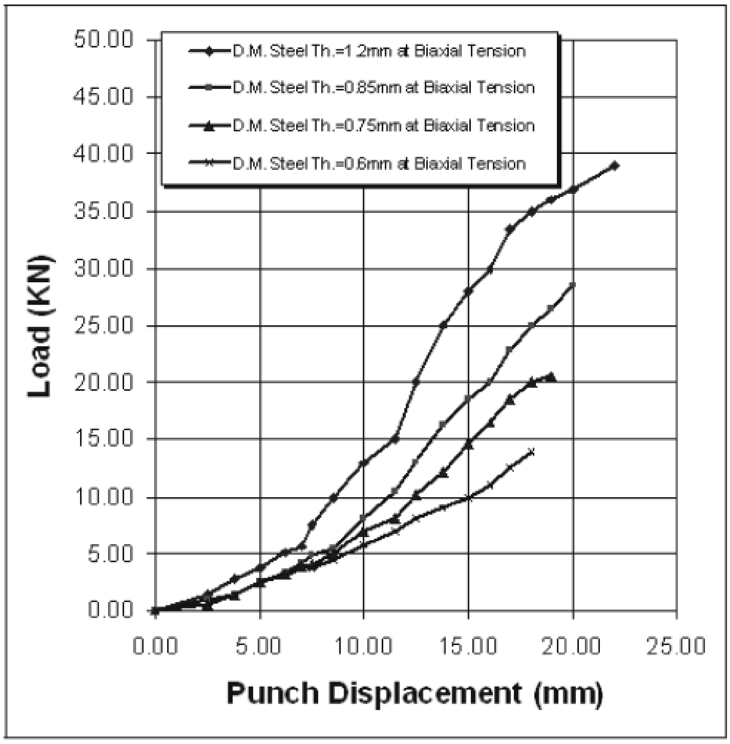


Figure (6): Load and punch displacement at biaxial stretch forming with different sheet thickness

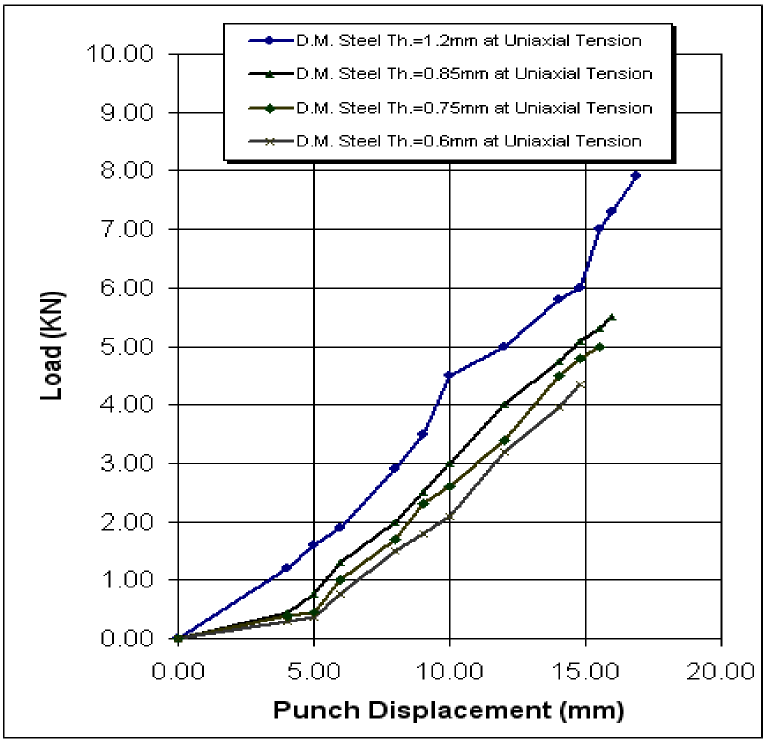


Figure (7): Load and punch displacement at uniaxial tension forming with different sheet thickness.

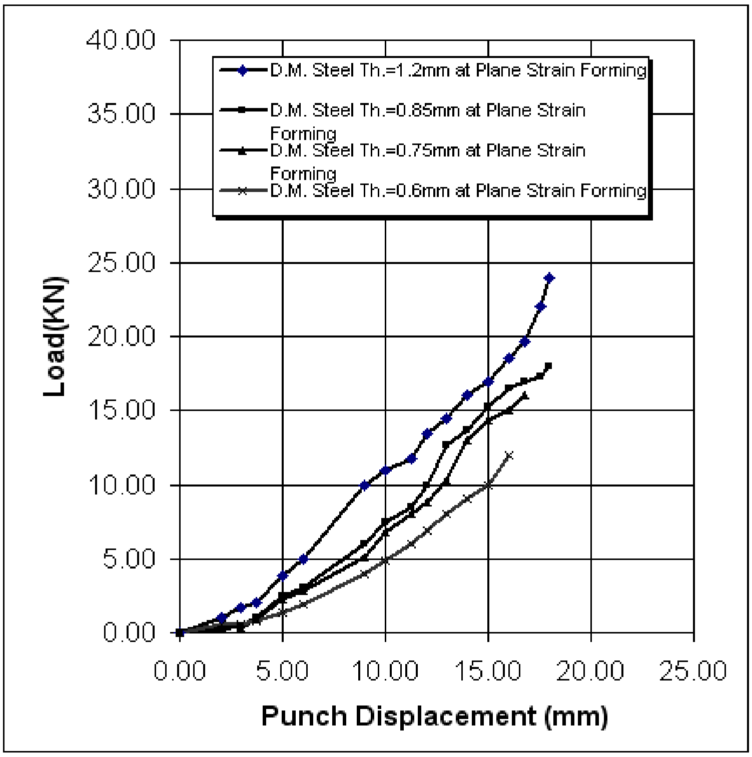


Figure (8): Load and punch displacement at plane strain forming with different sheet thickness.

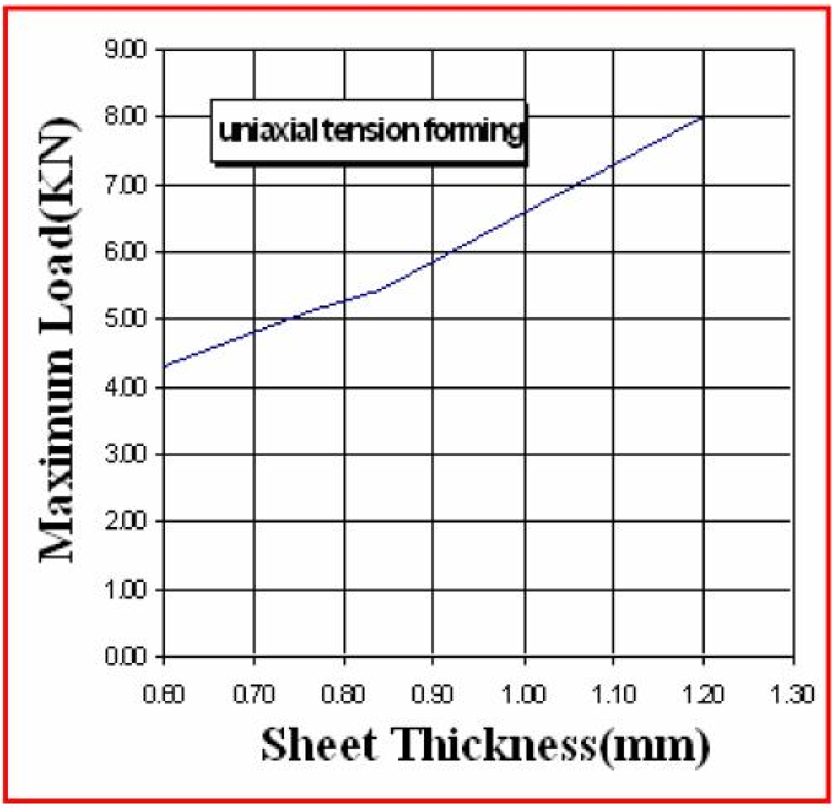


Figure (9): Maximum load and sheet thickness at uniaxial tension path.

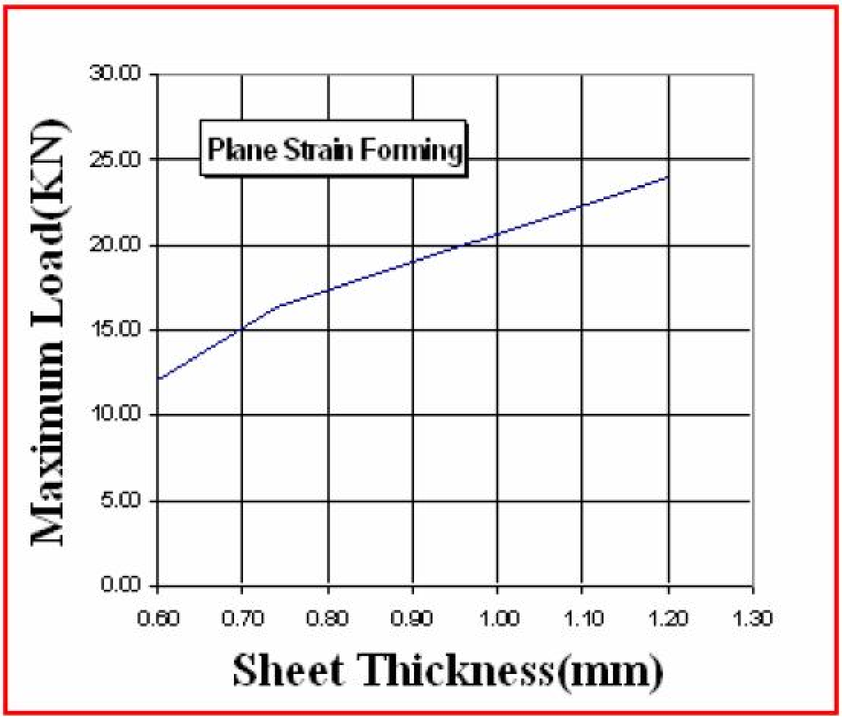


Figure (10): Maximum load and sheet thickness at plane strain path.

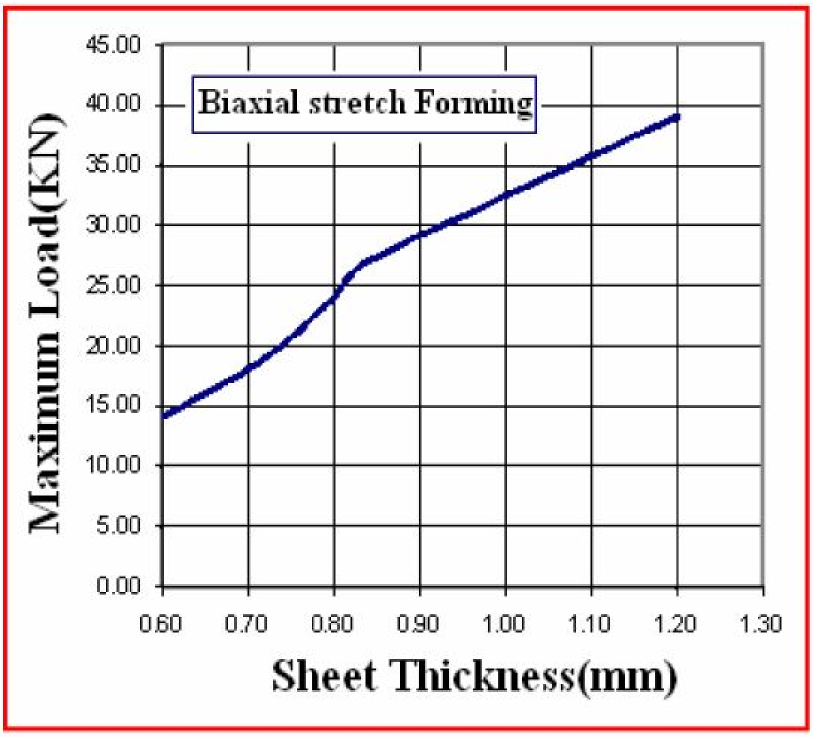
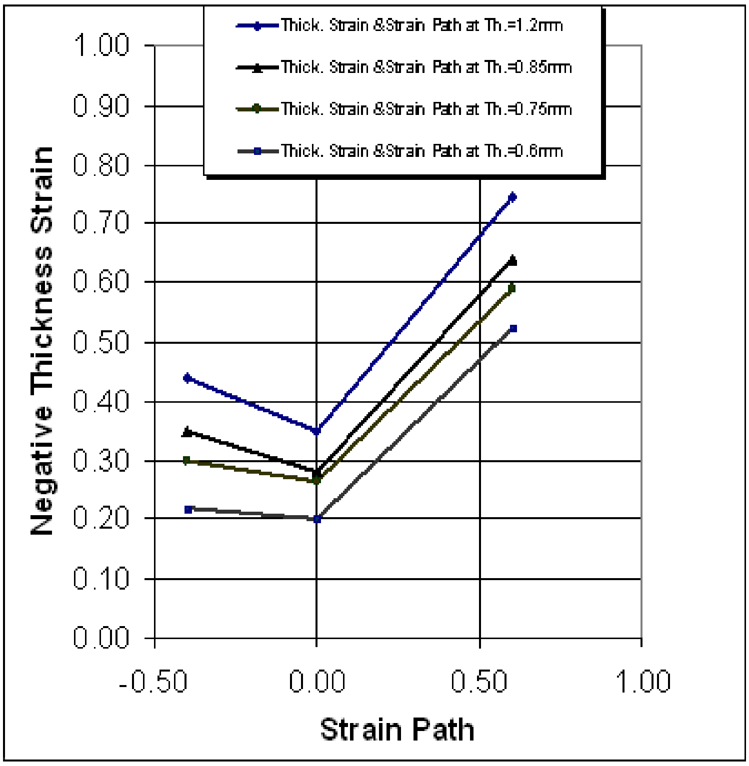


Figure (11): Maximum load and sheet thickness at biaxial stretch path.

R25mm



Figurre (12): Thickness strain and strain path with different sheet thickness.

تأثير الحمل المسلط من قبل الخرامة على حدود مسارات الانفعال لصفائح من الصلب (1006)باستخدام التشكيل بالمط

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الخلاصـة.

لكي نسيطر على عملية تشكيل الصفائح دون حدوث فشل يتم استخدام مخطط يُبين فيه مناطق التشكيل المقبولة ومناطق الفشل والمناطق الحرجة وهو مخطط حد التشكيل. يعتبر مخطط حد التشكيل من الأدوات والوسائل المهمة في تحديد قابلية تشكيل الصفائح المعدنية. لكل صفيحة معدنية منحني حد تشكيل خاص بها يحدد قابليتها على التشكيل وحدود الانفعال ومناطق التشكيل. في هذا البحث تم تعيين منحني حد التشكيل عمليا لصفائح من الصلب مختلفة السمك (0.6, 0.75, 0.85, 1.2mm) ووجد إن أعظم قيمة لحدود الانفعال في منحني حد التشكيل عندما تكون صفيحة الصلب ذات سمك (1.2mm) واقل قيمة عندما تكون صفيحة الصلب ذات سمك (0.6mm) وهذا يدل على أن قابلية التشكيل تتحسن مع زيادة سمك الصفيحة. وأن تأثير الحمل المسلط من قبل الخرامة يكون أعظم عند مسار الشد ثنائي المحور وأقل عند مسار الشد أحادي المحور .كذلك فأن الحمل المسلط من قبل الخرامة يتغير مع اختلاف السمك عند نفس مسار الانفعال. أن أعظم ترقيق حدث عند مسار الشد ثنائي المحور وأقل ترقيق عند مسار الانفعال المستوي.

الكلمات الرئيسية:مخطط حد التشكيل،تشكيل الصفائح،سمك الصفيحة،حمل التثقيب.