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Numerical Analysis of Process Parameters in Deep Drawing Operation

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ABSTRACT— Deep drawing is a sheet metal forming process which is widely used in manufacturing parts for automobile and aircraft industries of good strength and light weight. There are many process parameters and other factors that affect product quality produced by deep drawing. In this project, the effect of the geometrical parameters involved and the defects encountered in the process are presented and discussed. Wrinkling and tearing are common surface defects in sheet metal forming. It is unacceptable in the industries. Due to the rejection of the defective part, there is wastage in the production process, not only in terms of time but money as well. So, the prediction and prevention of defects becomes necessary. The problem was that wrinkles appear on the curved surface of part along with cracking in some of the parts during the drawing operation. Therefore, it was necessary to find out the forming limit diagram so as to minimize losses.

KEYWORDS: Deep drawing, process parameters, wrinkling, forming limit diagram.

I. INTRODUCTION

Sheet metal forming is a significant manufacturing process for producing large variety of automotive parts and aerospace parts as well as consumer products. Deep drawing is one of the widely used sheet metal working processes in the industries, to produce cup shaped components at a very high rate. Cup drawing, besides its importance as forming process, also serves as a basic test for the sheet metal formability. Thus, the deep drawing process involves complex deformation mechanisms. The parameters that affect the success or failure of a deep drawing operation are the blank holder force (BHF), punch force and punch speed, limit drawing ratio, friction, blank shape, forming limits, stress and strain distribution, and thickness variation.

II. RELATED WORK

The formability of five heats of locally made aluminum-killed EDD low carbon steel sheets was characterized by Ravi et al. in terms of their microstructure, mechanical characteristics, and forming limit diagram (FLD) [1]. Using the LS-Dyna code, S. K. Singh et al. carried out a number of simulations of the deep drawing process by altering the punch speed while maintaining the other parameters [2]. Mark Colgan et al. studied the deep drawing operations by combined experimental and finite element analysis [3]. R. Narayanasamy et al. proposed a non-dimensional parameter index to show the limiting draw ratio for thin sheet materials [8].

III. MODEL DEFINITION

The geometry of the cup is first decided and the whole setup of the deep drawing components is designed around it. The dimensions are presented in table 1. The modeling geometry is presented in fig 1.

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Table1. Dimensions of the deep drawing setup

Parameters	Dimension(mm)	Parameters	Dimension(mm)
Punch diameter	38	Die fillet radius	3
Blank diameter	60	Friction coefficient	0.1
Blank thickness	1	Clearance between die and punch	0.5
Punch fillet radius	3		

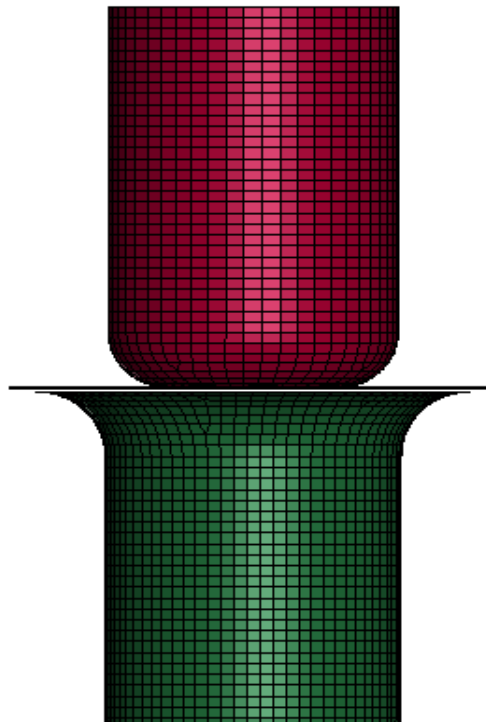


Fig. 1. Finite Element Model of Deep Drawing Setup

IV. MATERIAL DEFINITION

Aluminum (AA6061) is used as the blank material for this investigation. It is a soft, durable, light weight, malleable metal with an appearance ranging from silvery to dull grey, depending on the surface roughness. Aluminum is non-magnetic and non-sparking. It is also insoluble in alcohol, though it can be soluble in water in certain forms. Aluminum has about one-third the density and stiffness of steel. It is ductile and easily machined, cast, drawn and extruded. Corrosion resistance can be excellent due to a thin surface layer of aluminum oxide that forms when the metal is exposed to air, effectively preventing further oxidation. The strongest aluminum alloys are less corrosion resistant due to galvanic reactions with the alloyed copper. The strength of the aluminum alloys exceeds the strength of mild steel. The important factors in selecting aluminum and its alloys are their high strength-to-weight ratio, resistance to corrosion by many chemicals, high thermal and electrical conductivity, nontoxicity, reflectivity, appearance, and ease of formability, machinability, and their nonmagnetic nature. It has excellent drawing and forming properties. Mechanical properties are shown below in table 2 and chemical composition is shown in table 3.

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Table2. Physical Properties of AA6061

S.NO	PROPERTIES	VALUES
1	Ultimate tensile strength	320 MPa
2	Tensile yield strength	276 MPa
3	Poisson ratio	0.33
4	Melting point	582 - 652 °C
5	Modulus of elasticity	68.9 GPa
6	Density	2.7 g/cc

Table3.Chemical Composition of AA6061

S.NO	Element	Composition %
1	Al	96
2	Si	2.1
3	Mg	0.95
4	Fe	0.33
5	Cu	0.17
6	Cr	0.066
7	Mn	0.04
8	Ti	0.022
9	Zn	0.014
10	Ni	0.014
11	Ga	0.013
12	Bal	<0.01

V. FINITE ELEMENT SIMULATION AND THEIR RESULTS

It is a computerized numerical analysis for solving complex mathematical models mostly in mechanical engineering for stress analysis. It involves calculation of resultant displacement, energy distribution, Forming Limit Diagram throughout the model which is discretized in the form of mesh. A 3-d axisymmetric model is chosen for the creation in Pro-e and analysis is carried out in LS-DYNA. LS-DYNA is a general-purpose finite element program capable of simulating complex real-world problems. It is used by the automobile, aerospace, construction, military, manufacturing, and bioengineering industries. In preprocessor, input model such as die, blank, blank holder, and punch were constructed. After surface generation, the surface of the tool components is fine-meshed. Figure 1 depicts the complete model in the pre-processor.

The two different material definitions are used namely 'deformable' and 'rigid'. Deformable is the blank and rigid are the rest of their parts in the model. FLD is a concept established by Keeler and Goodman that depicts the deformation ability of a sheet metal at various strain settings prior to necking or failure. According to Dieter et al. [7], In the Fig.2,

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FLD clearly separates three regions: forming, necking, and fracture based on the greatest principal strain evolved during the forming procedure.

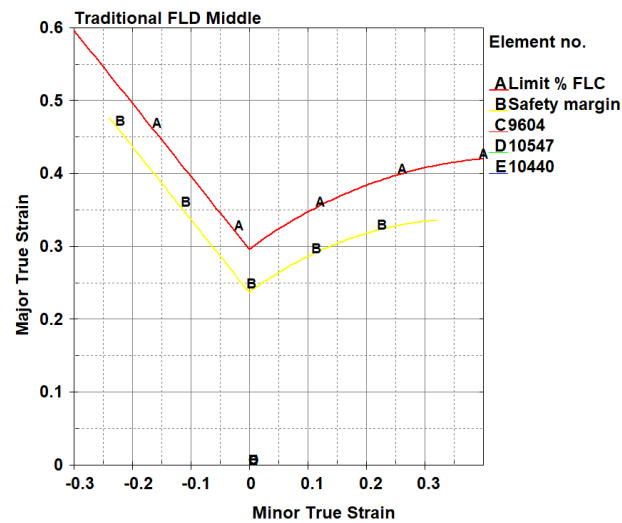
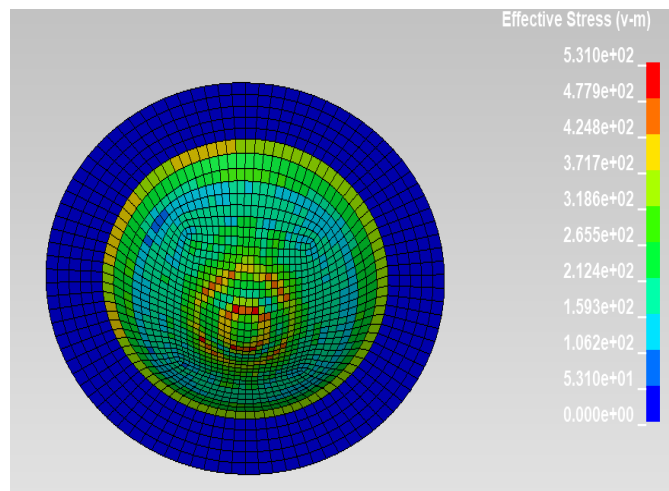


Fig.2. Forming limit Diagram



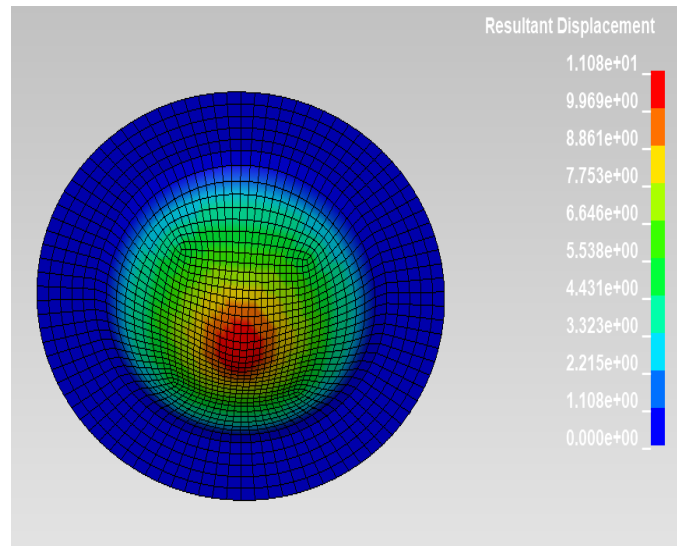
(a)

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(b)

Fig. 3. The results of finite element analysis: (a) Effective Stress (b) Effective Displacement

VI. CONCLUSION

The deep drawing process was modelled in LS-DYNA. Using the explicit simulation algorithm LS-DYNA, the following findings were obtained: displacement, effective stress distribution, and Forming Limit Diagram (FLD). The effects of these factors were examined.

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