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EXPERIMENTAL AND NUMERICAL ANALYSIS OF SPRINGBACK IN DEEP DRAWING PROCESS

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ABSTRACT

Many products in the automotive industry are produced with the deep drawing process. When the tools are released after the forming stage, the product springs back due to the action of internal stresses. Because the geometric tolerances can be tight for sheet metal products, this shape deviation can be unacceptable. In many cases spring back compensation is needed: the tools of the deep drawing process are changed so, that the product becomes geometrically accurate. In the industry, this is currently a costly and time consuming process of producing prototype products and redesigning the tools manually.In the case of deep drawing process, the spring back is an important phenomenon that leads to the modification of the part shape and dimensions after the tools removing. For this reason, in order to obtain a drawn part with a good accuracy of the shape and dimensions, this phenomenon must be controlled. The main cause of the spring back phenomenon is represented by the residual stress distribution on the sheet thickness of the drawn part. Hence, in order to control the spring back, the residual stress distribution on sheet thickness must be known and controlled. In this project an analysis was made concerning the influence of the residual stress distribution on the spring back intensity in the case of cylindrical drawn parts made from steel sheet[1][23][32].

Deep drawing is a process for shaping flat sheets into cup-shaped articles without fracture or Excessive localized thinning. The design and control of a deep drawing process depends not only on the work piece material, but also on the condition at the tool work piece interface, the mechanics of plastic deformation and the equipment used. This project describes the use of ABAQUS finite element code in sheet metal forming simulation on circular cup deep drawing. It presents FEM based predictions in cup drawing simulation of aluminum alloys. In order to use the model in sheet metal forming simulations we have implemented it in a general purpose finite element code ABAQUS Two aluminum alloys, namely AA6061. and AA 7075 have been used for a validation of the model. For both alloys Simulations are done to study forming of AA6061, AA7075 aluminum sheets and study of variation of cup Height with temperature[6][7][9].

Keywords :Deep drawing,Simulation.

I. INTRODUCTION

Sheet Metal Forming

Casting, machining, powder metallurgy forming and are some of the important manufacturing processes used in engineering. In casting, a liquid material is poured into a mould and then allowed to solidify in order to get the desired shape. By casting even a very big and complex parts like engines of heavy vehicles can be made. Machining is next to casting and the required shape can be obtained by removing excessive material from the work piece in the form of chips. Cutting tool is used for removing material from the piece while cooling fluid dissipates the heat generated from the process. In powder metallurgy articles can be produced by compacting the metal powder under required temperature. The last method is metal forming. Out of four important metal forming processes i.e., Casting, machining, forming and powder metallurgy, metal forming is a major family where the plastic property of a metallic materials is utilized to form them into useful shapes[6].

Metal forming is further classified into sheet forming and bulk forming. Sheet forming is a type of metal forming by which bends, shallow and deep recessed shapes can formed from a sheet metal. The initial work piece is in sheet form generally called blank has a large surface area to volume ratio in contrast to the "billet" used in bulk forming which has low surface area to volume ratio. Another difference is that the stretching is predominant in sheet forming process, while compression is predominant in bulk forming[8].

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II. DEEP DRAWING

Deep drawing process of sheet metal is an essential means for forming of cup shaped components often having ample applications in automobile, beverage, aerospace, kitchen utensils, cartridge bases and zinc dry cells. This process underwent lot of research in last two decades. In essence, the competitive environment is still demanding for further high strength, light weight and thin walled parts in particular. In Deep drawing process a punch is utilized to force a flat sheet metal (blank) to flow into the gap between the punch and die surfaces. As a result, the blank can be formed into the various shapes. A sheet metal may be drawn into simple cylindrical-, conic- and boxed-shaped part and also complicated parts which normally require redrawing processes using progressive dies. Deep drawing process is popular due to its rapid process cycle times and its capability of producing complicated axisymmetric as well as non-axisymmetric geometries in few operations with low technical labors requirement[7].
The important variables which affect the formability and outcomes of deep drawing can be grouped into two categories:

- Material and friction factors; and
- Tooling and equipment factors.

Proper selection of these variables is crucial in deep drawing to maximize the formability of the sheet metal while reducing undesirable outcomes which includes earing and defects such as wrinkling. The design and control of a deep drawing process depends not only on the work piece material, but also on the condition at the tool work piece interface, the mechanics of plastic deformation and the equipment used.

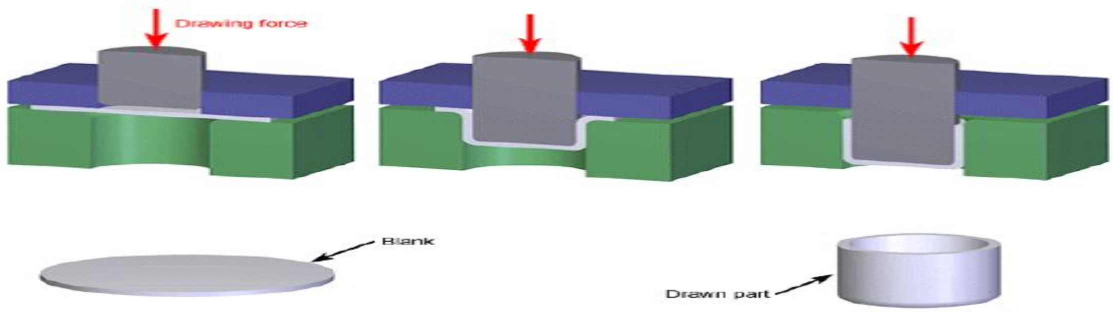

Figure 1 Conventional Deep Drawing Process

In the deep drawing process, flat sheet of metal called blank is placed over the die, and with the help of the punch, blank is pressed into the die cavity. Blankholder applies pressure to the blank in the flange region during the deep drawing process. The basic tools for the deep drawing process are as shown in Figure 2.

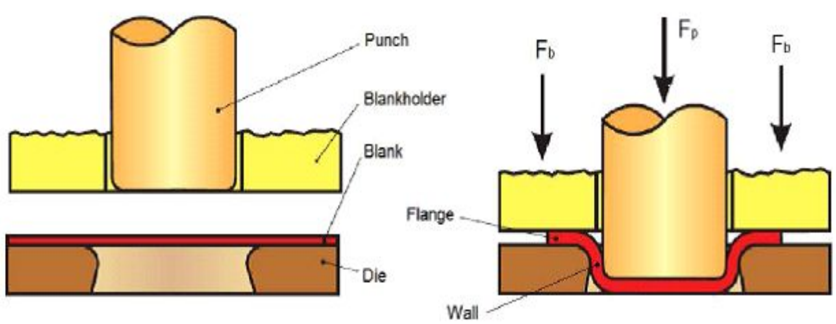

Figure 2 Basic Tools in Deep Drawing

Deep Drawing is widely used in industry for producing automobile, aircraft body parts, household applications and auxiliary parts in construction field. The method is very suitable for producing large amount of simple shaped parts, like cups, cans, vessels, etc. Deep drawn parts are shown in the Figure 2.

Deep drawing is affected by many factors, like material properties, tool selection, lubrication etc and improper selection of one or more factors leads to failure of the cup either in the form tears or wrinkles during the process[1].

Earing, necking, wrinkling, and poor surface appearance are the main failure types that can be seen in deep drawing process as shown in Figure 1.6. Tearing and necking are tensile instability caused by strain localization. The strength of the part is reduced and the appearance worsened because of tearing and necking. Another failure is wrinkling, caused by compressive stresses unlike to tearing and necking. Plastic buckling occurs because of the high compressive stress and waves formed on the part. The other one is earing. The main reason for earing is planar plastic anisotropy. Also other defects like orange peel, galling marks, ring prints, traces, and Luders strips are possible due to improper selection of influencing parameters.

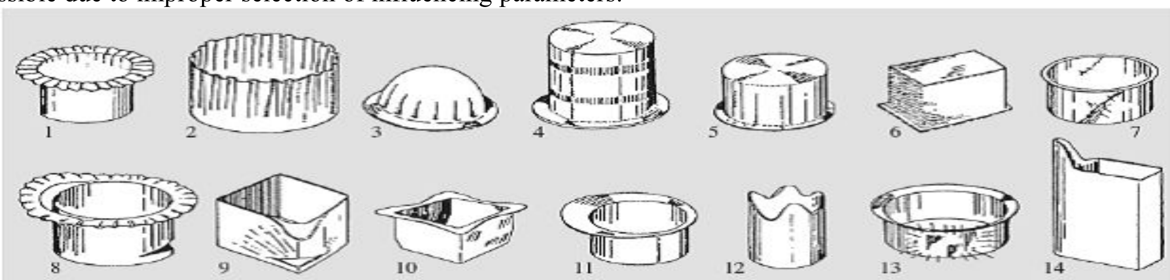

Figure 3 various failure modes in Deep Drawing

1-Flange wrinkling; 2-Wall wrinkling; 3-Part wrinkling; 4-Ring prints; 5-Traces; 6-Orange skin; 7-Lüder's strips; 8-Bottom fracture; 9-Corner fracture;10,11,12-Folding; 13,14-Cornerfolding.

A part wrinkled during the deep drawing process, will not be accepted and most likely become a scrap, a total waste of both money and time. Because of these reasons, wrinkling must be prevented. There are two main methods used in order to prevent wrinkling. The former is using a blankholder. Blankholder is a tool used for preventing the edge of a sheet metal part from wrinkling. There are two main blankholder types available namely, clearance and pressure type blankholder. In the former, the sheet metal kept at a constant thickness by adjusting fixed distance between blankholder and die, during the process and wrinkling is prevented. In the latter, force is applied to the blank from the blankholder, called blank holder force (BHF), in order to prevent wrinkling. Adjusting the BHF is very important, because high BHF leads to fracture at the cup wall and low BHF leads to wrinkling in the flange of the cup. The other method is using drawbead in the flange region. Drawbeads are placed to the die (small protrusions on the die surface) in order to control the flow of the material during the forming operations. The material fills the groove, this results in a change in the strain distribution in the flange region. Thinning of the blank is achieved and compressive stresses are decreased so wrinkling is avoided.

In manufacturing processes the main goal is to obtain defect free end product. The first step of manufacturing is the designing process, which enormously affects the whole manufacturing process. The designer must have knowledge about possible problems and their solutions during production. Many Researches have been completed in various manufacturing processes because of the knowledge needed to achieve better quality product. This thesis will discuss about LDR determination and check safe levels of strain developed with standard FLD for commercially available aluminum sheet metal[12].

III. CONCEPT OF DEEP DRAWING PROCESS

Sheet metal is a thin and flat piece of metal with thickness ranging between 0.15mm and 6.5mm. It is widely used in engineering to produce a large variety of products which includes containers, beverage cans, household applications, automotive parts, and aircraft panels. Sheet metal may be formed into desired geometry using various processes which includes deep drawing, shallow drawing, bending, blanking and stretch forming. The present study involves the study of deep drawing process[6].

Deep drawing is a process to form sheet metals using deep drawing die. A punch is used to force the sheet metal to flow into the gap between the punch and the die. As a result, a cylindrical-, conical- or box-shaped part is formed in the die with minimal material wastage. One of the most common examples of deep drawing is the cup-drawing operation. It is used to produce products such as cartridge bases, zinc dry cells, metal cans and steel pressure vessels. It is also used as a method for formability test of sheet metals such as the Swift cupping test.

There are two types of process in deep drawing: Pure drawing and ironing. Pure drawing is a deep drawing process without reduction of thickness of blank, whereas ironing is a deep drawing process with blank thickness reduction. The layout of a typical deep drawing die is as shown in Fig 3 (a) for pure drawing process. However, some products cannot be drawn in a single draw and requires secondary drawing operations which involve ironing process. As a result, the design of the die will be more complicated as a progressive die is normally required to allow multiple drawing operations under one production line.

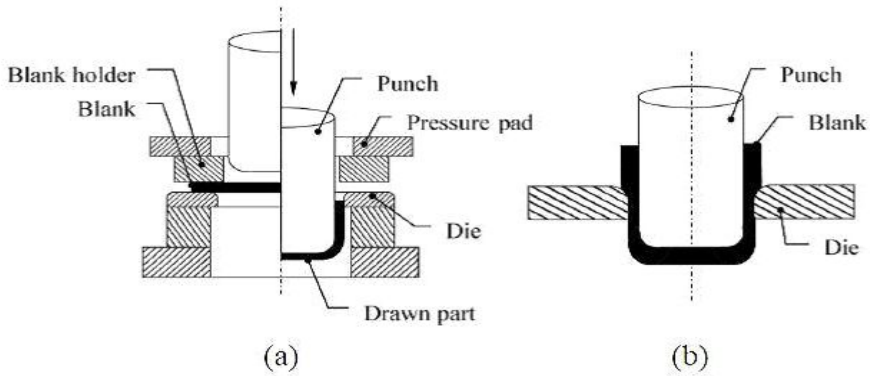

Figure 3 A schematic illustration of drawing process: (a) Pure Drawing; (b) Ironing.

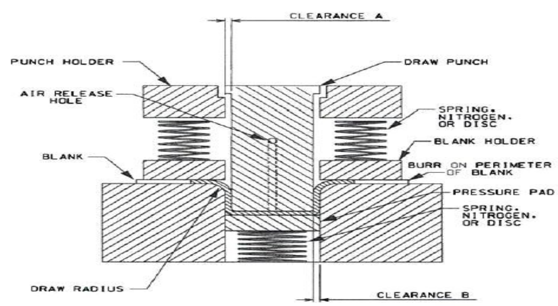

Figure 3.1 Constructional features of a typical deep drawing die.

Parameters of Deep Drawing

To describe the different interaction of the parameters in deep drawing for producing a cylindrical cup the following notations have been used.

D_0**:**Diameter of a circular sheet blank.
t_0: Thickness of the circular sheet blank.
R_d: Corner radius of the die opening.
Dp: Punch diameter.
R_p: Corner Radius of the punch.
W_p: Plastic Work required for deep drawing
V_0: Initial volume of blank to be drawn
V_c: Volume of drawn cup.
R : Drawing Ratio Do/Dp.
ε : The effective strain.
σ : Effective stress.

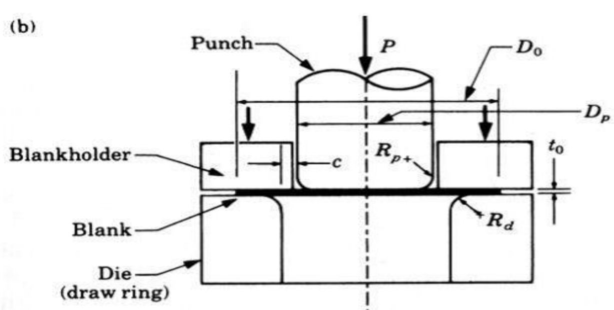

Figure 4 Variables in deep drawing of a cylindrical cup

As shown in Fig. 4 the blank is held in place with a blank holder, or hold-down ring, with a certain force. The punch moves downward and pushes the blank into the die cavity to form a cup[18].
Only the punch force is dependent variable, while significant independent variables are:
1. Properties of the sheet metal
2. The ratio of blank diameter to punch diameter *R* .
3. Sheet thickness.
4. The clearance between the punch and the die.
5. Punch and die corner radii.
6. Blank holder force.
7 Friction and lubrication at the punch die, and workplace interfaces.
8. Speed of the punch

Finite Element method (FEM) for Deep Drawing Simulation

Finite element analysis (FEA) technique had become a rapid and cost-effective tool for forming process and it significantly reduces the development time and cost associated with it. In essence, in depth research has been focused on development of proper FEA models in order to accurately predict the forming behavior and failure modes. Determination of optimal temperature for warm forming of sheet material is indeed essential requisite in order to achieve desired size, process robustness and productivity.

The most used numerical method for numerical simulation of the forming process is finite elements method (FEM). The numerical simulations included the evaluation of the influence of various factors on the production process, the analysis of various test geometry, as well as the evaluation of loads on the production process. Finite element method (FEM) is being gradually adopted by industry to predict the formability of sheet metals. Sheet metal forming operation involves complex physical mechanisms that give rise to a high order non-linear problem. A part from the nonlinearity induced by the contact and the friction, there is a geometrical non-linearity caused by large displacement and large deformation. Furthermore, non-linear material behaviors such as plasticity make the problem even more difficult to be solved analytically. Therefore, numerical techniques, such as FEM, are usually used to deal with this kind of problem. FEM can provide not only the final results, but also the information of intermediate steps, like the distributions of displacement, stress, strain and other internal variables[24].

IV. RESULTS AND DISCUSSION

In this study, forming of pure aluminum has been analyzed using CGSA and two different aluminum alloys has been simulated for circular cup drawing using ABAQUS. It has been confirmed that higher cup depth is possible at elevated temperatures.
The following studies are made and plotted

1. Forming limit diagram of pure aluminum
2. Deep drawing simulation of AA6061 Sheet metal
3. Deep drawing simulation of AA6061 Sheet metal
4. Study of Forming at Room Temperature of AA6061.
5. Study of forming at Room Temperature of AA7075.
6. Study of variation of cup Height with temperature.
7. Study of relationship between punch velocity & deformation

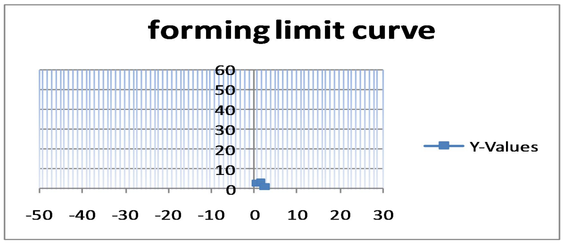

Fig 5.1forming limit diagram of pure aluminum diagram of pure aluminum

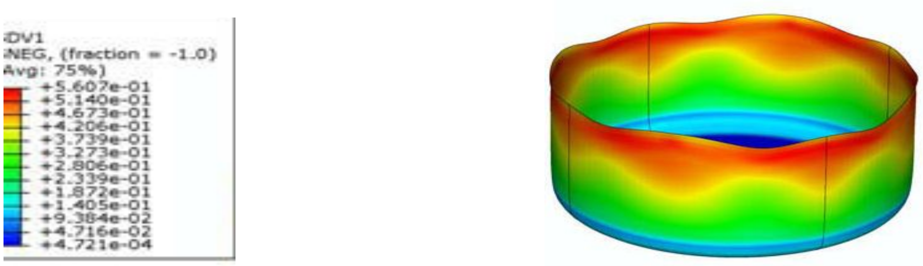

Figure 5.2 Deep drawing of AA6061 Sheet metal

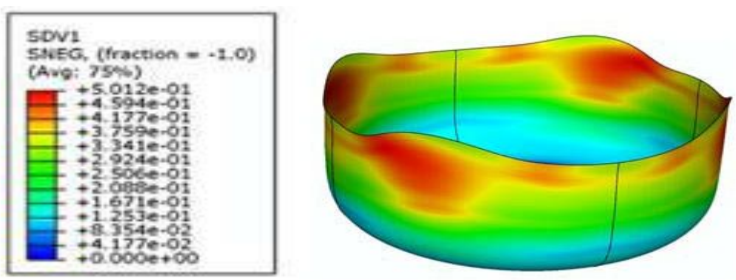

Figure 5.3 Deep drawing of AA7075 Sheet metal

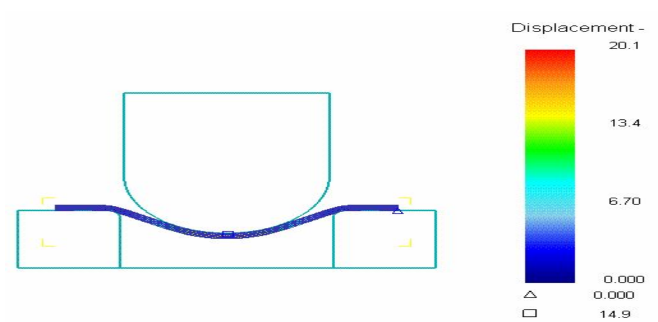

Figure 5.4Forming at Room Temperature of AA6061

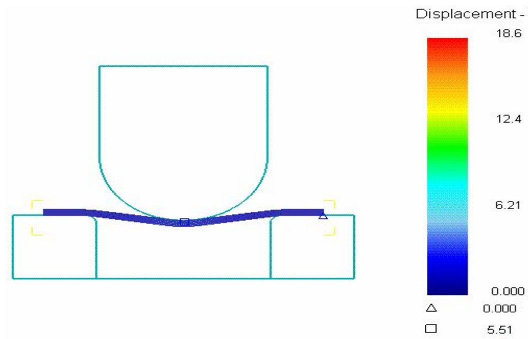

Figure 5.5 Forming at Room Temperature of AA7075

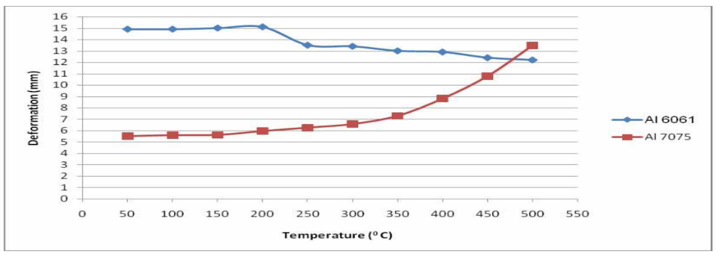

Figure 5.6Graph between cup height and temperature

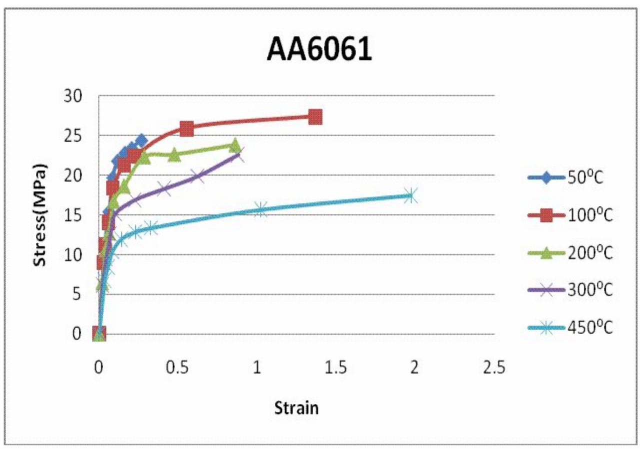

Figure 5.7 Stress –strain curve for AA 6061

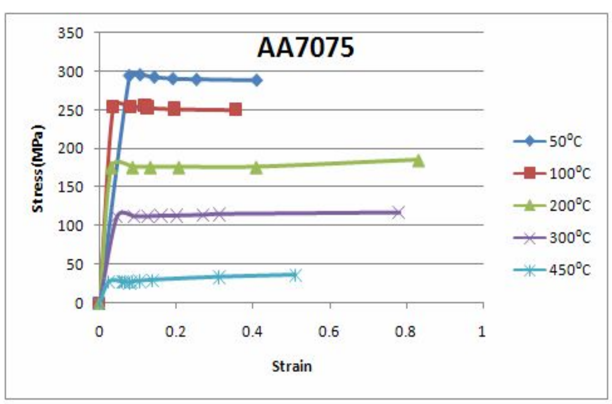

Figure 5.8 Stress-strain curves for AA 7075

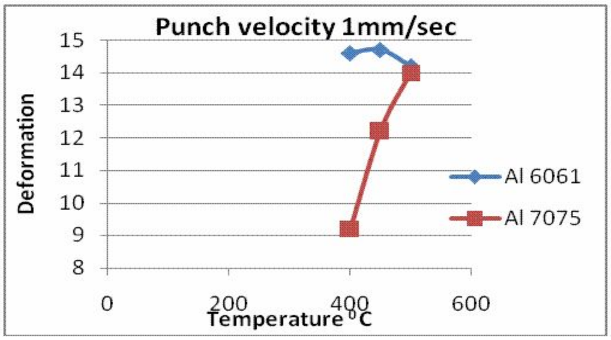

Figure 5.9 Punch velocity 1mm/sec

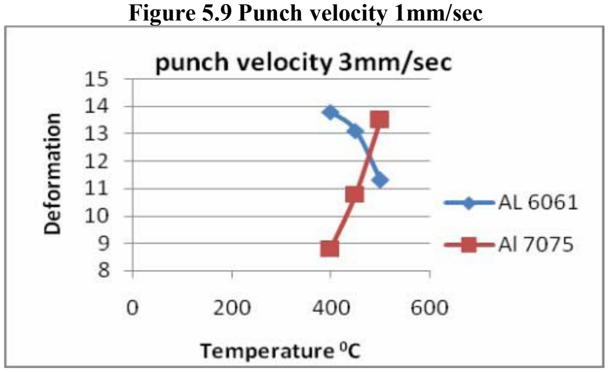

Figure 5.10 Punch velocity 3mm/sec

Table 5.1 Tool and process parameters for simulation

S.No	Temperature			LDR
	Blank	Die	Punch	
1	25	100	25	1.95
2	100	100	25	2.10
3	200	100	25	2.25
4	300	100	25	2.35

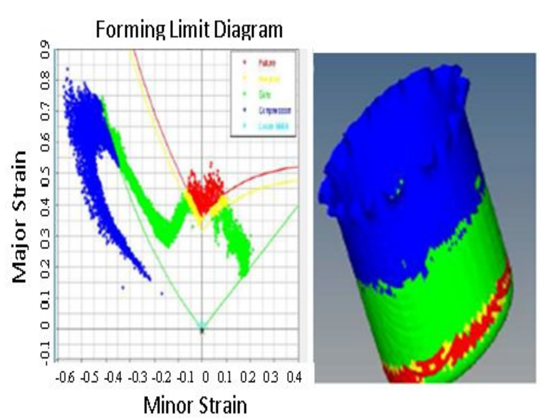

Fig.5.11 form limit diagram and fem model

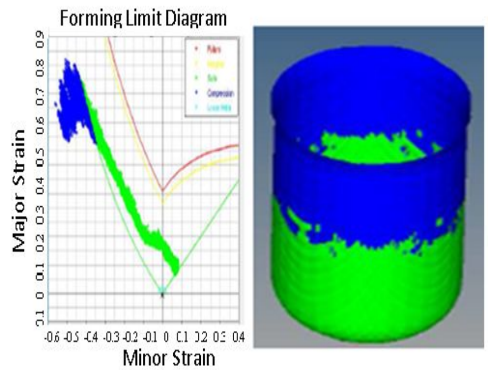

Fig.5.12 form limit diagram and fem model

COMPARISON OF EXPERIMENTAL AND FEM RESULTS

FEM results: It had been found that the LDR is increased significantly with increase in temperature. By doing deep drawing at elevated temperature LDR of more than 2 can successfully achieved without any failure. In addition the amount of blank holder force/pressure can be considerably reduced. It can be observed from the experimental as well as the simulation results that the raise in temperature increases the FLD and the strains in both cases are reduced and not crossing the limiting strains as it can be revealed from the forming limit diagram shown in Fig 5.11. Maximum strain induced is in safer zone and it can be clearly observed from Fig 5.12

CONCLUSION

The deep drawing at higher temperature is one of the important techniques used for increasing LDR in production of high quality defect free products. Both experimental and simulation results showed that the formability is superior at higher temperatures and greater LDR. The results are in good agreement with the results found in literature. It is recommended to use simulation study extensively before going for real production in order to reduce large amount of time and money.

In this paper a study concerning the influence of residual stress distribution on the spring back intensity was performed by using the finite element simulations. By analyzing the results it can be shown that the deviations of the geometric parameters of the drawn parts determined by spring back depend on the bending moment generated in the drawing stage. But this bending moment is determined by the distribution of residual stresses in the sheet thickness. Hence the distribution of residual stresses in the sheet thickness determines the spring back intensity.

FUTURE SCOPE

In contrast to the present isothermal conditions executed in the simulation study non-isothermal conditions may be implemented in order to bring close relations between experimental and simulations, as non-isothermal conditions are involved in practical conditions due to loss of heat from the blank. It has to be tested for improvement if any due to non-isothermal conditions of tools set up.

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