Study the Effect of Anisotropy on the Magnitude of Fracture Zone of Sheared Edge from the Sheet Metal

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ABSTRACT

The quality of product is related to the shape of blanked edge. The blanking process is referring to a shearing or punching process. In this work an experimental investigation to the blanking process was carried out using cutting die with three groups of specimens at different direction (0˚, 45˚, 90˚) with respect to the sheet rolling direction. The aim of this work is to study the effect of anisotropy on the characteristic features of sheared edge of aluminum sheet (Al-1100) with (2mm) thickness. The results of the experimental investigation show the effect of anisotropy on the magnitude of fracture zone for the sheared edges and on the shearing force-punch displacements curves. The rolling direction at 0˚ is the best shape which it has the less fracture zone (50%) and the less shearing force and that led to better dimensions with respect to other directions at 90˚ and at 45˚.

Keywords: Sheet metal blanking, Anisotropy, Ductile fracture

دراسة تـأثير التبـاين فـي الخـواص علـى مقدار منطقـة الكسر للحافـة المقطوعـة مـن الصفيح المعدني.

ألخلاصة

جودة المنتج تعود إلى جودة شكل الحافة المقطوعة للغفل،وإنّ عمليات قطع الأغفال تشير إلى عمليات القص والتخريم. في هذه الدراسة تم إجراء تحقيق عملي لعمليات قطع الأغفال ألتي نفذت باستعمال قالب قطع مع ثلاث مجموعات من العينات وباتجاهات مختلفة هي (0˚, 45˚, 90˚) نسبة إلى اتجاه الدرفلة.الهدف من هذا العمل هو دراسة تأثير التباين في الخواص على مقدار منطقة الكسر للحافة المقطوعة من صفيح الألمنيوم (1100) بسمك (2mm)، ونتيجة هذا التحقيق العملي أظهرَ تأثير التباين في الخواص (Anisotropy) على مقدار منطقة الكسر للحافة المقطوعة وكذلك تأثيره على منحني قوة القص-إزاحة الخرامة. اتجاه الدرفلة في 0˚ هو افضل شكل يملك اقل منطقة كسر (50%) واقل قوة قص والذي ادى إلى تكوين افضل الابعاد نسبة الى الاتجاهات الاخرى في 45° وفي 90° .

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INTRODUCTION

Blanking is one of the most widely used sheet metal operation in which a blank is separated from a sheet by a punch. The product can either be a blank or a sheet. The process itself is characterized by very large localized deformation followed by ductile material failure. In engineering practice, the property of the shape of the product, near the cut edge, is very important property. Here, four characteristic zones can be distinguished as shown in Fig (1) [1].

1. The rollover zone. This is the part of the edge that is drawn into the sheet by the punch.
2. The sheared zone. This zone is formed by the punch before the onset of ductile fracture. Generally, the surface of the sheared zone is rather smooth.
3. The fracture zone. This zone has a rough surface formed by ductile material fracture as the punch progresses through the sheet.
4. A burr is formed, because of the specific location of the fracture initiation [1, 2].

ANISOTROPY

Sheets do not have the same properties in all directions. This variation of material properties in relation to the rolling direction is called anisotropy. The reasons for this behavior are:

- The anisotropy of crystals (the variation of the properties of the elementary cells with direction).
- The texture (preferred orientation of certain crystallographic planes and directions).
- The grain anisotropy (preferred orientation of grains and grain boundaries, e.g. elongation of grains in the direction of rolling).

The grain anisotropy is mainly the result of previous cold working process, e.g. cold rolling. The anisotropy plays a very important role during the forming processes [3].

The directionality or anisotropy of properties (dependence on the direction of the testing) is evident in variations of the elastic modulus (E), yield stress (σy), ultimate tensile stress (σuts), elongation and other properties.

The parameter that is commonly used to characterize the anisotropy of sheet metal is the strain ratio (R) value which is defined as the ratio of the contractile strain measured in a tensile test before necking occurs.

TYPES OF ANISOTROPY

1. Normal or vertical anisotropy (R)

$$R = \frac{\epsilon w}{\epsilon t} \quad \text{.... (1)}$$

The normal anisotropy is the ratio of the logarithmic sheet width ϵw (true width strain) to the logarithmic change in the sheet thickness ϵt (true thickness strain).

$$R = \frac{\epsilon w}{\epsilon t} = \frac{\mathrm{Ln}\,\frac{w}{wo}}{\mathrm{Ln}\,\frac{t}{to}}$$

R0 = R 90 = R45 > or <1

2. Planar anisotropy
A significant measure for the variance of the normal anisotropy over the sheet plane is plane anisotropy ΔR. [4, 5]

$$\Delta R = \frac{RO - 2R\,45 + R\,90}{2} \quad \ldots\ldots (2)$$

$R0 \neq R\,90 \neq R45 \neq 1$

SOME RELATED WORKS

The study of S.K.Maiti, et al., 2000 [6] aims to evaluate the influence of tool clearance, friction, sheet thickness, punch/die size and blanking layout on the sheet deformation. The punch load variation with tool travel and stress distribution in the sheet has been obtained. After using an elastic-plastic finite element method the results indicated that a reduction in the tool clearance increases the blanking load, while the blanking load increases with an increase in the coefficient of friction.

R.Hambli, et al., (2001)[7]. studied the effects of the interaction between the clearance, the wear state of the tool and the sheet metal thickness on the evolution of the blanking force and the geometry of the sheared profile. The response surface methodology was used to analyze the relationships that describe process variations. The results of the proposed experimental investigation showed a strong dependence between the geometrical quality of the blanking part and the magnitude of the force applied on the tool as well as the variations in the process factors.

Ammar Baqer (2005) [8] studied the effect of some variables on the defects in blanking operation for sheet of metals. The defect appeared during a blanking are (Doming, Dishing) edge taper and decrease in edge blank thickness.

P.Picart, etc., 2005 [9] presented the main parts of a numerical tool developed to simulate the blanking process and predicted the geometric mechanical characteristics of the blanked component. The numerical results were compared to the experimental one.

Emad Al-Momani and Ibrahim Rawatedeh 2008 [10] presented the development of a modal to predict the shape of the cut side. The modal investigate three effects of potential parameters influencing the blanking process and their interaction. The result was a reduction of the necessary experimental cost and effort in addition to getting a higher level of verification.

EXPERIMENTAL INVESTIGATION

Experiment procedure.
1-Die cutting set up
2-Preparing the material of specimens [Aluminum sheet (1100) with 2mm thickness]
3-Preparing the specimens. Design and manufacturing of three groups of specimens according to the angles (0˚, 45˚, 90˚) with respect to the rolling direction.
4- Tensile machine set up.
The tests are as the following:-

A- Tensile test.
B- Anisotropy test.
C- Cutting test.

Tensile Test

Tensile tests were performed on standard specimens according to DINEN 10 002-20*80 [3]. Specimens of 2mm thickness were prepared from aluminum sheet at three directions (angles) with respect to the rolling direction. As shown in Fig (2).

Anisotropy tests

This test was carried out on specimens from the aluminum sheet at different directions (three angles) with respect to the sheet rolling direction at room temperature the gage length of the test specimen was divided in five regions of 10 mm length and width after 20% from the total elongation. The length and width of these specimens were measured again after the machine stopping.

The normal anisotropy (R), planar anisotropy (ΔR) and average anisotropy (R) [11]. Values where calculated at three angles of (0˚, 45˚, 90˚) with respect to the sheet rolling direction.

Cutting Test

After set up die cutting the test was carried out on specimens from the aluminum sheet at different direction at room temperature. The dimensions of the specimen's are 2mm thickness, 50mm width, and 150mm length. The sheared edges are shown in Fig. (3).

5- Digital camera for measurement of the characteristic sheared edges.

RESULTS AND DISCUSSION

Mechanical properties

The tensile properties for three specimens were measured in the different rolling directions at room temperature are shown in table (1) The engineering stress-strain curves for these specimens are shown in Fig (4). This figure shows that the tensile σ uts and yield strength values were at (90˚) > at (45˚) > at (0˚). The difference in the properties is due to the difference in direction with respect the rolling direction, and it is resulting from an increase of strain-hardening or work-hardening which is caused by the effects of an increase in shear stress thus causing an increase in the overall strength and the hardness of metal.

The Effect of the Anisotropy

Table (2) clarifies the values of the normal anisotropy (R) and the planar anisotropy (ΔR). It is show that R 90˚ > R0˚ > R45˚. The difference among the normal anisotropy is related to the behavior of the planar anisotropy, while table (3) showsthe magnitude of the fracture zone of sheared edge and the values of these zones were 0˚ < 45˚ < 90˚. The scale of pictures shown in Fig (3) is 5:1 because the thicknesses of the specimens are 2mm. The shearing force-punch displacement curves are shown in Fig (5). In this figure the x-axis (punch displacement) is multiplying by 10 times to explain the stage of shearing force action, which at first of operation is like the compression test. The straight line between punch force and punch displacement from the origin point to the first point of the curve is the elastic stage, the stage from the end of straight line to the upper point of the curve is a plastic shear deformation and the manner in which the magnitude of the punch force changes with the punch displacement reflects the strain hardening. The magnitude of shearing force for 0˚ < 45˚ < 90˚ that is mean the anisotropy is effecting on the shearing force.

CONCLUSIONS

The important conclusions of this work are as the following:

1. The anisotropy effects on the magnitude of fracture zone for sheared edges.
2. The anisotropy effects on the shearing force-punch displacement (Penetration).

The rolling direction 0˚ is the best shape which is has the less fracture zone and led to better dimensions with respect to another direction 90˚ and 45˚, and also it has the less shearing force.

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Table (1) Tensile properties of the specimens

	σy (MPa)	**σuts (MPa)**	**Elong at max %**
0°	112	130.4	2.38
45°	120	141.7	2.48
90°	130	144.5	2.832

Table (2) Normal and planar anisotropy

R 0°	**R 45°**	**R 90°**	**ΔR**
0.34	0.24	0.40	0.13

Table (3) The magnitude of the fracture zone of the sheared edge

	Fracture%
0°	50
45°	60
90°	70

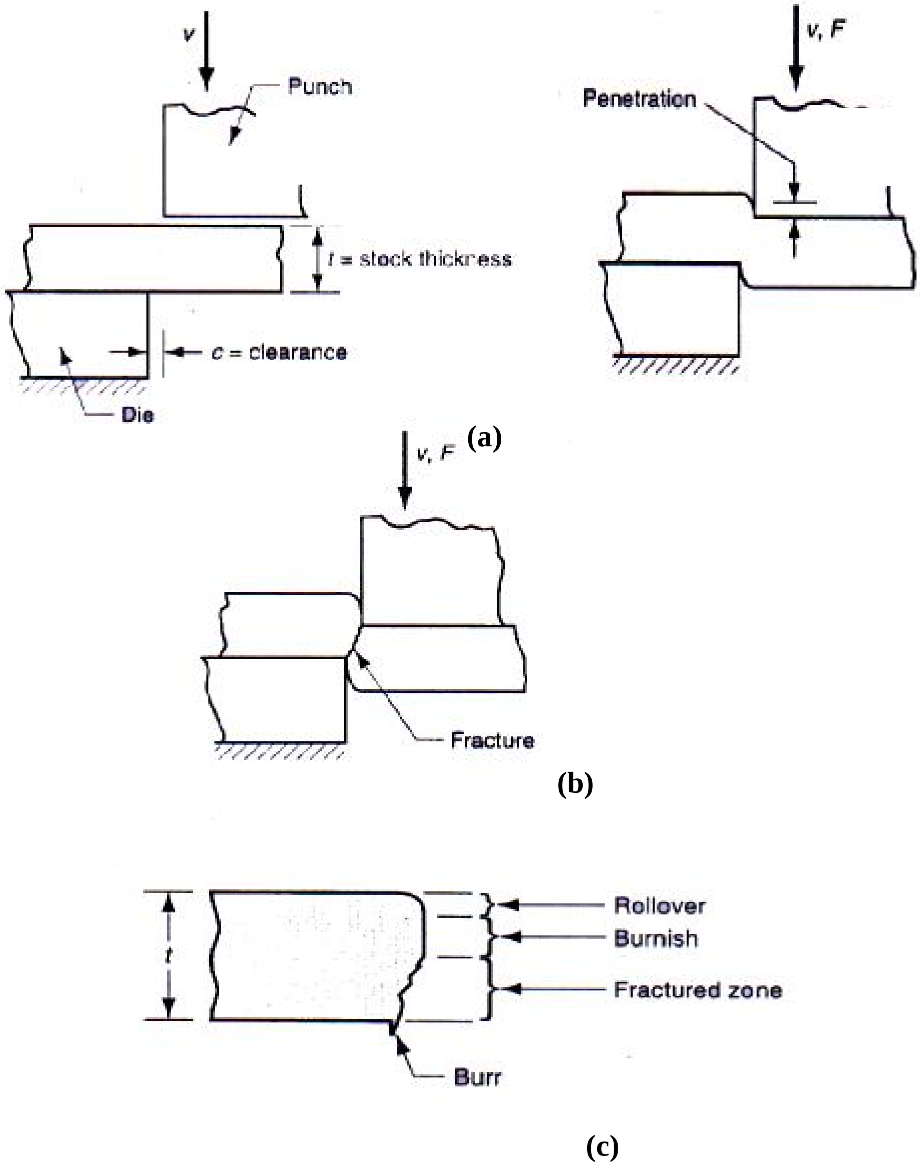

Figure (1) Characteristics of the sheared edge (a) the rollover zone.

(b) The sheared and friction zone. (c) Burr.

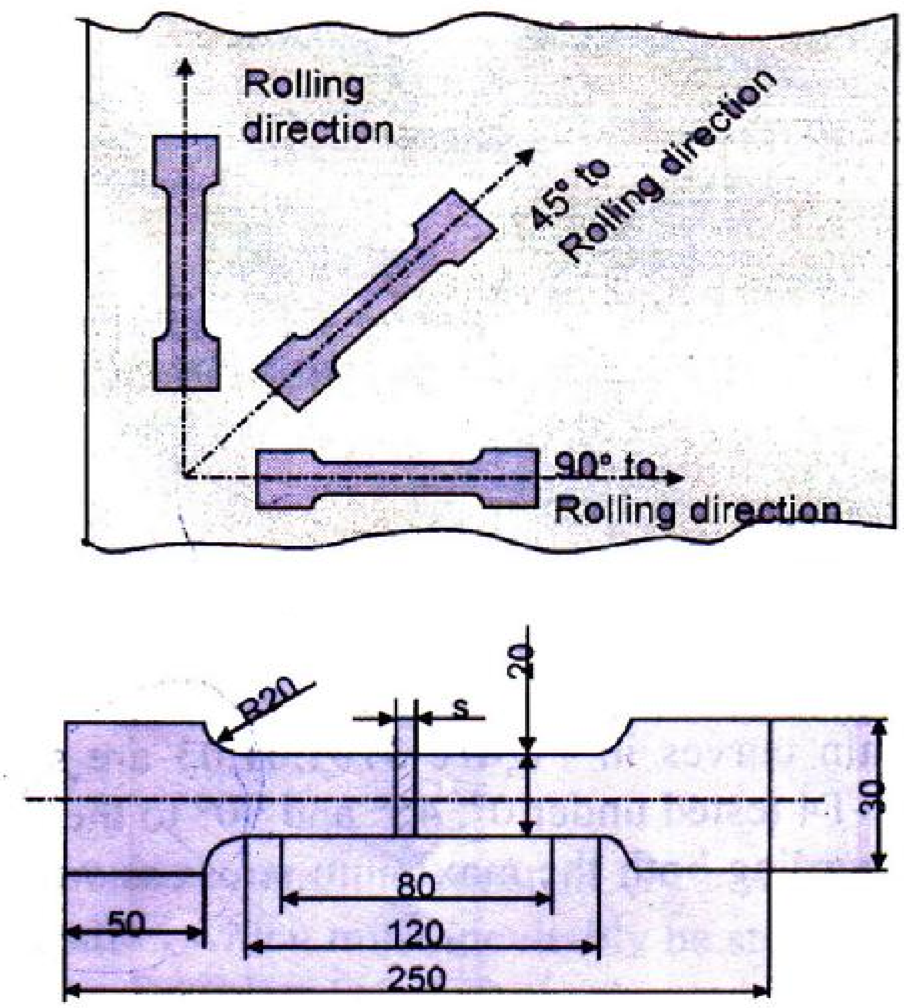

Figure (2): Preparing tensile & anisotropy test specimen.

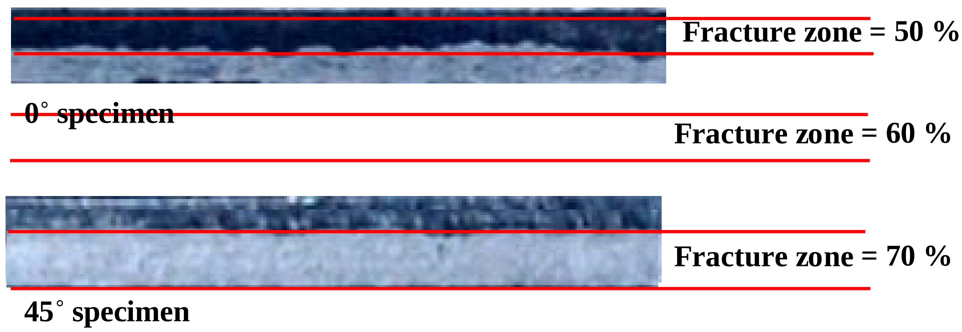

Figure (3) The side view of the sheared edges which are representing the magnitude of facture zone from sheet metal with respect to rolling directions (Scale 5:1).

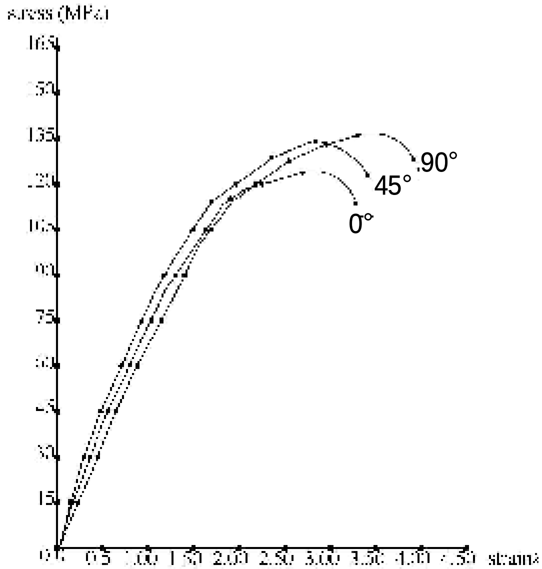

Figure (4)Engineering stress-strain curves for three specimens at different

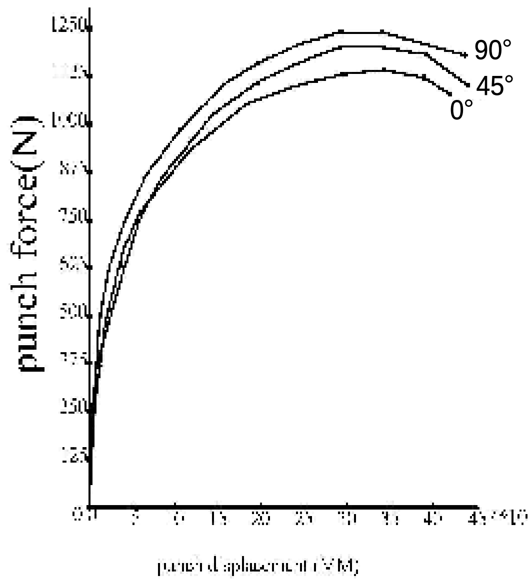

Figure (5) Comparison of experimental punch force-punch displacement curves for three different angle