Engineering and Technology Journal
Journal homepage: engtechjournal.org

Effect of Orientation and Pre-Tension on Stresses Distribution on V-Die Bending Processes by Finite Element Method

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Submitted: 15/07/2019 Accepted: 17/01/2020 Published: 25/05/2020

K E Y W O R D S

Keywords - Brass 65-35; Finite element method; Rolling Orientation; pre-tension; Forming..

A B S T R A C T

Simulation of metal forming processes using the Finite Element Method (FEM) is a well-established procedure, being nowadays possible to develop alternative approaches, such as inverse methodologies, in solving complex problems. This study investigated the effect of orientation and pre-tension on stresses distribution numerically by software ANSYS 19 using the finite element method. The pre-tension is 55% from total strained in each rolling direction. The results show that the orientation has a significant effect on stresses distribution and stress value before and after pre-tension 55%. Although there is a regular distribution of stresses in three direction, but there is significant difference in the values of stresses in each of (0, 45, 90) degrees. The highest value of the stress is in the 0° to rolling direction, while the least value of the stress recorded in 45° to rolling direction. The pre-tension has a greater impact on stresses distribution and stress value. Although, there is a regular distribution of stresses in blank before and after pre-tension, but there is significant difference in the values. Where in 0 degree on rolling direction the stresses increased by 31.7% from their values before pre-tension, while in 45 degrees on rolling direction the stresses increased by 35.6% and in 90 degrees on rolling direction the stresses increased by 23.6% from their values before pre-tension.

How to cite this article: A.S. Jabber, A.H. Abed, A.H. Zabon "Effect of orientation and pre-tension on stresses distribution on v-die bending processes by finite element method," *Engineering and Technology Journal*, Vol. 38, Part A, No. 05, pp. 636-648, 2020.
DOI: https://doi.org/10.30684/etj.v38i5A.457

1. Introduction

Numerical simulations in demanding applications such as metal forming processes are usually carried out within a direct engineering procedure, that is, given the input data available, to try to simulate the overall adopted process towards the achievement of a final part. Being a well established procedure, the finite element method (FEM) is the procedure of choice on the overall majority of metal forming numerical simulations, mainly when related to sheet metal forming products [1]. The sheet metal bending (SMB) takeover a role is much important in the manufacturing industry. While the industry has evolved, the size of the products being created becomes smaller and tolerances on them obtain compact. The geometrical precision of a bent piece is critical in determination of the quality of the product [2]. Hence, one of the most widely applied metals forming operation is bending. Using this technology, it can be processed materials with various cross sections (wires, rods, bars, pipes and sheet metal). However, bending of sheet metal (SM) is very often utilized in industrial practice and produce structural stamping parts. First of all in ship building and car industry, there are different types of SMB operations. The greatest important SMB Process is (V–Die) bending that produces a V-shape which includes two sub processes; first one air bending and the second one coining in which the punch fully sets in the die [3] [4]. In formability operation of SMB; while the punch is push over SM, tensile stress happen outside of the SM and compression stress happen inside the SM. Neutral axis is the line divide the section allocated for tensile and compression which goes past during the middle of the SM, ass shown in Figure 1 [5] [6].

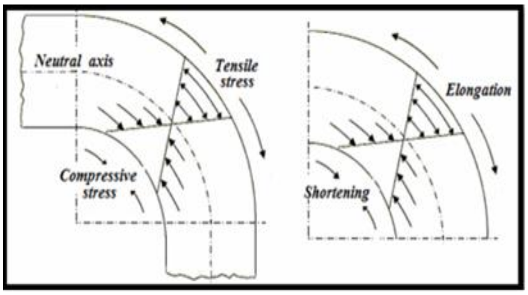


Figure 1: Deformation zone in sheet metal bending process

Brass is an alloy mainly that includes zinc (Zn) and copper (Cu). It is widely used in diverse manufacturing due of their superior formability, strength to weight ratio, as well elevated corrosion resistance and ductility. It is feasible for production of various parts and manufactured for automobile implementation using the brass alloy [7]. In the past years, oversize of numerical and theoretical studies to analytical model for prediction of bending process as a function of stresses distribution in the sheet thickness [8]. Simulation of the effect of material properties and interface roughness on the stress distribution by using finite element method [9]. The width of the sample bend in the V-bending test influences the stress-state in the cross-section of the sample [10]. Studies of the effect of pre-straining on the springback behavior of sheet under V-die bending by finite element simulation [11]. Studies the effect of normal anisotropy on springback [12]. Investigation of experimental and finite element of semi-constrained groove pressing process [13]. The purpose of this study was to analyze the stress distribution patterns within process of bending the sheet and study the effect of orientation and pre-tension on stresses distribution. It was found that the orientation and pre-tension has a significant effect on stresses distribution before and after pre-tension where although there is a regular distribution of stresses in three direction, but there is a significant difference in the values of stresses in each of (0, 45, 90) degrees.

2.Experimental Procedures

I. Material Selection

The Brass 65-35 sheet material with sheet thickness 0.7 mm was used in this work. It is called yellow brass C26800 according to (ASM) American Society of Metals [14][15]. Firstly, it is necessary to know the Material Characterization of it by testing chemical composition; Table 1 lists the results of the chemical test carried out at the Specialized Institute for Engineering Industries in Iraq, with the (ASM) characterization.

Table1: Chemical composition and the ASM for Brass 65-35.

Element	chemical composition	ASM
Zn%	35.23	35
Pb%	0.007	0
Mn%	0.00	0
Sn%	0.001	0
P%	0.007	0
Si%	0.001	0
Fe%	0.021	0
Ni%	0.001	0
Al%	0.002	0
Cu%	64.7	65

The gripper, on universal testing machine WDW-200E, model (200E) electromechanical load frame, fixed the specimens carefully. As shown in Figure 2. Nine tensile specimens tested in three rolling direction (0°, 45°,90°) degrees by three samples in each direction in order to take the average values to reduce the errors obtain from measurements as shown in Figure 3.

Figure 2: Universal testing machine WDW model (200E) electromechanical load frame with mechanical grips

Figure 3: Tensile specimens (a) before test (b) after test

The Mechanical Properties of yellow brass as (ASM) was illustrated in Table 2.while the relation between the true stress and true strain of Brass sheet in three different rolling directions was illustrated in Figure 4.

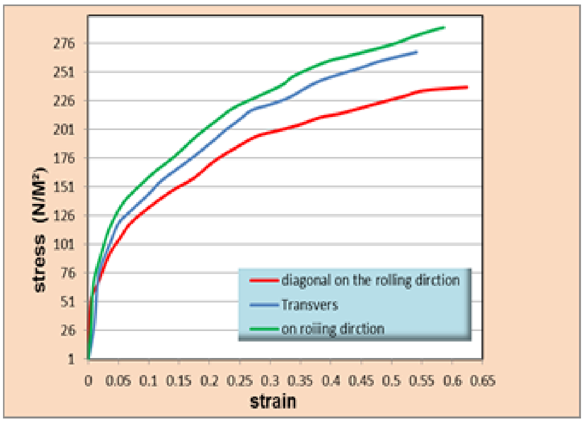


Figure 4: True stress-strain curves of Brass 65-35 sheet in three different directions of rolling

From the pre-tension the sheet of brass in level 55% from total strain in three rolling directions (0°), diagonal (45°), transvers (90°) the relation between the true stress and true strain of Brass sheet in three different rolling directions was illustrated in Figure 5.

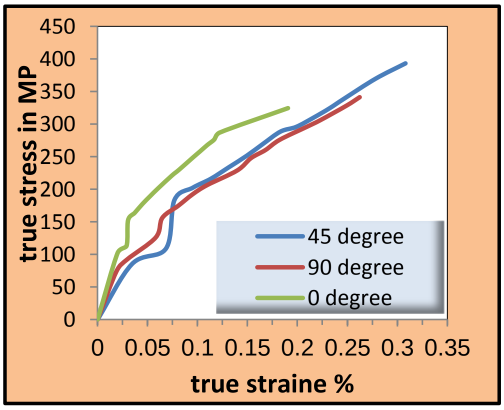


Figure 5: The true stress-strain curves of 55% pre-tension

In addition, the Mechanical characteristics that were resulted from the curve of stress-strain are presented in the Table 2.

Table 2: The mechanical properties of brass in two directions

Property	E (GPa)	YS (MPa)	UTS (MPa)	TE (%)	υ
Rolling (0°)	110	86	293	61	0.353
Diagonal (45°)	110	52	245	64	0.243
Transvers (90°)	110	64	270	55	0.239
ASM	110	97	317	65	0.355

E: Elastic modulus, YS: Yield Strength, UTS: Ultimate Tensile Strength and TE: Total tensile elongation (%), Poisson's ratio:υ .

This study examined V-die bending tool, which was designed and manufactured according to the standard specifications and consisted of two sections (punch, and general die) both of them formed from (CK45). The first one is the general die, which is called lower die of opened type 90° angle in bottom bending. It has a rectangular shape of (99×108) mm and the high (48) mm and with bending depth about (19) mm and opening die (40) mm. the second one is the upper die, which is called the punch having 90° angle as shown in Figure 6.

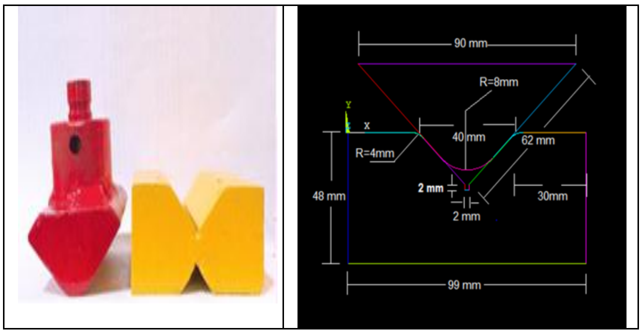


Figure 6: Shape and dimensions of die and Punch.

II. Pre-tension

The specimen is prepared following the rolling direction. Considering the maximum strain of 0.12 (where the local necking happens after this point) under uniaxial tensile loading path, pre-tension the sample 55% from total strained in each rolling direction with a steady as showing in Figure 7. The punching was performed at a constant deformation rate of (5) mm/min then unloaded at the same deformation rate. Table 3 contains the dimensions of sample before and after pre-tension 55%.

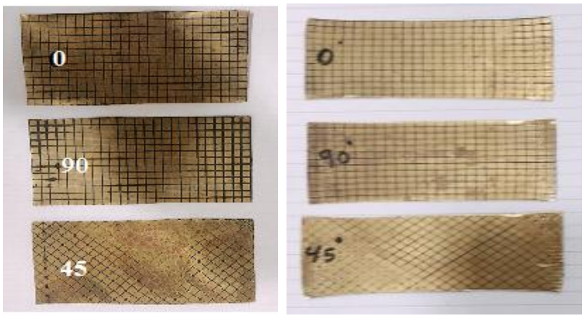


Figure 7: Sample of pre-tension 55% in three directions.

Table 3: Dimensions of the sample before and after pre-tension 55%.

Dimensions (mm)	***Befor pre-tension***	***After pre- tension 55%***		
		0°	**45°**	**90 °**
Length	100	115.5	117.65	114.85
Width	50	50	50	50
Thick	0.7	0.61	0.64	0.65

III. Experimental bending device

The universal testing machine model WDW-200E, was used in experimental work for the specimens in bending, was Standard with wedge-shaped stretching attached, compression, bending with the user and other attached to the form as show in Figure 8.

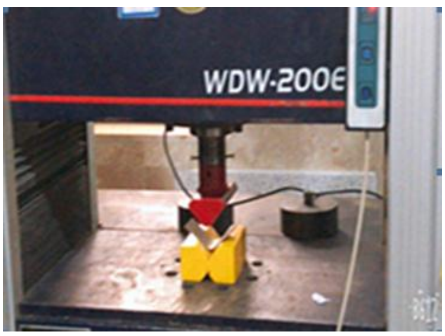
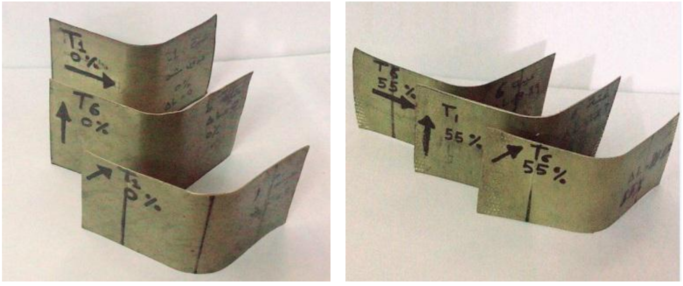


Figure 8: Bending device

The bending tests worked at a (25 mm/min) deformation speed before that it loaded the die and bunch. In begin three specimens without tension for each direction were bending. Then bending three specimens that were pre-tension 55% of three directions in the same groove where the samples were bended without tension as shown in Figure 9.rate of 15 specimen per direction in the same groove,



a b

Figure 9: Specimens of bending (a) before pre-tension (b) after pre-tension

V. Numerical simulation

Numerical simulation used computational simulation increasing important approach for solving complex practical problem in science and engineering. [16]. Finite element software packages ANSYS is useful in designing of tooling in SMFP since it is most cost effective than experiment and mistake method as applied to experimental works and it has become possible to get the local state of stress and strain, and other detailed information like pressure distribution and local workpiece deformation for work hardening materials. [17]:

VI. Finite element Software package (ANSYS 19)

ANSYS parametric design language APDL is FEA with ability to analyze spacious domain of various problems**.** Basic principle in the FEM is to be solve of a complicated problem by replace it by uncomplicated problem the solve zone is considered to be accumulated from many small and interconnected sub-regions called **elements**. In the status of structural (FEA), these simplified code bind impose to displacements while the **nodes** is algebraic equations bind physical amount at eclectic points, the element was progressing [18]. The important stages in Finite element model development are as shown in Figure 10.

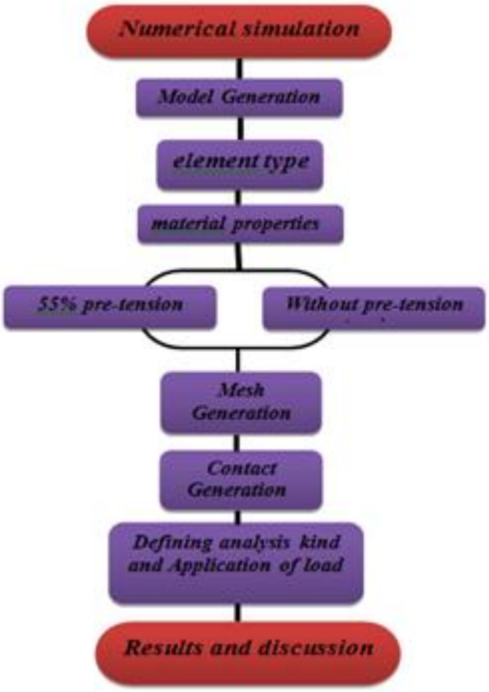


Fig. 10: Flow chart for numerical works

VII. Summary of Numerical Simulations.

A finite element model was used to simulate the bending forming operation employing ANSYS 19 parametric design language APDL the complex contact, geometric and material nonlinearities of such problem were modeled as show in Figure 11. The following summary of the model key features is given as:

i. Used ANSYS application to generate the forming (punch, die, blank) geometry.

ii. The mechanical properties that input to ANSYS package were imported from the tensile test as the true stress-strain curves data.

iii. Plane stress with thickness model was used instead of 3-D model to reduce the model size and computational effort.

iv.The work-piece was represented by using solid -183 element type.

v. Used rigid to-flexible contact between blank (which was modeled as flexible bodies) and the tool set (die and punch as rigid bodies).

vi.The meshes in the blank are finer which mapped type.

vii. The complex interaction among the forming punches, die and the WP was represented by using element target169 and contact172.

viii. The pilot node used to defined the movement of the punch.

ix.The Coulomb friction model described the coefficient of friction.

x. Assumed an isotropic material behavior when modeled the WP.

xi.BISO Hardening option uses the vonmises yield criteria with an isotropic work hardening presumption.

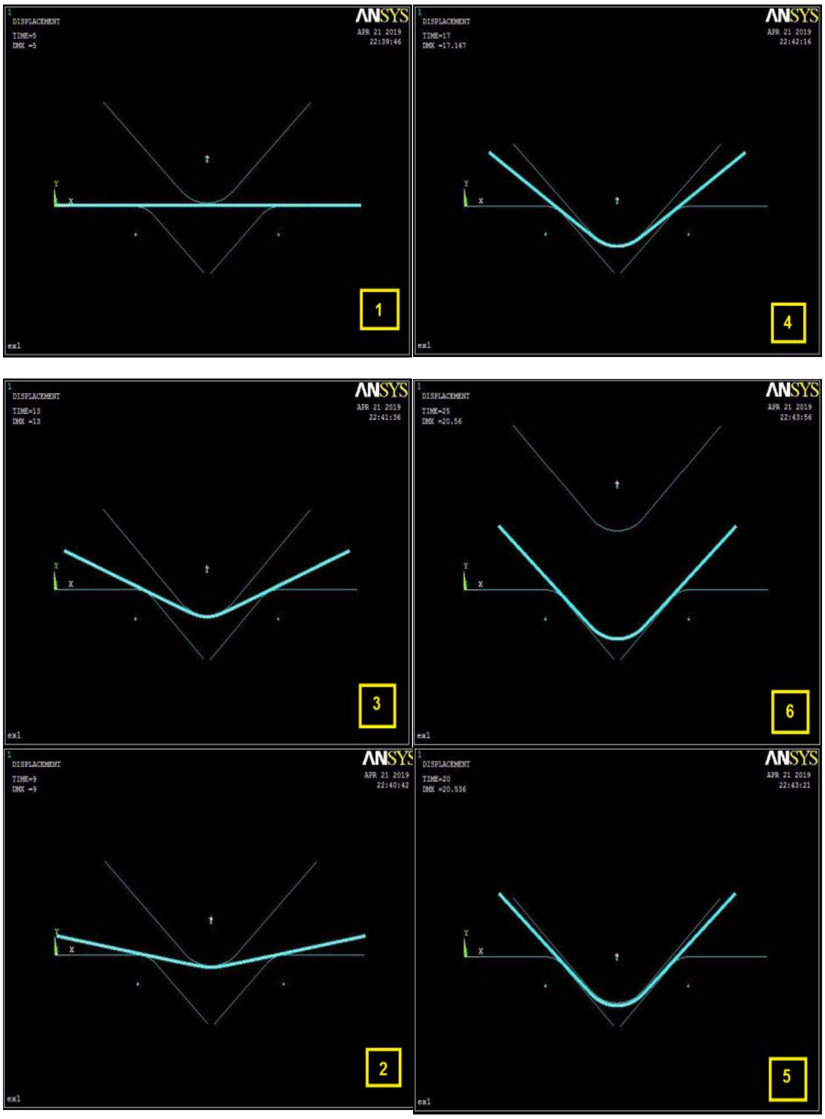


Figure 11: The sequence of bending process in FEM is determined by ANSYS19.0

2. Results and Discussions

The results that obtained from the using ANSYS software to present the finite element model for blank in three rolling direction (0, 45, 90) degrees. A four steps procedure as following; the first one when the bunch in touch with blank, and second step when the punch is push over blank in middle downing distance, third step when punch push blank fully sets in the die, and the last step when punch is unloading. The stress distribution greatly depends on punch movement, hence when the punch moves down, the contact (area, force) between the tool and the blank increased that lead to increasing stresses but the stress is decreases when punch is unloading. This behavior is illustrated in Figures 12, 13, 14.

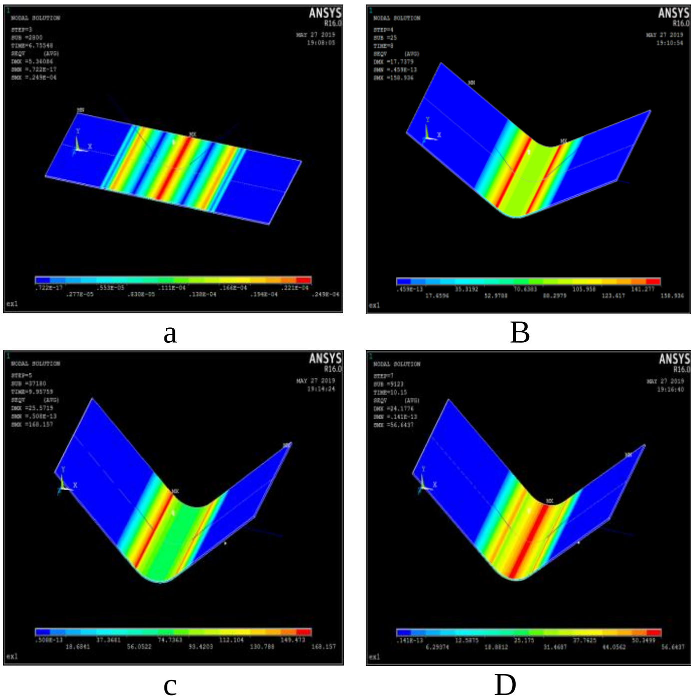


Figure 12: behavior of stress distribution in blank in 0º rolling direction at statues (a) when the bunch in touch with blank. (b) When the punch is push over blank in in middle downing distance. (c) When punch push blank fully sets in the die. (d) When punch is unloading.

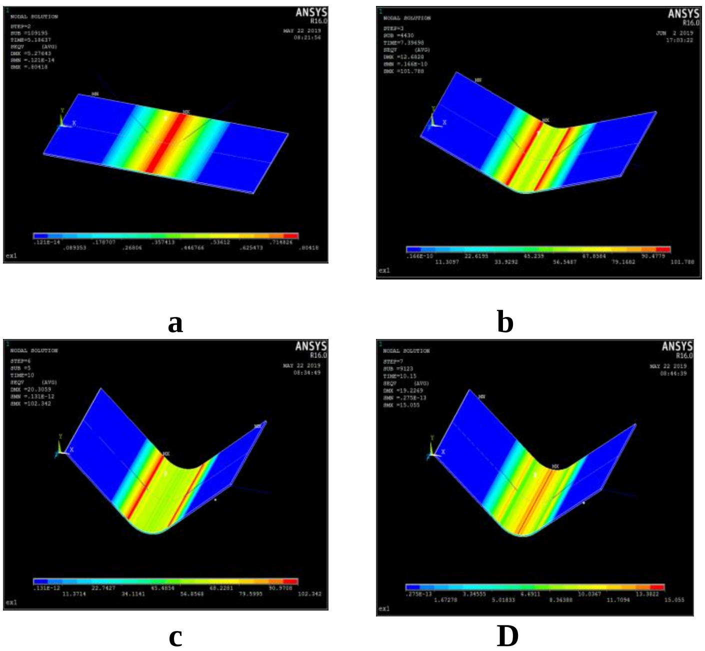
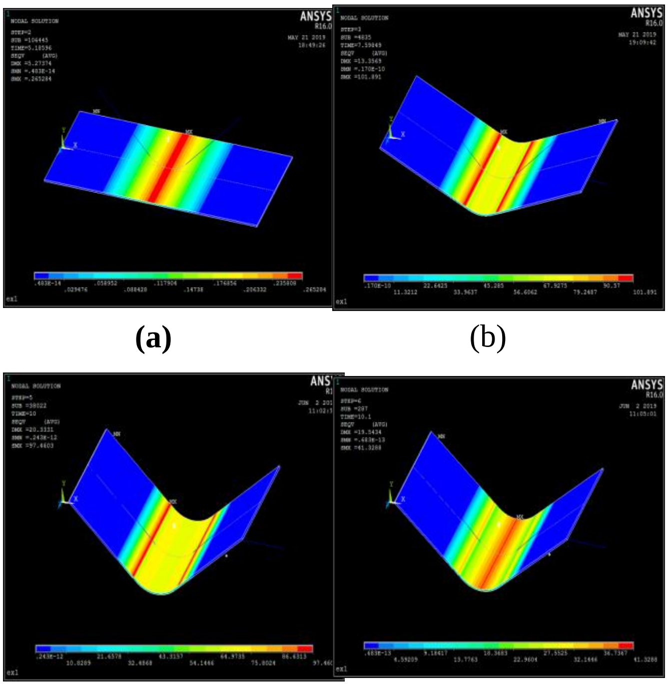


Figure 13:behavior of stress distribution in blank in 45º rolling direction at statues (a) when the bunch in touch with blank. (b) when the punch is push over blank in in middle downing distance. (c) when punch push blank fully sets in the die (d) when punch is unloading.



(a) (b)

(c) (d)

Figure 14: behavior of stress distribution in blank in 90º rolling direction at statues (a) when the bunch in touch with blank. (b) When the punch is push over blank in in middle downing distance. (c) When punch push blank fully sets in the die (d) when punch is unloading

By observing the pattern of stress distribution, it is clear that there is a regular distribution of the stresses for each of the three direction (0, 45, 90) degrees, but there is a significant difference in the values of the stresses in different rolling direction. Where the highest value of the stress recorded in the direction of 0̊ to rolling direction, and the least value of the stress recorded in the direction of 45̊ to rolling direction as shown in Figure 15, which illustrates the relationship between the effective stress and the punch displacement behavior for different rolling direction. This different back to the sheet of brass having planar anisotropy, which give various flow strengths in various directions in the plane of the plate.

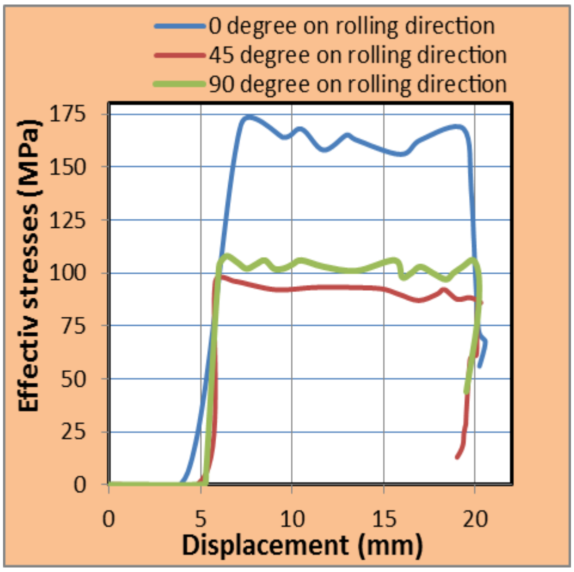


Figure 15: Effective stress versus punch displacement behavior for blank without pre-tension different rolling direction.

The results that obtained from the using ANSYS software to present the finite element model for blank after pre-tension 55% shown that at the stress distribution depends on punch movement as shown in Figures 16, 17, 18.

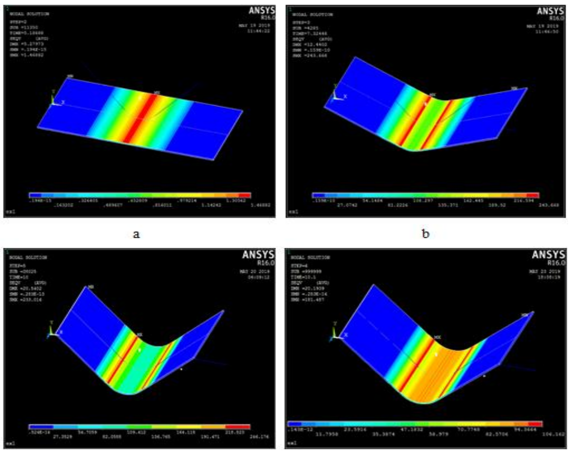


Figure 16: behavior of stress distribution in blank on 0º rolling direction after Pre-tension 55% at statues (a) when the bunch in touch with blank. (b) when the punch is push over blank in in middle downing distance. (c) when punch push blank fully sets in the die (d) when punch is unloading.

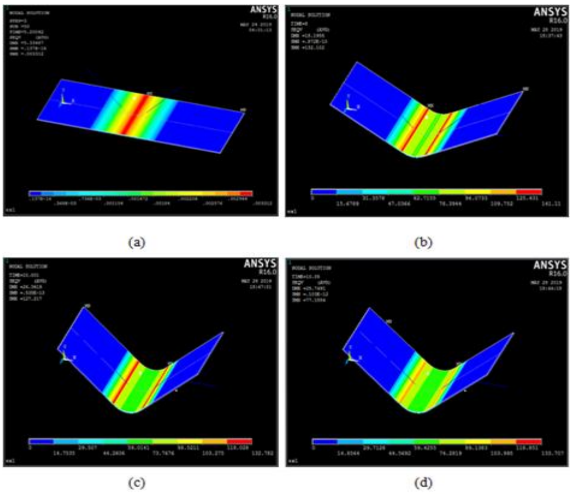


Figure 17: behavior of stress distribution in blank on 45º rolling direction after Pre-tension 55% at statues (a) when the bunch in touch with blank. (b) when the punch is push over blank in in middle downing distance. (c) when punch push blank fully sets in the die (d) when punch is unloading.

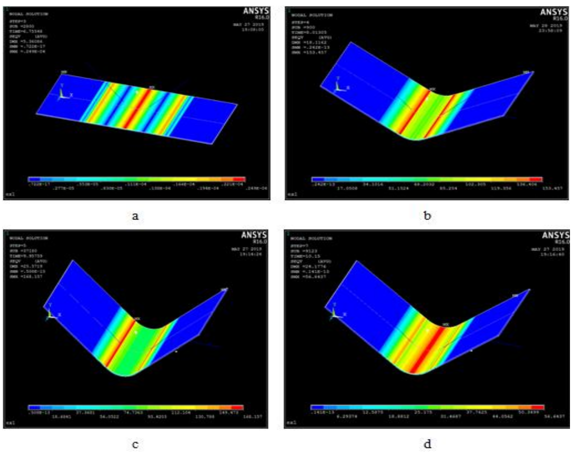


Figure 18: behavior of stress distribution in blank on 90º rolling direction after Pre-tension 55% at statues (a) when the bunch in touch with blank. (b) when the punch is push over blank in in middle downing distance. (c) when punch push blank fully sets in the die (d) when punch is unloading.

It is clearly seen that regular distribution of the stresses for each of the three direction (0, 45, 90) degrees, but also there is significant difference in the values of the stresses in different rolling direction for the same reasons mentioned earlier. This behavior is illustrated in Figure 19.

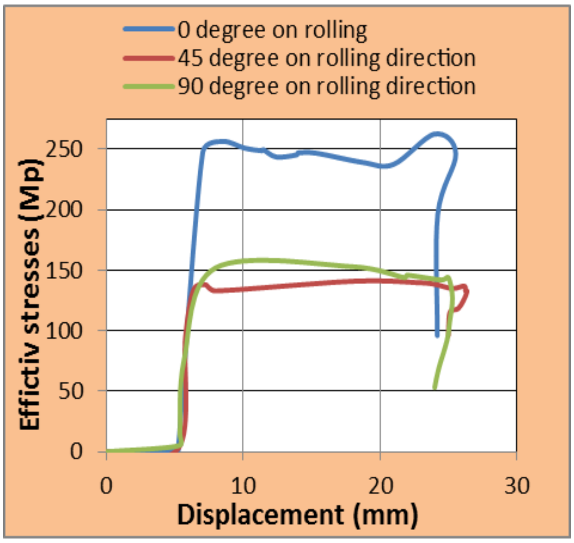


Figure 19: Effective stress versus punch displacement behavior for blank after pre-tension 55% different rolling direction.

It was also noted that there is a significant difference in each direction between the measured values of stresses for the blank before pre-tension and the value of the stresses for the blank after pre-tension 55%, this is observed as an increasing flow stress as shown in Figure 20, 21, 22. Where in 0° on rolling direction the stresses increased by 31.7 % and in 45° the stresses increased by 35.6 % while in 90° the stresses increased by 23.6 %. Because during the pre-tension process the blank is subjected to deformation that leads to change in the microstructure state which causes assembles dislocation and retardation to motion, this dislocation that will produce strain hardening. The retardation acts through internal resistance.

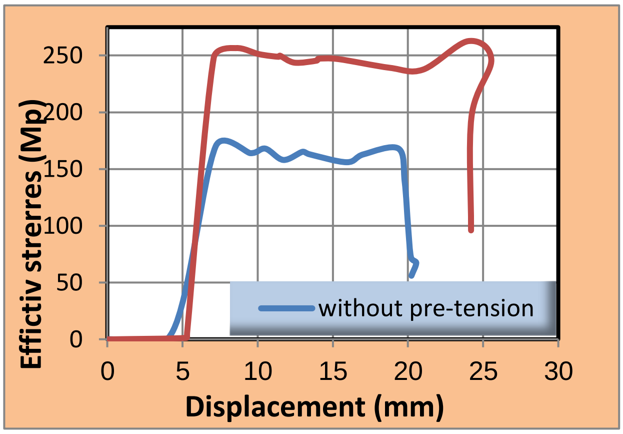


Figure 20: comparison of stress versus punch displacement behavior for blank without pre-tension and after pre-tension 55% in 0° on rolling direction.

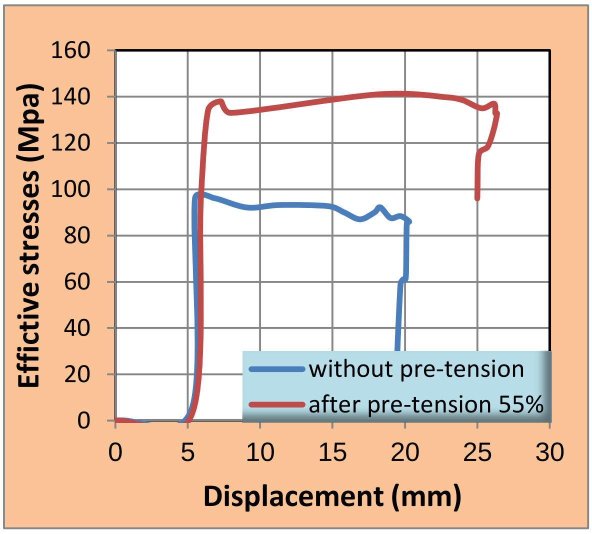


Figure 21: comparison of stress versus punch displacement behavior for blank without pre-tension and after pre-tension 55% in 45° on rolling direction.

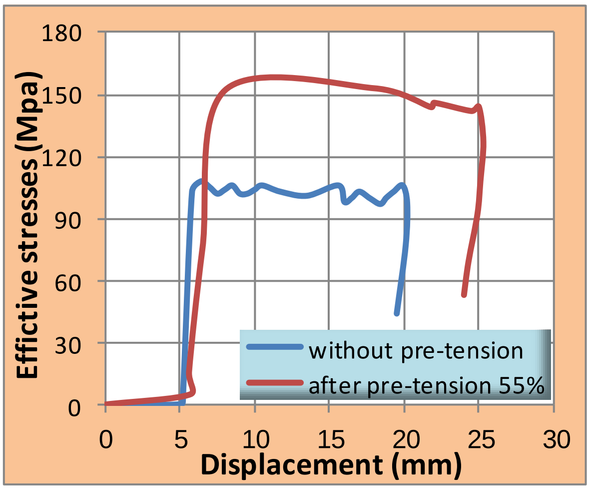


Figure 22: comparison of stress versus punch displacement behavior for blank without pre-tension and after pre-tension 55% in 90° on rolling direction

As the stress is further increased, new dislocations generated and even though some dislocations annihilated and no dislocations released from the pileups, the density of mobile dislocations increases. During the subsequent unloading, the mobile dislocation density decreases because of dislocation annihilation and runback. When the material is loaded again, the density of mobile dislocations increases and new dislocation pile-ups formed. Due to the increased dislocation density, there are more possibilities for the generation of dislocation pile-ups at barriers, which may be created. During subsequent unloading the line, tension of the dislocation straightens the bowed dislocations again. Thus, the deformation during the loading - unloading cycle is partly elastic. Similarly, dislocation pile-ups may be generated by short range dislocation motion during loading. The pile-ups create internal stresses (back stresses), which again during the unloading sequence break down the pile-ups and move the dislocations back towards their original positions.

4. Conclusions

The present work has reached the following conclusions:

i. The orientation has a significant effect on stresses distribution before and after pre-tension. Where although there is a regular distribution of stresses in three direction but there is significant difference in the values of stresses in each of (0, 45, 90) degrees where the highest value of the stress recorded in the direction of 0° to rolling direction and the least value of the stress recorded in the direction of 45° to rolling direction.

ii. The pre-tension has a greater impact on stresses distribution where although there is a regular distribution of stresses in blank before and after pre-tension but there is significant difference in the values of stresses in blank before and after pre-tension for each one of direction as follows:

A. In 0 degree on rolling direction, the stresses increased by 31.7 % from their values before pre-tension.

B. In 45 degrees on rolling direction, the stresses increased by 35.6% from their values before pre-tension,

C. In 90 degrees on rolling direction, the stresses increased by 23.6% from their values before pre-tension.

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