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Finite Element Simulation of Deep Drawing of Aluminium Alloy Sheets

M.Yashwanth Kumar[1], Ravisandeep Kumar. K[2], B. Abhimaan[3]

[1,2]Guru Nanak Institute of Technology, Ibrahimpatnam, R.R District, Telangana, India
[3]Swami Vivekananda Institute of Technology,Secunderabad, Hyderabad, Telangana, India

Abstract— *More and more automobile companies are going for weight reduction of their vehicles for fuel economy and pollution control. At elevated temperatures aluminum sheet alloys 6061 and 7075, the blank temperature effect on forming behavior and damage factor of these sheets is the objective of the present study. In automotive parts the aluminum alloys have good corrosion resistance, high strength to weight ratio and low formability of aluminum sheets limits in some products with complex shapes. The elevated forming process is intended to overcome this problem. An insight into such a study will throw light on the different temperatures required by the above materials when they are made into TWBs. Using ANSYS a series of simulations were carried out in the present investigation on the formability behaviour of deep drawing of aluminium alloys in the temperature range 200-500°C.*

Keywords— ***Deep Drawing, Geometric modeling, Simulation, Deflection, Stress intensity, Aluminium alloys 6061 and 7075, Ansys software, Manufacturing process.***

I. INTRODUCTION

Casting, machining, welding and metal forming are the main methods of manufacturing. Metal forming is process, applying force to the piece forms the material shape used for achieving complex shape products and improving the strength of the material. During forming, little material is wasted compare to other manufacturing processes. Sheet metal forming is done by many ways such as shearing and blanking, bending stretching, spinning and deep drawing. These methods are widely used for producing various products in different places of industry. The parts manufactured by sheet metal forming are widely used in automotive and aircraft industries. Deep drawing is one of the most important sheet metal forming processes. A 2-d part is shaped into a 3-d part by deep drawing. 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. Blank holder applies pressure to the blank in the flange products of aluminium alloy sheets is still limited because region during the deep drawing process. Deep drawing is affected by many factors, like material properties, tool selection, lubrication *etc*. Because of these factors, some failures may occur during the process. Tearing, necking, wrinkling, earing and poor surface appearance are the main failure types that can be seen in deep drawing. 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. On the walls of the totally drawn part earing can be seen. The main reason for earing is planar plastic anisotropy. Also the last defect types, which poorly affect the appearance of the sheet metal part, are ring prints, traces, orange skin (or orange peel structure), and Lauders strips. 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 researchers have been completed in various manufacturing processes because of the knowledge needed to achieve better quality product. This thesis will discuss finite element analysis of deep drawing of aluminum alloys at elevated temperatures.

II. PROBLEM DEFINITION

More and more automobile companies are going for weight reduction of their vehicles for fuel economy and pollution control. Now a day, there is a great concern about weight reduction of automobile due to increased production of aluminium alloy with better formability. Aluminium alloy sheets are being widely employed in making components for automobile and shipbuilding due to their excellent properties such as high specific strength, corrosion resistance and weld ability. Although cast aluminium alloys are being employed for a considerable number of components, the use of forming the formability of aluminium alloy sheet is still poor due

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to lack of understanding of flow behavior during deformation.

III. METHOD OF STUDY

The work piece materials chosen for this study are aluminium alloys AA6061 and AA7075.

Aluminium 6061 is a precipitation hardening aluminium alloy containing magnesium and silicon as its major alloying elements. Originally called "Alloy 61S," it was developed in 1935.[1] It has good mechanical properties and exhibits good weldability. It is one of the most common alloys of aluminium for general-purpose use.

Composition and properties of aluminium are shown below:

Table-1 Composition of Aluminium Alloy AA 6061

Element	**Amount (wt %)**
Al	97.9
Mg	1.0
Si	0.6
Cu	0.8
Cr	0.2

Table-2 Properties of Aluminium Alloy AA 6061

Poisson's ratio	0.33
Elastic modulus (GPa)	70-80
Tensile strength (Mpa)	115
Yield strength(Mpa)	48
Elongation (%)	25
Hardness (HB500)	30
Thermal expansion (10^{-6} / °C)	23.4
Thermal conductivity (W/mK)	180

Aluminium alloy 7075 is an aluminium alloy, with zinc as the primary alloying element. It is strong, with strength comparable to many steels, and has good fatigue strength and average machinability, but has less resistance to corrosion than many other Al alloys. Its relatively high cost limits its use to applications where cheaper alloys are not suitable.

The composition and properties of aluminium 7075 are shown as

Table-3 Composition of Aluminium Alloy AA 7075

Element	**Amount (wt %)**
Al	90.0
Mg	2.5
Zn	5.6
Cu	1.6
Cr	0.23

Table-4 Properties of Aluminium Alloy AA 7075

Poisson's ratio	0.33
Elastic modulus (GPa)	70-80
Tensile strength (Mpa)	220
Yield strength(Mpa)	95
Elongation (%)	17
Hardness (HB500)	60
Thermal expansion (10^{-6} / °C)	23.2
Thermal conductivity (W/mK)	130

IV. EXPERIMENTAL METHOD

In this study, V-cup drawing simulations were performed. All the simulations were performed with blank of 20mm diameter with 5mm thick sheets of aluminium 6065 and 7075 sheets. The motion at both the ends of blank are constrained in both X and Y directions. For each material a series of cups were drawn at temperature range 200-500^{0}C. In this deep drawing, study has been performed using ANSYS software for determining the formability behaviour of aluminium alloys at elevated temperatures and a set of results have been formulated. Now a days, designers and manufacturers are preferring simulation of process before implementation of actual process as this provides more information related to the process performance to evaluate the effect of different process variables during process that result in saving material and manufacturing cost. In this context, a deep drawing model has been formulated using finite element code.

The first main step is selection of model type. As simulation of deep drawing is structural type, therefore structural analysis is selected. A solid brick of 8 node 185 model has been created using element type. Solid brick is directly selected to make problem simple and easy. Before creating the volume of required model, material properties like Young's modulus, Poisson's ratio, Density and Secant co-efficient should be given. To solve FEM oriented problem suitable material properties are required. After material properties are given volume is created directly with required values, since the element type is solid brick.

Geometric modelling is done in preprocessing step. Analyzing and solution is done in post processing step. All the results are auto saved in post processor of the software. As the volume is created, the total area is to be meshed and before meshing the element, mesh tool is selected and element edge length is entered and then the model is meshed. As nodes are created problem can be solved quickly and loads can be applied on required nodes easily. Element edge length is specified so that the

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discretized length will be equal and uniform. After meshing is done, load is applied on the model. By applying load the model should be constrained. The model is constrained in all directions linearly and rotationally. The main purpose of constrain is the model will not move in restricted direction and deformation don't effect in that particular directions. As nodes are created after meshing, force and temperatures are applied on selected nodes of the model.

After applying loads of required values then the model is analyzed. To obtain solution, problem should be solved. The given problem is solved by ANSYS software itself. The required equations and SI units are installed in the software. Therefore the problem is solved and solution is obtained with correct SI units. Therefore the required results are obtained from post processor.

V. RESULTS AND DISCUSSIONS

Solutions in ANSYS provide the ability to simulate every structural aspects of a product, including linear static analysis that simply provides stress or deformations. The fidelity of the results is achieved through the wide variety of material models available, the quality of the elements library, the robustness of the solution algorithms and the ability to model every product, from single parts to very complex assemblies with hundreds of components interacting through contacts or relative motions.

Each color in deformation and stress intensity nodal solution represents the damage level. Where blue represents minimum damage and red represents maximum damage at required nodes. After meshing i.e. element will be discretization. Therefore at each node the solution will be displayed in X, Y, Z directions. The first graph is drawn between distance and deflection and the second graph is drawn between distance and stress intensity

The set of results that has been formulated using ANSYS at elevated temperatures are displayed further.

RESULTS FOR ALUMINIUM–6065

At 200^{0}C

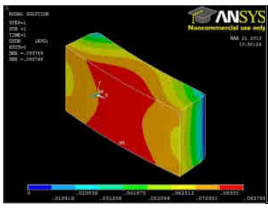
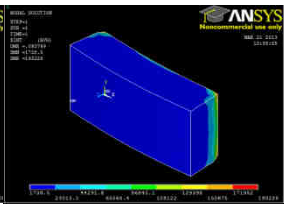

Fig. 1: *Deformation* *Fig. 2:* *Stress Intensity*

GRAPHS

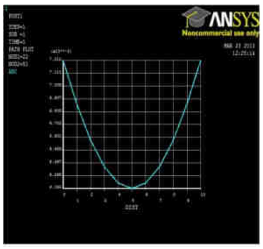
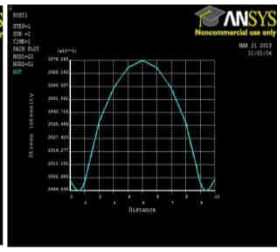

Fig. 3: *Distance Vs Deflection* *Fig. 4:* *Distance Vs Stress Intensity*

At 500^{0}C

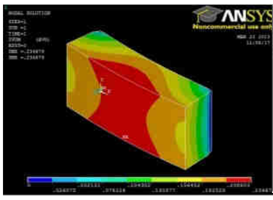
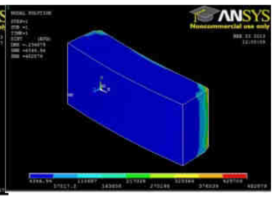

Fig. 5: *Deformation* *Fig. 6:* *Stress Intensity*

GRAPHS

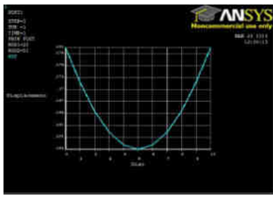
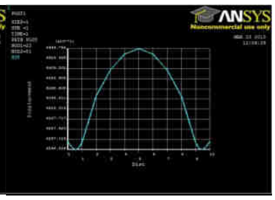

Fig. 7: *Distance Vs Deflection* *Fig. 8:* *Distance Vs Stress Intensity*

RESULTS FOR ALUMINIUM-7075

At 200^{0}C

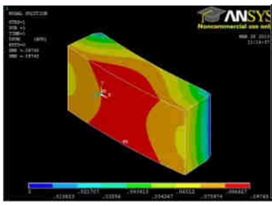
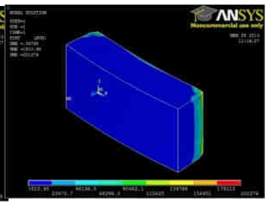

Fig. 9: *Deformation* *Fig. 10:* *Stress Intensity*

GRAPHS

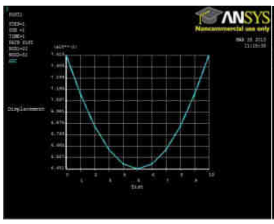
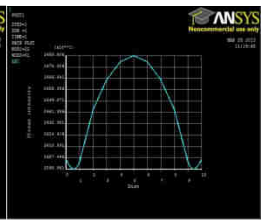

Fig. 11: *Fig. 12:*

Distance Vs Deflection Distance Vs Stress Intensity

At 500^{0}C

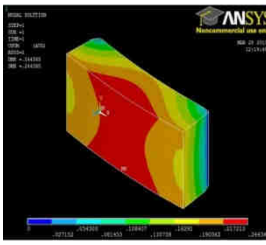

Fig. 13: Deformation

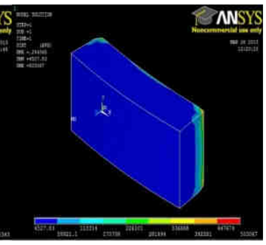

Fig. 14: Stress Intensity

GRAPHS

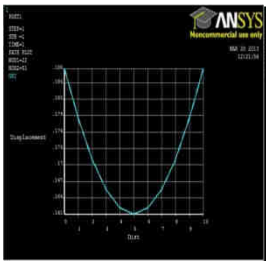

Fig. 15: Distance Vs Deflection

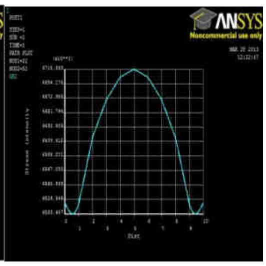

Fig. 16: Distance Vs Stress Intensity

The induction principle was employed to decrease the heat-affected zone (HAZ) and improve process performance. Elevated temperatures not only increased the ductility but also decreased the spring back thus improving the quality of the product. The same material, tool and process parameters were used to produce cups under dynamic heating conditions. The two aluminum sheets were heated to different temperatures ranging from 200-500^{0}C. Under the uniform temperature condition, the cup height increased with increase in temperature. The multipurpose code of ANSYS is suitable for doing the finite element simulations of the formability of aluminum sheets at various temperatures since it can handle coupled thermo mechanical models.

Figure- shows the graph between cup height and temperature

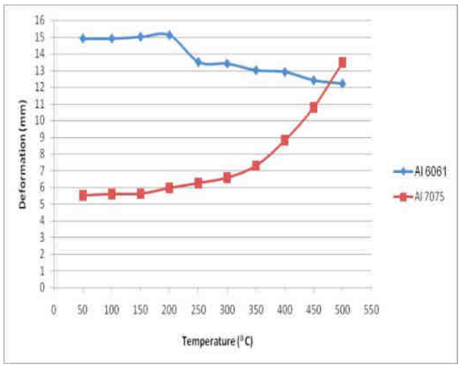

Fig. 17: Graph between Cup Height and Temperature

It is found that the draw ability of AA 6061 remains almost same and in the case of AA7075 it has stated to improve up to a temperature of 450^{0}C. At 450^{0}C the cup height was almost same for both materials.

From 200^{0}C to 250^{0}C there is a sharp decrease in draw ability of AA 6061. It may be because AA 6061 comprises magnesium and silicon as major alloying elements. As the temperature increases these alloying elements restricts the draw ability of alloy.

It is thus inferred that, if the temperature is maintained at 450^{o}C for a blank with material combinations of AA6061 and AA7075, a more or less equal deformation can be achieved.

VI. CONCLUSIONS

In this study, forming of two different aluminum alloys has been simulated for V-cup drawing using ANSYS. Use of ANSYS makes the simulation process easy as the software is user friendly flexible and economical. ANSYS also gives accurate and precised results. It has been confirmed that higher cup depth is possible at elevated temperatures. It is inferred that AA 6061 is having better formability than AA 7075 at initial temperatures, but at elevated temperatures both the materials are having approximately equal formability. The optimum temperature at which both the blanks will have identical maximum uniform cup depths has been found during deep drawing.

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