

Formability Studies on AA 6061 Sheet Metal for Automotive Body Structures using Deform-2D

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ABSTRACT

Pure stretch forming and pure deep drawing are most commonly used terms in the study of sheet metal forming processes and formability tests. Pure stretch forming results in considerable thinning and increase surface area of the blank due to biaxial stretching. In Pure deep drawing, the complete blank is being drawn into the die without changing thickness, so that there is no change in the surface area of the final product but it does not exist in the stretch forming. It means that the deep drawing process lies between the two extreme conditions representing pure stretch forming and pure deep drawing. In this investigation, a series of simulations were performed using DEFORM- 2D to determine the amount of deep drawn using a parameter χ which explains the extent of stretching and drawing. By using this parameter, the effect of the process parameters, such as the punch nose radius, the blank diameter and thickness of the blank on the draw-ability of aluminium material can be understood.

Key words: Formability, D-Form-2D, Aluminium, Stretch forming.

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INTRODUCTION

Deep drawing and stretch forming are most important methods used to form sheet metal. These can be easily distinguished from the flange movement during forming. Currently, in the modern industry, the deep drawing process is extensively used because it is most common manufacturing process for forming automotive inner and outer parts. The plain strain formability analysis which evaluates automobile panel's formability at early design phases, before finalizing the design and production tool commitments, can save time and cost. The problem at early design phases, however is that the designs are not complete and are rapidly changing. For these reasons, there is a need for fast formability evaluation tool that requires minimum geometric definitions with minimum simulation time and modeling effort [2]. The advent of simulation tools for sheet metal forming analysis has enabled precise prediction of forming strains and other process parameters during sheet metal forming [3].

As the sheet forming processes fall into the category of pure deep drawing or pure stretch forming, the introduction of the forming limit diagram, which uses the limiting strains at the location of failure as the limit of forming, attempts to quantify the formability of sheet materials formed by different processes [2-4]. Two features are distinct in this general sheet

forming process: drawing-in of the flange towards the die throat, and deformation of the blank being more severe within the die throat than the flange. The degree of movement of the flange subsequently yields the following two processes that are of special interest to the sheet metal engineer: (a) stretch forming in which flange movement is prevented and overall thinning is more severe within the die throat than the flange, and (b) deep drawing in which the flange is drawn completely into the die throat and the thickness of the blank remains substantially unchanged [4]. Finite element method (FEM) is a very effective method to simulate the forming processes with accurate prediction of the deformation behaviors. FEM can be used not only in the analysis but also in the design to estimate the optimum conditions of the forming processes. This can be done before carrying out the actual experiments for an economical and successful application of SPF to industrial components [5]. In recent years, the use of aluminium alloys has remarkably been increased in automotive industry due to its light in weight [6]. This is attributing not only saves the energy but also provides environment friendliness [6]. There has been little research on the influence of process parameters on formability behaviour of 6061 aluminum alloy. In the present study, the influence of the punch radius, rim radius and length of the work piece on deep drawing process has been investigated by simulation using DEFORM-2D, finite element analysis software.

MATERIAL AND NUMERICAL SIMULATIONS

Commercially available Al-6061 aluminum sheet with various thicknesses of 3.0 mm was used for the blank material. The composition and properties are given in Table 1 & 2.

Table 1. Composition of AA6061

Component	Au	Mg	Si	Cu	Cr
Amount (wt %)	97.9	1.0	0.6	0.8	0.2

Table 2. Properties of AA 6061

Poisson's Ratio	0.33
Elastic Modulus (GPa)	70-80
Tensile Strength (MPa)	115
Yield Strength (MPa)	48
Elongation (%)	25

The basic layout for an axisymmetrical cup drawing is shown in Fig1. A blank of radius R_b is clamped between a pressure pad and a die of shoulder radius R_s . A cylindrical solid punch of radius R_p and nose radius R_n is used: $R_n < R_p$ implies a flat-bottomed punch and $R_n = R_p$ implies a hemispherical punch. The clearance between the punch and the die throat is small, so that, for simplicity, the throat radius is taken as being the punch radius R_p . A full cup is formed when the outer rim of the blank is drawn completely into the die throat, the drawing ratio being (R_b/R_p) .

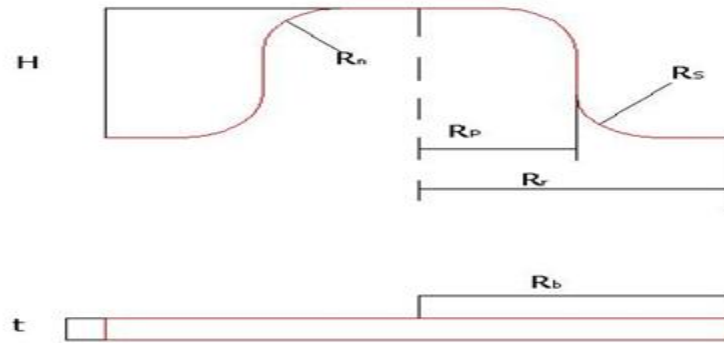


Fig 1: Basic layout for deep drawing

Where: R_n – radius of the nose (mm) , R_p – radius of the punch (mm), R_r -radius of the rim (mm), R_b - radius of the blank (mm). H- Height of the cup (mm), t- thickness of the work (mm).

SELECTION OF PROCESS PARAMETERS

Various combinations of process parameters namely nose radius, R_n , blank radius, R_b and thickness of the blank, t were used to analyze the deep drawing process [1].

$$\Psi = \log_e (A_b / A_r) = 2 \log_e (R_b / R_r) \quad (1)$$

$$\xi = \log_e (A / A_b) = \log_e (t_b / t) \quad (2)$$

$$\chi = \xi / \Psi \quad (3)$$

Where $\Psi = 0$, pure stretching and $\xi = 0$, pure deep drawing

Table 3. Various combinations of parameters

	t	R_n	R_b		t	R_n	R_b		t	R_n	R_b
Case: 1	3	5	55	Case:2	3	5	65	Case: 3	1	5	55
		10	55			10	65			10	55
		15	55			15	65			15	55
		20	55			20	65			20	55

For a given blank material and blank dimensions, a change in the forming conditions, such as in the blank holding load and tool geometry, changes the limiting drawing ratio (LDR) as a result of variations in the thickness distribution. These variations, which lead to the formation of a successful cup in one instance, and an unsuccessful cup in another, suggest that the blank material is subjected to different degrees of stretching. Hence, it is important to investigate the effect of stretching on the deep draw ability of sheet materials.

RESULTS AND DISCUSSION

The values ξ , Ψ and χ have been calculated using E.q (1), (2) and (3). The thickness of the blank at various locations has been measured and average thickness considered for calculating the value ξ .

Simulation for case 1:

Case1 has been considered as varying R_n values for a blank radius of 55 mm with 3mm thickness. The deep drawn cup with thickness distribution at various locations for R_n , 15 and 20mm is shown in Fig. 2. The data measured from the simulations is presented in Table 4.



Fig 2: Drawn cup with thickness distribution at various locations for R_n , 15 and 20mm

Table 4. Simulation Data

S.No	R_n	R_r	R_b	\bar{t}	Ψ	ξ	X	Damage	Height	R_p	Draw ratio
1	5	37.791	55	2.95	0.7505	0.0168	0.02239	0.343	25.1	25	2.2
2	10	35.745	55	2.97	0.8618	0.01005	0.01166	0.197	30	25	2.2
3	15	32.75	55	2.975	1.0368	0.008	0.00771	0.872	35	25	2.2
4	20	35.35	55	2.983	0.884	0.00568	0.00642	1.58	40.1	25	2.2

The Table 4 indicates the damage value, the displacement, the rim radius and LDR for various R_n . It is observed that the damage value decreases as the R_n value increases and displacement height increases with decreasing R_n . The graph between nose radius (R_n) and χ value and χ value and full cup height are shown in Fig.3 and 4 respectively. Fig.3 and 4 indicate that the χ value decreases with increasing R_n value and the full cup height decreases as the χ value increases. The graph between R_n and full cup height is shown in Fig.5. Fig. 5 indicates that the full cup height (H) increases not only with χ but also with the nose radius. It is observed that the nose radius is less than the punch radius for all cases except in case of 25mm. From the above results, it is concluded that the nose radius R_n , 5, 10, 15, 20 mm are treated as flat bottomed punches and the nose radius 25 mm as hemispherical punch because which equal to the punch radius. Thus the curve is linear for all the values of the flat bottomed punch but slightly varied in the case of hemispherical punch.

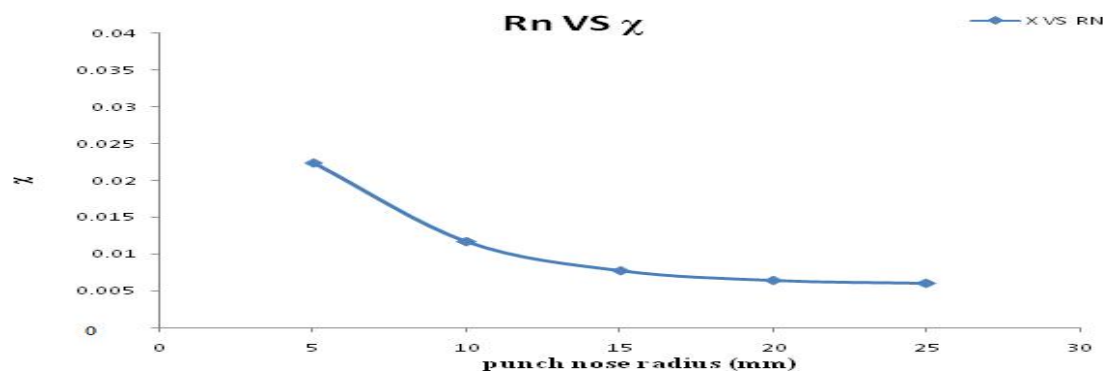


Fig 3: Graph drawn between nose radius and χ

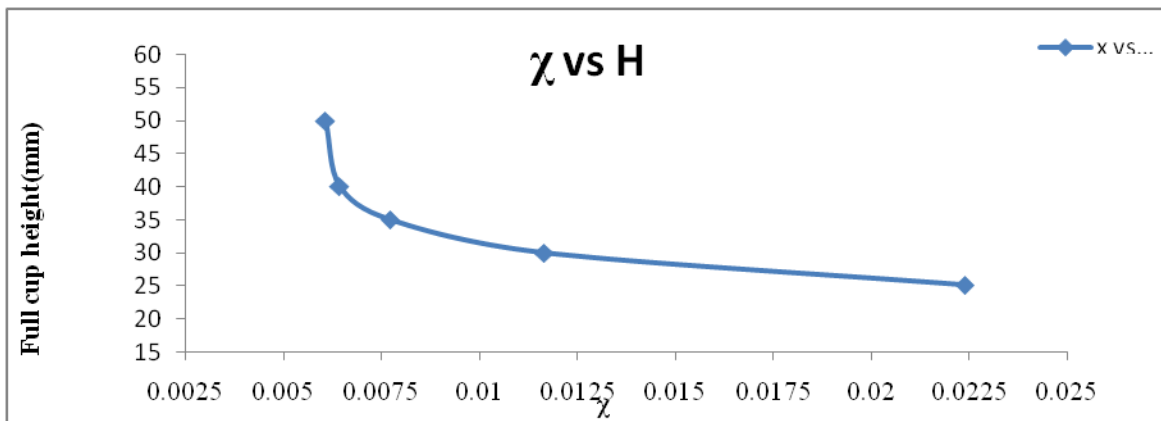


Fig 4: Graph between χ versus Full cup height.

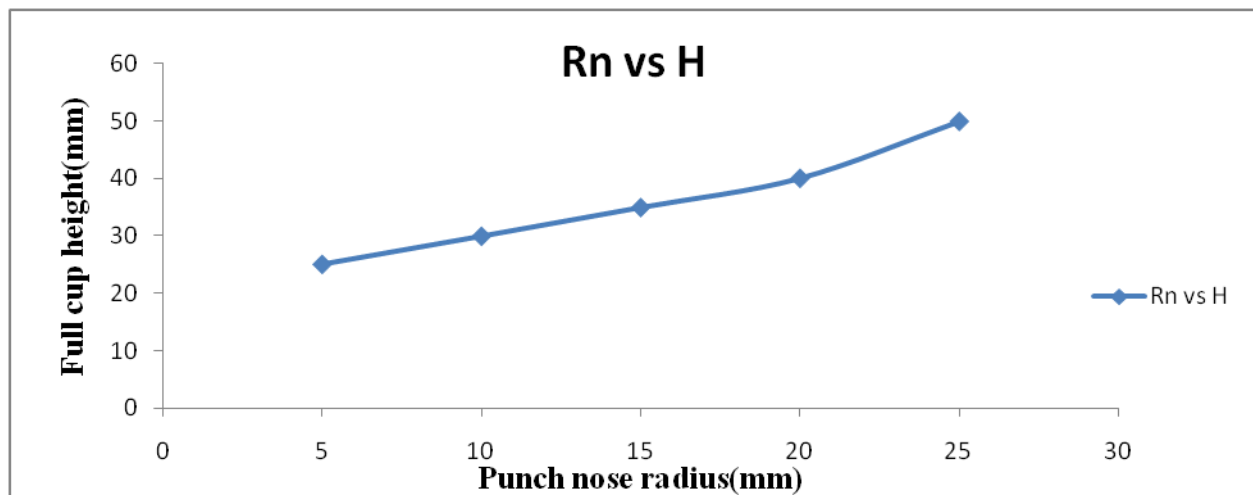


Fig 5: It shows that curve between the nose radius and full cup height.

Case 2:

Case2 has been considered as varying R_n values for a blank radius of 65 mm with 3mm thickness. The deep drawn cup with thickness distribution at various locations for R_n , 15 and 15 mm is shown in Fig. 6. The data measured from the simulations is presented in Table 5. It is observed from the table 5 that the LDR increases with increasing the sheet blank diameter increases. The relation between χ versus Full cup height (H) is followed the same trend as followed in the case 1.



Fig 6: Drawn cup with thickness distribution at various locations for Rn 5 and 15mm

Table 5. Simulation data

S.No	Rn	Rr	Rb	\bar{t}	Ψ	ξ	χ	Damage	Height	Rp	Draw ratio
1	5	45.807	65	2.97	0.6999	0.01005	0.0143	0.326	25.1	25	2.6
2	10	43.47	65	2.98	0.8046	0.0066	0.0082	0.154	30	25	2.6
3	15	41.833	65	2.987	0.8814	0.0043	0.0049	0.101	35	25	2.6
4	20	43.684	65	2.993	0.7948	0.0023	0.0028	0.123	40.1	25	2.6

Case 3:

Case 3 in which blank thickness is 1 mm, radius of the blank is 55 mm and the nose radius is varying from 5-25 mm. The deep drawn cup with thickness distribution at various locations for R_n 10 mm is shown in Fig. 7. Data measured from the simulations is presented in Table 6. From the Table 6, it is very clear that the value of $\xi = 0$ is for a case of drawing tending towards zero having a thickness of 1 mm. This case corresponds to pure drawing.

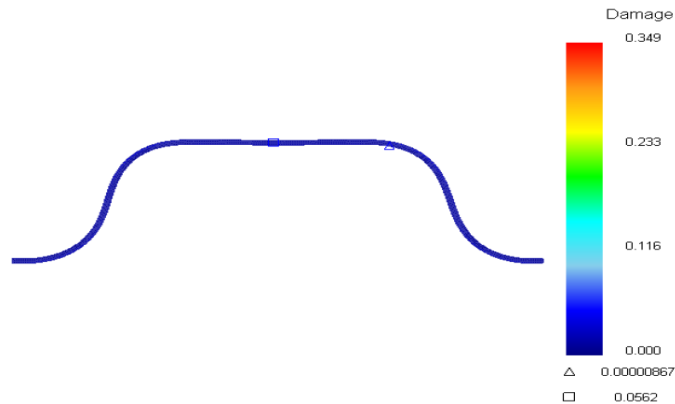


Fig 7: Drawn cup with thickness distribution at various locations for Rn10 mm

Table 6. Simulation data

S.No	R _n	R _r	R _b	\bar{t}	Ψ	ξ	χ	Damage	Height	Rp	Draw ratio
1	5	35.597	55	0.999	0.87	0.001	0.00014	0.0835	25.	25	2.2
2	10	33.307	55	1.000	1.01	0.000	0.00000	0.0562	30	25	2.2
3	15	33.730	55	1.000	1.16	0.000	0.00000	0.1020	35	25	2.2
4	20	33.260	55	1.000	1.00	0.000	0.00000	0.1190	40	25	2.2

CONCLUSION

The present work results reveal that stretching is more prominent than drawing for a larger punch nose radius, blank-holding load or blank size. Stretching, however, becomes less severe than drawing for a larger die shoulder radius. Improving the χ -value increases the net process efficiency, implying that a cup with a more uniform thickness can be produced. Also, a greater cup height can be obtained by increasing χ . The results also indicate that the full cup height (H) increases not only with χ but also with the nose radius. For all the cases, the nose radius is less than the punch radius except in case of 25mm. The nose radius with 5, 10, 15, 20 mm are treated as flat bottomed punches and nose radius with 25 mm is equal to the punch radius than that is the hemispherical punch. Thus the curve is linear for all the values of the flat bottomed punch. It is slightly varied in case of the hemispherical punch

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