Journal of Mechanical Research and Application (JMRA), Vol. 11 No.3, 1400(2021),51-57

Numerical Simulation of effective parameters on Deep Drawing process of AL- Alloys Sheets

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***Received**: 2022-08-22* ***Accepted**: 2023-2-12*

Abstract

In this research paper, Deep drawing process is one of the most complex forming processes that is widely used in various industries and has the ability to produce with high speed and high accuracy. Many parameters such as behaviour and properties of materials, stress rate, lubrication conditions, tools and equipment used in the process are optimally effective. The effect of deep drawing parameters on the ductility of a cylindrical piece of aluminium alloy O-1050, O-5182, O-5251, O-5754 has been investigated. The deformation process of the cylinder was simulated and analysed by Autoform finite element software and the effect of effective parameters such as sheet force and friction changes on the displacement of the mandrel, the amount of matrix force and the minimum amount of sheet thickness were investigated.

Keywords: Deep drawing Process; Al- Alloys Elastic foundations; Auto form software

1- Introduction

Nowadays, Aluminium alloys are used widely in the automotive, shipbuilding, oil and gas, chemical and petrochemical, food and aerospace industries as an alternative to steel sheets and plastic panels reinforced with fiber is widely used in buildings, bridges, marine industries, fuel and food storage tanks, and systems and pressure ducts used at low temperatures. O- series aluminum alloys, O-1050, O-5182, O-5251, O-5752, the main alloying elements of which are magnesium, have the ability to strain hardening and have properties such as relatively high strength, good corrosion resistance, good welding ability, low density and high resistance to fatigue and failure [1].

The deep drawing process is one of the most important processes in the field of metal forming, which creates seamless hollow parts with different shapes. Many factors such as sheet thickness, lubrication conditions, radius of the punch and the cavity of the Die, the looseness between the wall of the punch and the Die, tensile strength, tensile depth, mechanical and metallurgical properties of the sheet, etc. in the production of the final part are effective. Accurate determination of these factors using trial and error is time consuming and costly and hence, simulations with finite element software have been developed [2]. Dwievdi et al. [3] examined the process parameters and their effect, including the sheet binder force and the lubricant condition and friction coefficient in the production of an aluminum cup. They showed that the binder force and the

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lubricant conditions very important parameters and should be chosen carefully. They also showed that surface quality and thickness distribution depended on lubricant conditions. Yoshihara et al. [4] showed that the thinning of the sheet thickness in the areas of the punch edge and the wall of the stretched cup is strongly dependent on the control of the sheet binder force. Using FEM with Taguchi method, Padmanabhan et al. [5] evaluated the effect of three important parameters of matrix ring radius, sheet binder force and friction coefficient on the surface quality of a cylindrical steel cup. Using analysis of variance, they found that after the radius of the matrix, the shear force and the friction coefficient had the greatest effect on the shaping quality of the cylindrical cup, respectively. Diwang et al. [6] by examining the punch force using the finite element method in the deep drawing process of 5052 aluminum alloy in different conditions found the sheet binder force. With the increase of the sheet binder force, the punch force also increases. Singh et al. [7] analyzed the deep drawing process by finite element method to investigate the tensile strength of a cylindrical cup under different lubricant conditions. They showed that reducing friction coefficient has a great effect on reducing wrinkles and improving the FLD curve.
In this work, the effect of important parameters such as sheet binder force and friction coefficient on the drawing process of O-1050, O-5182, O-5251, O-5754 Aluminium alloys cylinderical cup was performed using Auto-form software, so that the effect of changes in these parameters on sheet displacement, punch force has been studied.

2. Simulation

To simulate the single-step cylindrical traction process in Auto-form software, the Die tool were first design in Catia software and entered into Auto-form software by igs extension file. punch components including mandrel with a diameter of 32 mm and a corner radius of 2,2.5,3,3.5 mm and a Die cavity with a diameter of 33.8 mm and a radius of the Die cavity of 2.2, 2.7, 3.2, 3.7 mm have been considered after initial orientation to the Die parts in the Auto-form software.

Properties of alloy aluminium sheets with a thickness of 0.2 mm has been selected from the Auto-form material library of the European standard section. Some of the mechanical properties of the sheets are given in Table 1.

Table 1. Mechanical properties of Aluminium Alloys sheets

Aluminium Alloy	Strength coefficient (Mpa)	Stress hardening	Yield stress(Mpa)	muduls of Elastisity (Gpa)
1050	312	0.122	48.4	70
5182	558.4	0.319	136.5	70
5251	394.4	0.273	94.6	70
5754	411	0.223	146	70

The deep drawing process was performed under some different sheet binder forces and during each of these processes, friction coefficient changes were applied. Working conditions such as press speed and process time were determined. After creating the process, a mesh was made in accordance with the working conditions of the process and finally, the deep drawing file was executed.

3. Results

In this section, by applying different coefficients of Lubrication in Six different sheet binder forces, the effect of these changes on the displacement of the blank sheet, the force required for the Die and the minimum thickness of the material after the deep drawing operation is investigated.

in tables 2-5, positive results of cylindrical cup forming, cup height in terms of different lubricant coefficient in different Binder force for Die radius 2, 2.5, 3, 3.5 mm for Aluminum Alloys sheets have been highlighted and presented.

Table2. Cylindrical cup forming, cup height in terms of different lubricant coefficient in different sheet Binder force (Die radius 2 mm)

Die force (KN)	Result 5754	Die force (KN)	Result 5251	Die force (KN)	Result 5182	Die force (KN)	Result 1050	Lubricant coefficent	Displacement (mm)	Binder force (KN)
10.6	+	10.1	+	11.3	+	7.8	+	0	16.8	6
10.6	+	10.2	+	11.4	+	7.8	+	0.03	14.3	
11.0	-	10.6	+	11.9	+	8	+	0.07	12.8	
11.1	-	10.7	-	12.1	-	8	-	0.09	10.8	
11.1	-	10.7	-	12.1	+	8	-	0.1	8.8	
11.0	-	10.7	-	11.9	+	8	-	0.11	6.8	
10.5	+	10.3	+	11.2	+	7.9	+	0.12	4.8	
14.6	+	14.1	+	15.3	+	11.9	+	0	16.8	10
14.7	-	14.3	+	15.6	+	11.9	+	0.03	14.3	
15	-	14.6	-	16.1	-	11.9	=	0.07	12.8	
15.1	-	14.7	-	16.3	-	12	-	0.09	10.8	
15.1	-	14.7	-	16.3	-	12	-	0.1	8.8	
15.1	-	14.8	-	16.2	-	12	-	0.11	6.8	
15.9	-	14.6	-	15.7	+	11.9	+	0.12	4.8	
16.6	+	16.1	+	17.3	+	13.7	+	0	16.8	12
16.8	-	16.4	+	17.7	+	13.9	-	0.03	14.3	
17	-	16.6	-	18.2	-	13.9	-	0.07	12.8	
17.1	-	16.7	-	18.3	-	14	-	0.09	10.8	
17.1	-	16.8	-	18.3	-	14	-	0.1	8.8	
17.2	-	16.8	-	18.3	-	14	-	0.11	6.8	
17.0	-	16.7	-	17.9	+	13.9	+	0.12	4.8	
18.6	+	18.1	+	19.3	+	15.7	+	0	16.8	14
18.8	-	18.4	-	19.8	+	15.9	-	0.03	14.3	
19	-	18.6	-	20.2	-	16	-	0.07	12.8	
19.1	-	18.7	-	20.3	-	16	-	0.09	10.8	
19.1	-	18.6	-	20.3	-	16	-	0.1	8.8	
19.2	-	18.7	-	20.3	-	16	-	0.11	6.8	
19.0	-	18.7	-	20	+	15.9	+	0.12	4.8	
20.6	+	20.1	+	21.3	+	17.7	-	0	16.8	16
20.8	-	20.5	-	21.8	+	17.7	-	0.03	14.3	
21	-	20.6	-	22.2	-	18	-	0.07	12.8	
21.1	-	20.6	-	22.2	-	18	-	0.09	10.8	
21.1	-	20.6	-	22.2	-	18	-	0.1	8.8	

21.1	-	20.7	-	22.4	-	18	-	0.11	6.8	
21.1	-	20.7	-	22.1	-	17.9	+	0.12	4.8	
22.6	+	22.1	+	23.2	+	17.9	+	0	16.8	
22.8	-	22.5	-	23.9	+	19.8	-	0.03	14.3	
23	-	22.6	-	24.2	-	20	-	0.07	12.8	
23	-	22.6	-	24.3	-	20	-	0.09	10.8	18
23.1	-	22.7	-	24.3	-	20	-	0.1	8.8	
23.1	-	22.7	-	24.4	-	20	-	0.11	6.8	
23.1	-	22.7	-	24.1	-	19.9	+	0.12	4.8	

Table3. Cylindrical cup forming, cup height in terms of different lubricant coefficient in different sheet Binder force (Die radius 2.5 mm)

Die force (KN)	Result **5754**	Die force (KN)	Result **5251**	Die force (KN)	Result **5182**	Die force (KN)	Result **1050**	Lubricant coefficent	Displacement (mm)	Binder force (KN)
١٠	+	١٠	+	١١	+	٧,٦	+	0	16.8	
١١	+	١٠	+	١١	+	٧,٨	+	0.03	14.3	
١١	-	١١	+	١٢	+	٨	+	0.07	12.8	
١١	-	١١	-	١٢	-	٨	-	0.09	10.8	6
١١	-	١١	-	١٢	+	٨	-	0.1	8.8	
١١	+	١١	+	١٢	+	٨	+	0.11	6.8	
١٠	+	١٠	+	١١	+	٧,٧	+	0.12	4.8	
١٤	+	١٤	+	١٥	+	١١,٦	+	0	16.8	
١٥	+	١٤	+	١٦	+	١١,٩	+	0.03	14.3	
١٥	-	١٥	-	١٦	-	١١,٩	-	0.07	12.8	
١٥	-	١٥	-	١٦	-	١٢	-	0.09	10.8	10
١٥	-	١٥	-	١٦	-	١٢	-	0.1	8.8	
١٥	-	١٥	-	١٦	-	١٢	-	0.11	6.8	
١٤	+	١٤	+	١٥	+	١١,٧	+	0.12	4.8	
١٦	+	١٦	+	١٧	+	١٣,٦	+	0	16.8	
١٧	-	١٦	+	١٨	+	١٣,٩	+	0.03	14.3	
١٧	-	١٧	-	١٨	-	١٣,٩	-	0.07	12.8	
١٧	-	١٧	-	١٨	-	١٤	-	0.09	10.8	12
١٧	-	١٧	-	١٨	-	١٤	-	0.1	8.8	
١٧	-	١٧	-	١٨	-	١٤	-	0.11	6.8	
١٦	-	١٦	+	١٧	+	١٣,٧	+	0.12	4.8	
١٨	+	١٨	+	١٩	+	١٥,٦	+	0	16.8	
١٩	-	١٨	+	٢٠	+	١٥,٩	-	0.03	14.3	
١٩	-	١٩	-	٢٠	-	١٥,٩	-	0.07	12.8	
١٩	-	١٩	-	٢٠	-	١٦,٠	-	0.09	10.8	
١٩	-	١٩	-	٢٠	-	١٦	-	0.1	8.8	14
١٩	-	١٩	-	٢٠	-	١٦	-	0.11	6.8	
١٩	-	١٩	-	١٩	+	١٥,٧	+	0.12	4.8	
٢٠	+	١٩	+	٢١	+	١٧,٦	+	0	16.8	
٢١	-	٢٠	-	٢٢	+	١٧,٩	-	0.03	14.3	
٢١	-	٢١	-	٢٢	-	١٨	-	0.07	12.8	16
٢١	-	٢١	-	٢٢	-	١٨	-	0.09	10.8	
٢١	-	٢١	-	٢٢	-	١٨	-	0.1	8.8	
٢١	-	٢١	-	٢٢	-	١٨	-	0.11	6.8	
٢١	-	٢٠	-	٢١	+	١٧,٧	+	0.12	4.8	
٢٢	+	٢٢	+	٢٣	+	١٩,٦	+	0	16.8	
٢٣	-	٢٢	-	٢٤	+	١٩,٩	-	0.03	14.3	
٢٣	-	٢٣	-	٢٤	-	٢٠	-	0.07	12.8	
٢٣	-	٢٣	-	٢٤	-	٢٠	-	0.09	10.8	18
٢٣	-	٢٣	-	٢٤	-	٢٠	-	0.1	8.8	
٢٣	-	٢٣	-	٢٤	-	٢٠	-	0.11	6.8	
٢٣	-	٢٢	-	٢٤	+	١٩,٧	+	0.12	4.8	

Table4. Cylindrical cup forming, cup height in terms of different lubricant coefficient in different sheet Binder force (Die radius 3 mm)

Die force (KN)	Result 5754	Die force (KN)	Result 5251	Die force (KN)	Result 5182	Die force (KN)	Result 1050	Lubricant coefficent	Displacement (mm)	Binder force (KN)
١٠	+	١٠	+	١١	+	٧,٥	+	0	16.8	
١١	+	١٠	+	١١	+	٧,٨	+	0.03	14.3	
١١	-	١١	+	١٢	+	٧,٩	+	0.07	12.8	
١١	-	١١	-	١٢	-	٨	-	0.09	10.8	**6**
١١	-	١١	-	١٢	+	٨	+	0.1	8.8	
١١	+	١٠	+	١١	+	٧,٩	+	0.11	6.8	
١٠	+	١٠	+	١٠	+	٧,٦	+	0.12	4.8	
١٤	+	١١	-	١٥	+	١١,٥	+	0	16.8	
١٥	+	١٤	+	١٦	+	١١,٩	+	0.03	14.3	
١٥	-	١٤	+	١٦	+	١١,٩	=	0.07	12.8	
١٥	-	١٥	-	١٦	-	١٢	-	0.09	10.8	**10**
١٥	-	١٥	-	١٦	+	١٢	-	0.1	8.8	
١٥	-	١٥	-	١٦	+	١١,٩	+	0.11	6.8	
١٤	+	١٥	-	١٥	+	١١,٦	+	0.12	4.8	
١٦	+	١٤	+	١٧	+	١٣,٥	+	0	16.8	
١٧	-	١٤	-	١٨	+	١٣,٩	+	0.03	14.3	
١٧	-	١٦	+	١٨	-	١٣,٩	-	0.07	12.8	
١٧	-	١٦	+	١٨	-	١٤	-	0.09	10.8	**12**
١٧	-	١٧	-	١٨	-	١٤	-	0.1	8.8	
١٧	-	١٧	-	١٨	+	١٣,٩	+	0.11	6.8	
١٦	+	١٧	-	١٧	+	١٣,٦	+	0.12	4.8	
١٨	+	١٨	+	١٩	+	١٥,٥	+	0	16.8	
١٩	-	١٨	+	٢٠	+	١٥,٩	-	0.03	14.3	
١٩	-	١٩	-	٢٠	-	١٥,٩	-	0.07	12.8	
١٨	-	١٨	-	٢٠	-	١٦,٠	-	0.09	10.8	
١٩	-	١٨	-	٢٠	-	١٦,٠	-	0.1	8.8	**14**
١٩	-	١٩	-	٢٠	+	١٥,٩	+	0.11	6.8	
١٨	+	١٨	+	١٩	+	١٥,٦	+	0.12	4.8	
٢٠	+	١٨	-	٢١	+	١٧,٥	+	0	16.8	
٢١	-	٢٠	+	٢٢	+	١٧,٩	-	0.03	14.3	
٢١	-	٢٠	+	٢٢	-	١٧,٩	-	0.07	12.8	**16**
٢١	-	٢٠	-	٢٢	-	١٨	-	0.09	10.8	
٢١	-	٢٠	-	٢٢	-	١٨	-	0.1	8.8	
٢١	-	٢٠	-	٢٢	-	١٧,٩	+	0.11	6.8	
٢٠	-	٢٠	-	٢١	+	١٧,٦	+	0.12	4.8	
٢٢	+	٢٠	+	٢٣	+	١٩,٥	+	0	16.8	
٢٣	-	٢٠	-	٢٤	+	١٩,٩	-	0.03	14.3	
٢٣	-	٢٢	+	٢٤	-	١٩,٩	-	0.07	12.8	
٢٣	-	٢٢	-	٢٤	-	٢٠	-	0.09	10.8	**18**
٢٣	-	٢٢	-	٢٤	-	٢٠	-	0.1	8.8	
٢٣	-	٢٢	-	٢٤	-	١٩,٩	+	0.11	6.8	
٢٢	-	٢٢	-	٢٣	+	١٩,٦	+	0.12	4.8	

Table5. Cylindrical cup forming, cup height in terms of different lubricant coefficient in different sheet Binder force (Die radius 3.5 mm)

Die force (KN)	Result 5754	Die force (KN)	Result 5251	Die force (KN)	Result 5182	Die force (KN)	Result 1050	Lubricant coefficent	Displacement (mm)	Binder force (KN)
١٠	+	١٠	+	١٠,٩	+	٧,٥	+	0	16.8	
١١	+	١٠	+	١١,٣	+	٧,٨	+	0.03	14.3	
١١	-	١١	+	١١,٨	+	٨	+	0.07	12.8	
١١	-	١١	-	١٢	-	٨	+	0.09	10.8	**6**
١١	-	١١	+	١١,٨	+	٨	+	0.1	8.8	
١٠	+	١٠	+	١١	+	٧,٨	+	0.11	6.8	
٩	+	٩	+	١٠	+	٧,٤	+	0.12	4.8	

١٤	+	١٤	+	١٤,٩	+	١١,٥	+	0	16.8	**10**
١٥	+	١٤	+	١٥,٥	+	١١,٩	+	0.03	14.3	
١٥	-	١٥	-	١٦,١	+	١١,٩	+	0.07	12.8	
١٥	-	١٥	-	١٦,٣	+	١١,٩	-	0.09	10.8	
١٥	-	١٥	-	١٦,١	+	١٢	+	0.1	8.8	
١٥	-	١٤	+	١٥,٤	+	١١,٨	+	0.11	6.8	
١٤	+	١٤	+	١٤,٤	+	١١,٥	+	0.12	4.8	
١٦	+	١٦	+	١٦,٩	+	١٣,٥	+	0	16.8	**12**
١٧	-	١٦	+	١٧,٦	+	١٣,٩	+	0.03	14.3	
١٧	-	١٧	-	١٨,٢	-	١٣,٩	-	0.07	12.8	
١٧	-	١٧	-	١٨,٣	-	١٤	-	0.09	10.8	
١٧	-	١٧	-	١٨,٢	+	١٤	+	0.1	8.8	
١٧	-	١٦	-	١٧,٥	+	١٣,٨	+	0.11	6.8	
١٦	+	١٦	+	١٦,٥	+	١٣,٥	+	0.12	4.8	
١٨	+	١٨	+	١٨,٩	+	١٥,٥	+	0	16.8	**14**
١٩	-	١٨	+	١٩,٦	+	١٥,٩	+	0.03	14.3	
١٩	-	١٨	-	٢٠,١	-	١٥,٩	-	0.07	12.8	
١٩	-	١٩	-	٢٠,٣	-	١٦	-	0.09	10.8	
١٩	-	١٨	-	٢٠,٣	-	١٦	-	0.1	8.8	
١٩	-	١٨	-	١٩,٦	+	١٥,٨	+	0.11	6.8	
١٨	+	١٨	+	١٨,٦	+	١٥,٥	+	0.12	4.8	
٢٠	+	٢٠	+	٢٠,٩	+	١٧,٥	+	0	16.8	**16**
٢١	-	٢٠	+	٢١,٧	+	١٧,٩	-	0.03	14.3	
٢١	-	٢٠	-	٢٢,١	-	١٧,٩	-	0.07	12.8	
٢١	-	٢٠	-	٢٢,٣	-	١٨	-	0.09	10.8	
٢١	-	٢٠	-	٢٢,٢	-	١٨	+	0.1	8.8	
٢١	-	٢٠	-	٢١,٧	+	١٧,٨	+	0.11	6.8	
٢٠	-	٢٠	+	٢٠,٧	+	١٧,٥	+	0.12	4.8	
٢٢	+	٢٢	+	٢٢,٩	+	١٩,٥	+	0	16.8	**18**
٢٣	-	٢٢	-	٢٣,٨	+	١٩,٩	+	0.03	14.3	
٢٣	-	٢٢	-	٢٤,١	-	١٩,٩	-	0.07	12.8	
٢٣	-	٢٢	-	٢٤,١	-	٢٠	-	0.09	10.8	
٢٣	-	٢٢	-	٢٤,٢	-	٢٠	+	0.1	8.8	
٢٣	-	٢٢	-	٢٣,٧	+	١٩,٨	+	0.11	6.8	
٢٢	-	٢٢	+	٢٢,٨	+	١٩,٥	+	0.12	4.8	

4. Conclusion

In this study, the effect of changes in binder force and lubricant coefficient on the deep drawing process of O-1050, O-5182, O-5251, O-5754 aluminium cylinder cup was investigated.
The designed model in Catia software is imported in the auto-form simulation software for analysis. Deep drawing process analysis for European standard aluminium sheets was performed. At different heights for the cylindrical cup and for the radius of the punch head and the bottom of the Die was investigated and the results were presented in Tables 2-5.
1 - With increasing the shear force in each material, the required force for the Die increases.
2 - With increasing lubrication coefficent in each process, the deep drawing strength of the sheet with the constant tensile force, for a shorter tensile depth, the required force for the matrix increases.
3- It can be seen in sheet o-5182 that the lower the gripping force of the sheet, the better the drawing sheet without tearing in compare with other sheets.
4. The ductility of o-5182 sheet was better than other sheets.
5 - Punching force with increasing the coefficient of lubrication decreased and this was due to reduced material displacement and premature rupture of the cup.
6- The results indicate that with increasing the shear force, the percentage of material reduction decreases and this behavior was also observed with increasing the coefficient of friction.

Compliance with Ethical Standards

Conflict of interest The authors state that they are not involved in any conflict of interest.

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