

Changing Forming Path of Sheets Metals via Different Punch Radii during Stretch Bending Forming Process

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Abstract - The new way of sheet forming process is combining two processes to improve the sheet forming application and make a complex design of sheet without any problems. The two processes are stretch and bending forming operations participating under title stretch bending process. Changing forming path is a new way to deform sheet using two stages of forming sheet processes to avoid the fracture forming way, and making improving the formability of sheet via selecting the high limit of forming strain. In this paper, the effect of punch radii on the formability for SS304, SS316 sheets have been calculated experimentally representing via stretch bending ratio which is used scale of sheet formability, also the impact of sheet width was employed to improving the effect this parameter in the formability of sheet metals.

Keywords: Forming path, Sheet width, Punch radii, Sheet formability.

I. INTRODUCTION

Stretch bending process plays a significant role to improve the sheet metal operation this is because using two difference operations in the same process[1][2]. It can be affected by many parameters such as strength coefficient, thickness, sheet width and punch radii [3][4][5].

Stretch bending was simulated to show the position of necking in different steel sheets during forming process. Also they used different punch radii such as 6, 10,14,18, 22, 30mm to change the R/t ratio. They concluded that the crack in formed sheet change position due to increase the punch radii [6]. Anas mikes a new design for stretch bending process to show stretch bending limit ratio experimentally for different sheets such as steel, aluminum, and aluminum alloy sheet, and also he made a comparison between experimental work and simulation results.

He pointed that the forming specimen depth obtained experimental has good agreement with numerical results [7].

In 2021, spring back in aluminum hollow tube during stretch bending process was studied experimentally and analytically connecting with FE method to make spring back

mode. They found that the FEM with analytical solution curve for spring back close to experimental curve [8]. In 2016, stretch bend was numerically simulated using FEM to show the effect of punch radii in forming force and displacement. They used different punch (1, 2.5, 5, 10, 15, 20) with different friction condition (0, 0.03, 0.07, 0.15, 0.2) to show the necking position. They concluded that the position of necking in sheet during forming process moves and changes due to increase the punch radii and friction condition [9].

The stretch bending process was studied experimentally for steel alloy sheet (1.2mm) using different punch radii (1, 3, 5, 10, 20mm) to show the effect of punch radii in the formability of steel sheet. They concluded that forming with a punch with a diameter of (20) mm gave a (20%) improvement in forming ability, on the contrary, the second punch with a diameter of (3) mm gave a lower formability [10].

In 2010, researchers studied the formability of steel alloy sheet in stretch bending experimentally and comparing with numerical solution using the finite element method, they used four die radii to study the effect of this parameters on the fracture location. They pointed that the fracture position changes due to increase the die radii, and they discovered the fracture position in steel sheet during experiment forming process close to numerical simulation of fracture location [11].

The aim of this research determines the effect of punch radii on the formability for SS304, SS316 sheets experimentally representing via stretch bending ratio which is used scale of sheet formability, also the impact of sheet width was employed to improve the effect of this parameter on the formability.

II. EXPERIMENTAL TECHNIQUE

2.1 Chemical Compositions for sheets:

The chemical analyses for sheets are very important due to display the major elements in sheet, and to know the types of sheets. Table (1) shows the effective elements of SS304, SS316.

Table 1: Chemical analysis of SS304 and SS316 sheet

Material	C%	P%	Mn%	S%	Si%	Mo%	Cr%	Cu%	Ni %
SS304	0.085	0.041	2.12	0.029	0.85	-	18.35	0.01	10.32
SS316	0.082	0.043	1.98	0.03	0.90	2.57	17.12	0.02	10.89

2.2 Mechanical properties for sheet metals:

The main important step in plastic deformation is to know the effective mechanical properties for all sheets due to discover the behavior of sheet during forming processes. A tensile test for dog bone specimens (ASTM E8/E8M –16a) were used to determine the mechanical properties for all sheet. Table (2) displays the mechanical properties for two sheets (SS304, SS316).

Table 2: Mechanical properties of sheets

Material	Tensile stress (MPa)	Proof Stress (MPa)	Elongation%
SS304	660	230	48
SS316	640	211	53

2.3 Stretch bending process:

The stretch bending process depends on forming punch which plays an important role in this process due to changing strain path in forming process. This process was combined two processes in one forming process. . The stretch bending limit ratio was used as a scale to know the formability of sheet metal.

A V-Punch, upper and lower die, and a Blank Holder were used as stretch bending process equipment that manufacturing from high carbon steel. The procedure of S.B. process is to put forming specimen between blank holder and die, and starting process with movement of punch inside two dies due to make deformation of specimen inside dies. The forming specimen can be change from flat sheet to final forming product due to apply force into forming V- punch.

Two V-punches with different radii (5mm,10 mm) are employed with die and a blank holder, as shown in figure (1). Figure (2) displays two V-forming punches which uses in stretch bending forming process as forming tool. Two types of sheets metal was used such as SS316 and SS304 sheet with three different specimen widths.

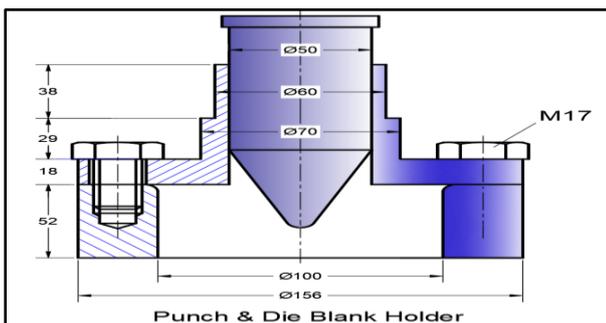
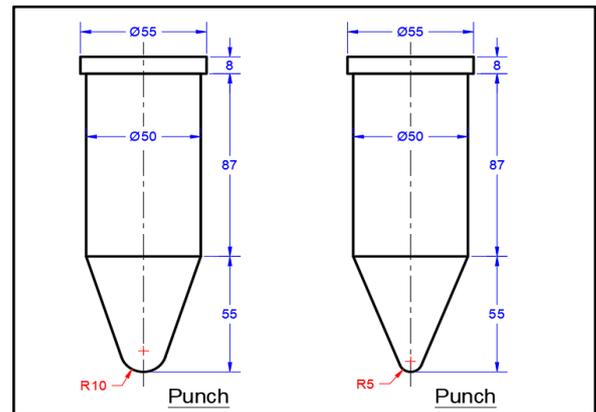


Figure 1: V-punch with blank holder & lower die



(a) (b)
Figure 2: V-punch dimensions: (a) v punch of 10 mm radii (b) v punch of 5 mm radii

The stretch-bending limit ratio, as illustrated in figure (3), shows the maximum length of the deformed specimen to the original specimen length. The thickness ratio, which compares punch radius to sheet thickness, is another crucial factor.

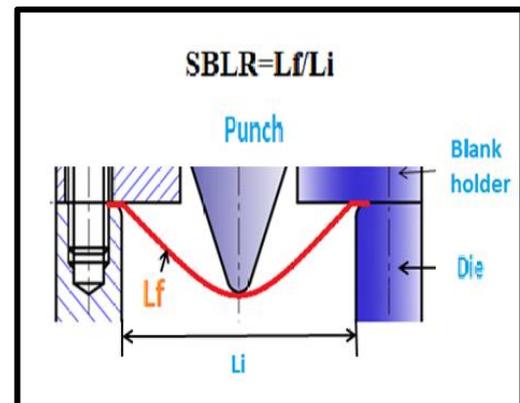


Figure 3: Stretch bending limit ratio (SBLR)

III. RESULTS AND DISCUSSIONS

The combining of stretch and bending process is a new way to extend the engineering application for sheet metal. The new method for sheet metal process participates in many manufacturing application such as airplane and car structure. The depth of forming sheet during stretch bending is influenced by punching radii due to changing strain path.

Figure 4 shows the stretch bending specimens after plastic forming with difference specimen widths.



Figure 4: Forming specimens after plastic deformation

Figure (5) illustrates forming depth as a function of the specimen width for SS304sheet (0.6mm thickness). Two types of punch are used to show the improvement of formability. Overall, it can be noted that the forming depth increases with increasing specimen width. Also, the formability of sheet improved due to changing forming punch size. The maximum depth of sheet is 27 at a specimen width 25 mm for two stages of sheet forming processes, while the minimum is 16.5mm for only single stage of forming.

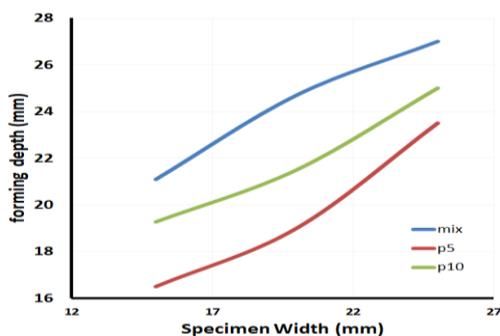


Figure 5: Forming depth for different punch radii and specimen widths for SS304 sheet

Figure (6) shows the effect of different punch radii in stretch bending limit ratio for SS304 sheets. Three specimens' widths were used in this research to illustrate the impact of specimen width on formability of sheet. The horizontal axis represents forming path while the vertical axis represents stretch bending limit ratio. Overall, it can consider that the SBLR increases with increasing specimen size. Also, the formability of sheet improved due to changing forming path using different punch size. The maximum SBLR of sheet is 1.12 at a specimen width 25 mm for two stages of sheet forming processes, while the minimum is 1.05mm.

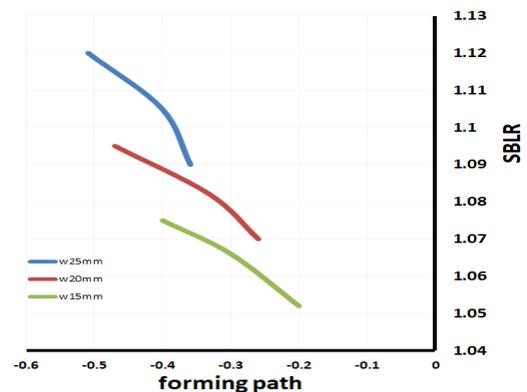


Figure 6: Stretch bending limit ratio for SS304sheets (0.6mm thickness)

Figure (7) shows the effect of different punch radii in stretch bending limit ratio for SS 316 sheets. Three specimens' widths were used in this research to illustrate the impact of specimen width on formability of sheet. The horizontal axis represents forming path while the vertical axis represents stretch bending limit ratio. Overall, it can consider that the SBLR increases with increasing specimen size. Also, the formability of sheet improved due to changing forming path using different punch size. The maximum SBLR of sheet is 1.35 at a specimen width 25 mm for two stages of sheet forming processes, while the minimum is 1.2mm.

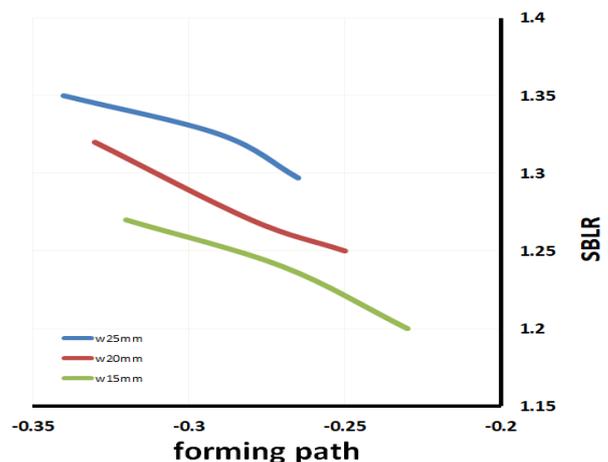


Figure 7: Stretch bending limit ratio for SS316 sheets (0.6mm thickness)

The formability for SS316 sheet was numerical investigated to show the formability of SS316 during sheet metal forming. Figure (8) shows the comparison between SS304 and SS316 sheets for forming depth using the same forming punch (5mm) to illustrate the highest formability during stretch bending process. Also all forming process did experimentally. Three sheet widths (15-20-25) mm used in this research to show the effect of width on the stretch bending process. Overall, it can be noted that the formability of SS316 sheet is higher than SS404L this is because the SS316 sheet more ductile than SS304 sheet. In addition, the forming depth increases due to increase specimen width for all sheets metals. The maximum forming depth of sheet is 38mm at a specimen width 25 mm for two stages of sheet forming processes, while the minimum is 16mm.

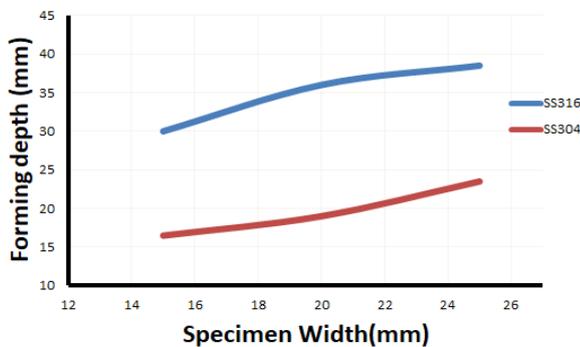


Figure 8: Forming depths for SS304 and SS316 sheets using forming punch of radii 5mm

The stretch bending limit ratio is important scale in sheet metal forming this is because it can discover the best formability for all sheets when making comparison. Figure (9) displays the comparison between two types of sheets SS304, SS316 (0.6mm) for stretch bending limit ratio. It can be seen that the curve of SS316 sheet is highest to the SS304 sheet for SBLR, in general the SBLR increases due to decrease in forming path this is happen due to using different forming punch radii especially to do changing strain path. In addition, the maximum stretch bending ratio in SS316 is 1.35 while the minimum is (1,085) mm for SS304 sheet.

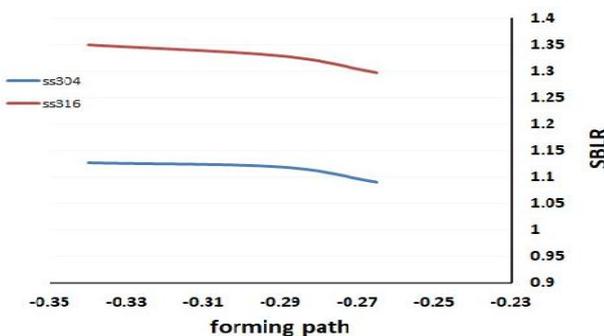


Figure 9: Stretch bending limit ratio for two sheets (SS304, SS316) with different forming paths

Figure (10) illustrates comparison of stretch bending limit ratio between two punch radii (5,10mm) for SS304 sheet, and width 25mm. Overall, it can be seen that the stretch bending limit ratio increases due to increase punch radii. Also, the maximum stretch bending ratio for punch radii (10) is 1.118, while the minimum stretch bending ratios is 1.09 for punch radii 5mm.

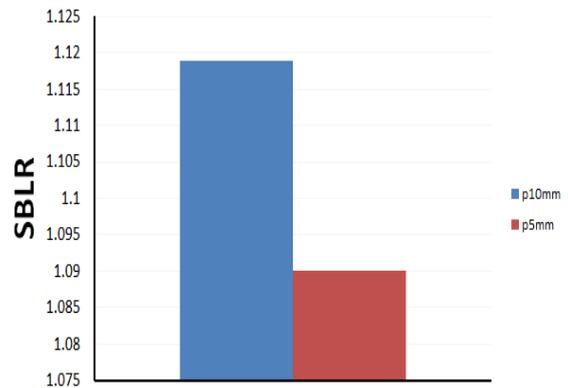


Figure 10: Stretch bending limit ratio SS304 Sheet for two punch radii 5, 10 mm

IV. CONCLUSIONS

The main conclusions are recorded below:

1. For both sheets, there is good correlation between theoretical and practical forming depth.
2. The formability of the SS316 sheet is higher than SS304 sheet.
3. The stretch bending limit ratio is higher with the punch of 10 mm radius compared with the punch of 5 mm radius.
4. The stretch bending limit ratio is higher with the specimen width of 25 mm compared with the specimen width of 20 mm and 15 mm.
5. The SS316 sheet has high load than SS304 sheet.

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