Bending of Sheet Metal (st37) Using 90 Degree to Estimate Blank Dimensions

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Abstract—**Several factors must be considered when designing parts that are being made by bending. The primary factor is minimum radius and angle of bending that can be bent successfully without metal cracking. Low carbon steel metal (st37), manufactured by Libyan Iron and steel Company, was used in this study. Various bending processes by Vee die for different radii and calculate thickness were conducted and bending zones were tested to find the mean radius and calculate the bending allowance. These calculations depend upon the inner bend radius and thickness of the sheet metal. The thickness was reduced and the neutral axis were moved up in the direction of compression side. Form the values of reduction in thickness and different radii of bending a chart was drawn. Another chart was drawn to minimums the process of trial and error for estimating the blank length of the bending sheet metal. Form these charts, the initial blank sizes can be determined, so that products can bend without loss and crack in the material. As a result time and material can be saved. The results of the present study can have practical applications for this material (st37) which is in common use by the Libyan industry.**

Index Terms: **Bending, Sheet Metal, Crack, Blank length, Thickness.**

I. INTRODUCTION

Most of the operations for shaping sheet metal into finished products can be described as cutting, forming or drawing operations. These operations are generally referred to as stamping or press-working, or punch press working of sheet metal. Bending operation in dies essentially is a process whereby working parts of the die exert pressure upon a flat blank to bend it and to impact its shape. Bending dies can produce parts of a great variety of shapes.

The fundamental elements of bends are the bend radius, bend lines and bend axis. The bend radius is the radius of the inner arc of the bend. The extreme positions of the bend radius are tangent to the inner plane surfaces of the piece part. Therefore, the extreme positions of the bend radius are perpendicular to the inner flat plane surfaces. Throughout the process of bending the blank has fillet exceeding the corner radius of the punch with a gradual decrease of the curvature radius and the bending leg.In its gradually decreasing fillet the blank contacts against the female die walls at two points, and after a certain moment it is pressed against the punch at three points, it is only at the end of stroke that the blank fully contacts the working surface of the punch and is finally shaped by the sizing blow [1,2]. In most cases, parts are bent with a small radius, which is accompanied by thinning of the material at the stressed zone. The thinning of the blank where it is bent depends on the ductility of the material, the plastically without fracturing. It is a major factor that must be considered in selecting a material for bending [3,4]. Elongation of the outside of a bend is one of the key factors in determining the minimum radius of bend possible in any material [1,5,6 and7].

When sheet metals are bent through angles of 90 degree the material on the outside surfaces becomes stretched whilst that on the inside surfaces of the bends is compressed [8]. It is therefore necessary to make an allowance, since the bend allowance curve is subtended by the bend angle, the length of the curve is directly proportional to the size of the angle. The neutral line is an imaginary curve somewhere inside the bend. The neutral line lies in a position nearer the inside of the bend. The true length of the sheet metal blank has been never equal to the inside or outside, the dimension of the bend metal.The pierce position of the neutral line inside the bend depends upon a number of factors, which include the properties, thickness of material and the inside radius of the bend. Early D.E. And Reed E.A. [9] Says in general the position of the neutral line is 0.4 times the thickness of the material from the inside of the bend. Edward M.M. [10] And Serope K. [11] say the neutral axis shifts toward the centre of curvature, by amount varies from 0.3 to 0.5 time thickness on the average. Bending develops elastic strains (spring- back of metal) owing to which the shape of a bent part differs from that of the punch and die. The degree of spring – back depends on many factors, mainly, mechanical properties of the stamping material, its thickness, the bend radius, and the method spring back is measured as the difference between the punch in the bending die [13, 14,15 and 16]. Beyond the bend lines, the material is not affected. Hence, to calculate the length required, t is necessary to find out the bend allowance, which is the arc length of the

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neutral axis between the bend lines. Bend allowance can be calculated by the following formula[8,10 and17].

$$BA = \alpha\,(Rpt + y.\,t) \quad (1)$$

Where Ba is bending allowance in mm, α is equal (2πϴ/360) bend angle radians, Rpt is the inside radius of the bend in mm, t is the sheet thickness in mm and y is the location of the neutral axis from bottom surface. Y = 0.33 when R is less than 2t and y = 0.5 when R is bigger than 2t.

Knowing the location of the neutral axis of a part helps in analysing the results that take place when bending occurs. It is the deformation of the fibre parts during a bending action that is significant. The outer and inner surfaces are of particular interest, and the deformation of their fibre is greatly influenced by the location of the neutral axis in the parts cross section. The extent, to which a fibre distorts, whether in compression or in tension, can be considered to be proportional to the fibres perpendicular distance from the neutral axis.

When bent around a die, a thin part, such as a sheet experiences a little distortion of it is outer fibre, not enough to reach the yield state. Somewhere in the cross section, a plane of demarcation separates the tension and compression zones. The fibre lying in this plane is affected by the bending in a neutral manner, neither forced to stretch nor to compress. This plane of zero stress, situated on the cross section parallel to the surface around which the part is bent, is called the neutral axis of the parts cross section [5].

The strains in the outside (convex) layers of material, when bending to small radius and can be so great as to cause cracks and even breaks in parts. To avoid this the bend radius should be selected to suit the steel material [11, 17], from 0.5t for 0.1 %C to 1.5t for 0.6%C.

Sheet metal bending is one of the most widely applied sheet metal operations. The bending operations present several technical problems in production, such as prediction of spring-back and the punch load. The influence of the area of the holes, die angles, die widths and punch radius on the value of the spring-back and the bending forces in V-die bending is studied by M. Ali FarsiI; Behrooz Arezoo, It is found in this work that all these parameters affect the spring-back and the bending forces and the influence of the die width of the final angle in 90 and 120-degree dies is also studied in this work [16].

A. Definition of the Problem

In order to produce parts by bending operation, the first step to design any sheet metal by stamping dies, it is necessary to made calculation for the blank length of the final product. Estimating the required flat shape of length is a matter of determining the length of the neutral axis, and to calculate the bend allowance for each bend using the values of y neutral axis. The estimated blank length will then be the sum of the length of the bend legs and allowance. General Company for Traillors is a company working in the sheet metal industry. Most of small and medium size components which require production dies are imported recently the company approached the Advanced Center Technology for the production of several dies. During the production of the dies (ACT) expert some problems with one of the dies. As the trial is made in U shape bending dies for Chace support the diet failed to meet the final dimension required by the company.

II. EXPERIMENTAL WORK

A. Die Design

The experimental work reported in this paper was conducted using sheet metal die to bend the parts. This die has been designed and manufactured in Advanced Center Technology to estimate the blank dimensions of the sheet metal with different radius and 90 degree angle, manufactured by Libyan Irion and Steel Company, which called black sheet metal, rolled low carbon steel and are used in this work. The sheet metal die stamping designed consisting of main parts such as die, punch, shank and lower plate as shown in fig. 1 and the values of Rpt in this work can be calculated by using this general formula Rpt=nt for different thicknesses where n is variable value dimensionless (0,0.3,0.4,0.5,1, 1.5,2,4 and 6 as shown in the following table (I) when n =0.5 as for example, the experimental work was conducted using 45 (Rp and Rdie) has been manufactured in A.C.T. The values of punch radius Rp can be calculated using this formula where k is spring back factor [11,17,18 and 19]:

$$R_p = k.(R_{pt} + t/2) - t/2 \quad (2)$$

Table 1. The Values Of R_{pt} and R_p

No.	Thickness t (mm)	R_{pt}=0.5t (mm)	R_p (mm)
1	3	1.5	1.44
2	4	2	1.92
3	6	3	2.88
4	8	4	3.84
5	10	5	4.8

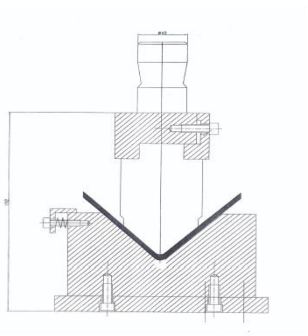

Figure 1 . Assembly Drawing Of The Bending Die

B. Material Preparation

The blanks of sheet metal were prepared, before starting the experiments for different thickness (3,4,6,8 and 10 mm) with different width of the blanks 20,40 and 60 mm and length of the blanks 40,45,75, 90 and 115 mm using sawing, milling and grinding machines to prepare the flat blanks (work piece) as shown in table 2below.

Table 2. Blank Dimendisions

Thickness t (mm)		Width W (mm)		Length L (mm)
3	20	40	60	40
4	20	40	60	45
6	20	40	60	75
8	20	40	60	90
10	20	40	60	115

C. Design of Experimental

In the bending operation, the flat blank is located into the nest in the assembly as shown in the figure 2. The values of the bending force (Fb) were selected and calculated depending upon the thickness (t), length L (mm), width between the contact points of die (mm) approximately is w=8t [6,17] and ultimate tensile strength S (413Mpa) of the sheet metal by using the formula of bending forces [6,8,10 and 17].

$$F_b = (1.33.SLt^2)/w \quad (3)$$

Table 3. Bending Force

No.	Thickness t (mm)	Force F_b (KN)
1	3	8
2	4	12
3	6	29
4	8	49
5	10	79

In the bending operation there are three stages of bending in V-bending. The radius (Rp) of the punch is the bend radius, which will be reproduced in the piece part [20,21,22 and 23]. The first stage (early stage) of bending action as it occurs in a V- bending die as showing in Figure 2. In this stage, the punch has descended until its nose radius Rp is tangent to the top plane of the die block in the centre of the block, the punch has depressed the work- piece a distance equal to the stock material thickness (t). The extremities of the bend legs have reacted by swing upward, rocking a slight distance around the arcs of the bending radii Rdie as showing in Figure 3. The result was the tendency of the work- piece to resume its original shape, causing the bend to spring small amount that reaction is called spring-back. After this stage, the punch has entered deeper into the die bending, the reaction of the workpiece has advanced accordingly : it has been pulled deeper into the centre and swing higher at its extremities as showing in Figure 4. The action continues until the punch bottom as showing in Figure 5. After bending of each sample for each thickness of sheet metal, the final shape of bending was analysed in metallographies Lab by cutting off machine. The analysis was done by cutting the final shape of each specimen at the centerline of bending zone for each of the three samples, then the average of these three values taken as the new thickness and compared with the original thickness to evaluate the reduction of thickness. By this way, the effect of the applied force, radius of punch and the original thickness of sheet metal (t) on the reduction of thickness can be found for the width of blank 20,40 and 60 mm. The ratio Rpt/t and tr/t are shown in the figure 6,7 and 8. By using the equation of the displacement of the neutral axis of bending zone is given as [15].

$$C = tr/t \quad (4)$$

$$Y = 0.5\,C^2 - R_{pt}(1-C)/t \quad (5)$$

Where Rpt is the inner radius of the shape (mm), y is the location of the neutral axis dimensionless, c is the ratio of the reduction of the thickness (dimension less), tr is the reduction of the thickness (mm) and the result of these calculations are shown in figure 9, 10 and 11.

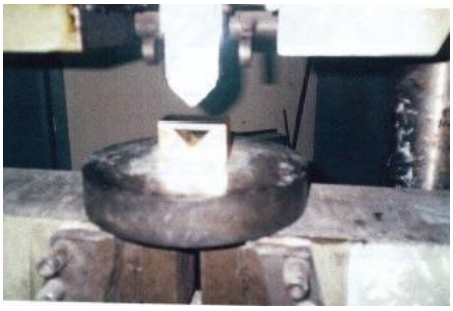

Figure 2. Movement Of The Punch

Figure 3. Starting Of Bending Operation

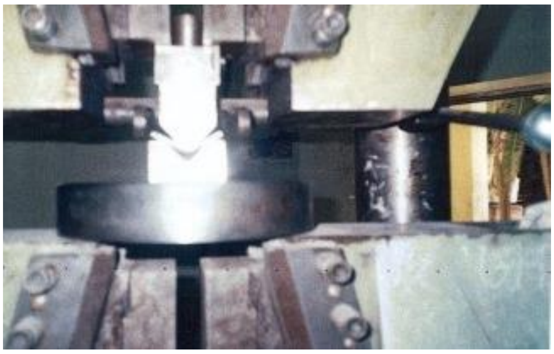

Figure 4 .Bending Operation Increasing

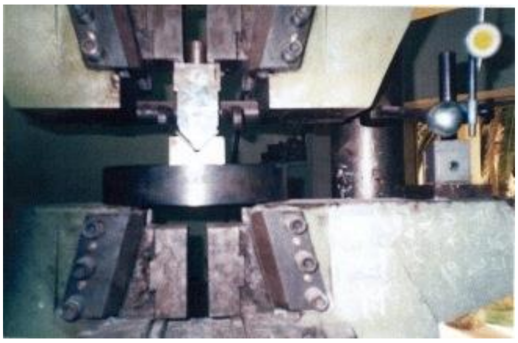

Figure 5 .Final Stage Of The Bending Operation

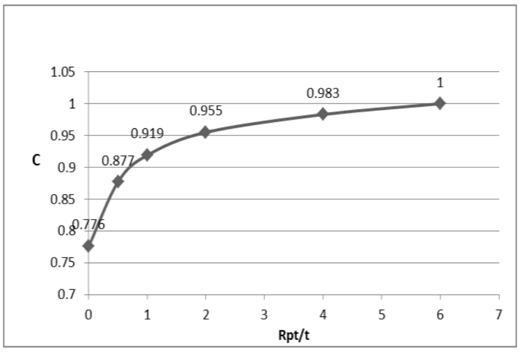

Figure 6. Relationship Between The Tatio Rpt/t And Value Of The Ratio (Average c) For Width 20mm.

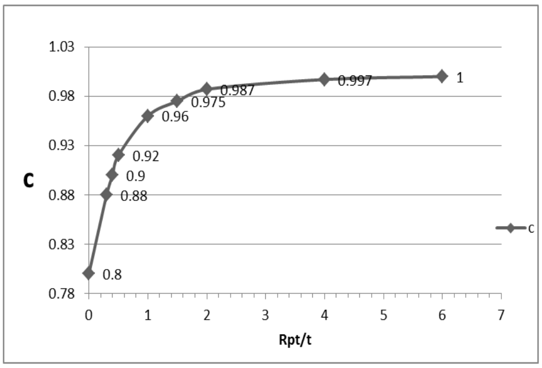

Figure 7 .Relationship Between The Ratio Rpt/t And Value Of The Ratio (Average c) For Width 40mm.

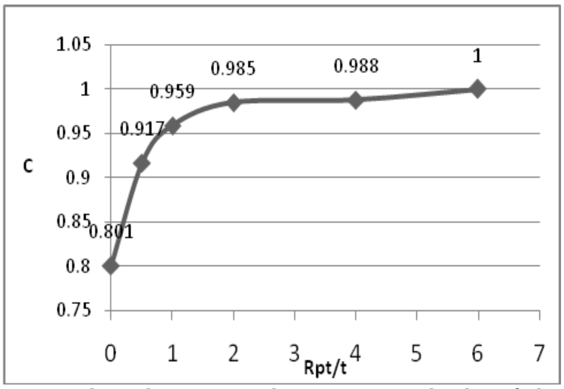

Figure 8 . Relationship Between The Ratio Rpt/t And Value Of The Ratio (Average c) For Width 60mm.

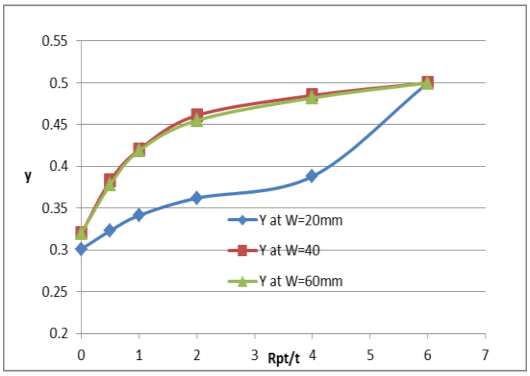

Figure 9 . Relationship Between The Ratio Rpt/t and y Value.

III. RESULTS AND DISCUSSION

The analysis of the results of this work was done by cutting the final shape of each specimen as the centerline of bending into two symmetrical parts. Measuring the thickness of the product in the bending zone has been investigated. The amount of the reduction in the thickness was known. From these measurements, the effects of the radius of punch rap and original thickness of sheet metal, steel (t) have been cleared on the product of bending. Actually, some distortion, proportional to the ductility of the material exists beyond the bend area. This cause of distortion is called plastic deformation. The crystalline structure of the metal is represented by cubical units equal in size and shape, as shown in Fig. (10 A and B), which is taken before bending operation.

After bending operation, the units are displaced and deformed. The outside of the neutral axis where the units are stretched longitudinally as shown in Figure 10-C and 10-D. Tests of this work were conducted under different punch profile radii (RP =0) and RP =6t mm. From the experiment, it can be seen that the original thickness decreases as the punch profile radius decreases. At sufficient values of forces, when the radius of punches is small will be more reduction in the cross section area where the material is reduced in both width and thicknesses, as indicated by the as shown in Figure 10-D, as indicated by the dotted lines, dotted lines. The units inside the neutral axis are compressed longitudinally, which increases their cross sectional area, the material budges wider than its original width. At the same time when the radius of the punches is increased gradually the reduction in the original thickness decrease up to the radius of the punches reached. The value of Rpt =6t, the material is not reduced in the original thickness, this means that the neutral axis is not shifted and remains constant.

Thinning of material on the tension side of the bend is more pronounced than the bulging on the compression side, and the neutral axis tends to shift toward the compression side of the bend. The radius of punches increase gradually, then the neutral axis move toward the centerline of the bend area, where the radius of punches are equal or more than 6 times the thickness; then the neutral axis remain constant as 0.5t.

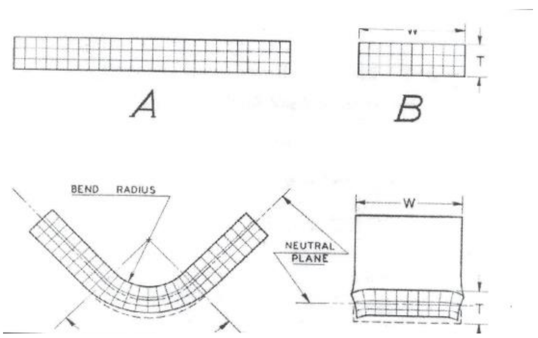

Figure 10 . Plastic Deformation: A) And B) Longitudinal And Transverse Sheet Metal Before Bending, C) After Bending And D) After Bend With Cutting Transverse Direction.

VI. CONCLUSION

Previous studies concluded that the minimum bend radius (Rmin) to avoid the crack occur in bending is Rmin=0.5t, without showing the degree bend angle. This study showed that no cracks occur in bending for the type of low carbon sheet metal, steel when bend radius Rmin =0 and bend angle 90 degrees. The thickness of the material cross section at the centre of the bend area will be an average of C=tr /t of 0.8% where RP =0 which shows no crack and no reduction 100% where, Rp=6t or more.

On the other hand, for R≥6t no shift of the neutral axis y=0.5 occurred and no reduction in the thickness is found after bending operation for all the width 20, 40 and 60mm. For the width 40 and 60 mm has no significant change in the values of Y but width 20mm becomes less values in Y unless, y=0.5. Therefore the authors recommend using these empirical values of y in Fig. 9 in the design department to calculate the bend allowance in V bending dies and then can estimate the blank length without trial and error to save time, material and effort. So using this figure make it easy to estimate the blank length of the sheet metal for the V bending process.

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