STAMPING SIMULATION STUDY ON AL-6061 ALLOY USING FEA APPROACH

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ABSTRACT

Roof header made of Al-6061 alloys an important component in a passenger car. It is the roof headers profile that plays an important role in giving the befitting elegance to an automotive vehicle. The key features of the roof header are built in using the stamping operations of a sheet metal of light alloys like Al. 6000 series. During the stamping process it's of utmost importance to ensure all the key features in the roof header die gets impressed to the closest tolerance. It is equally important to ensure good surface finish during the stamping operation. All the above factors discussed in this section are mainly controlled by the stamping process parameters. Ram velocity, clamp holding pressure, the uniformity in the thickness of the sheet metal, the design of the die and the punches are some of the important parameters to control in order to ensure high quality roof header. Optimizing the stamping process for the metals in producing high quality roof headers is time consuming and very expensive because of much Iteration involving several combinations of the designs of the die and the punch and the work piece materials. In the light of the above: researchers are currently adopting FEA based software's to overcome the challenges associated with the stamping process. With the advent of high computing technologies, complex shaped sheet metal profiles for automotive applications can be modeled with ease and can be imported to FEA solvers for design optimization studies of die and tooling's . In this regard the present work focuses on the use of ANSA. For modeling of roof headers, dies, punches and blank holders. For roof header, tooling and dies the modeling and assembly is carried out using ANSA modeling software and Stamping simulations are solved using LS-Dyna. Its been observed from the present study that with the increase in the thickness of the sheet, the resultant displacement of the sheet gets along the Z direction marginally. With the initial increase in thickness of the sheet the plastic strain and the max. von misses stress decreases up to a certain thickness level beyond which there is a further increase in the max. von-Mises stress and the plastic strain. It's been observed that the variation in the clamp holding force has no effect on von misses stress, plastic strain, displacement and on the shear stress. Its been observed that increase in the ram velocity, the von misses stress, max shear stress, plastic strain and displacement along Z direction also increases along with the ram velocity. Further energy changes during the variation in the thickness of the blank, clamp holding forces and the ram velocity have been predicted and are observed to be closely associated with each other.

1. INTRODUCTION

Stamping is very important in aspect for manufacturing of any sheet metal components. In the past decades it has been found that stamping simulation can save lot of metal and also can be cost effective, will make the manufacturing cheaper and with better quality product. In the present study a portion of the roof header is considered of an automotive convertible roof system and it's made up of alloy-Al 6061. An attempt has been made to reduce the metal for

a quality product and comparison study for different thickness of the work piece and with various Ram velocities is presented to understand the forming / stamping urge in the current scenario of the competitive market.

Formability plot shows the cracks and other important aspects for the metal thinning after it is formed. The strain and von-Mises stress plays a major role in the forming process. Many times it's possible to get the risk of cracks in the locations near the transition from concave and convex geometry. A comparative study based on three different parameters and we along with results based on the combination of the parameters tabulated. Following are the parameters considered for the forming / stamping.

1. Variation of Blank Thickness
2. Variation of Clamp Holding Pressure
3. Variation of Ram Velocity.

2. FE MODEL SET UP

FE modelling for the simulation is done using ANSA (Beta-CAE-Systems). For setting up the simulation deck the CAD models are derived from the CAD software. Basically we have 3 parts Punch, Holder and Blank for the simulation. Initially the CAD data of Punch or Die is considered then suitable modifications are made to fit in to other parts like blank die. As in the stamping / forming process of any sheet metal features are the important ones. The features like fillets, bosses, beads, grooves are very vital from the modeling perspective as these are the regions where the forming is very different from normal flat regions. These are the areas where there will be maximum material flow and maximum stress builds up so these regions needs to be dealt with more care. So typically flat regions are modeled with an average element size of 8-10 mm where as the critical features are modeled with extremely finer element size like 2-3 mm. Hence forth the features on die are modelled in detail as shown in Figure 1.

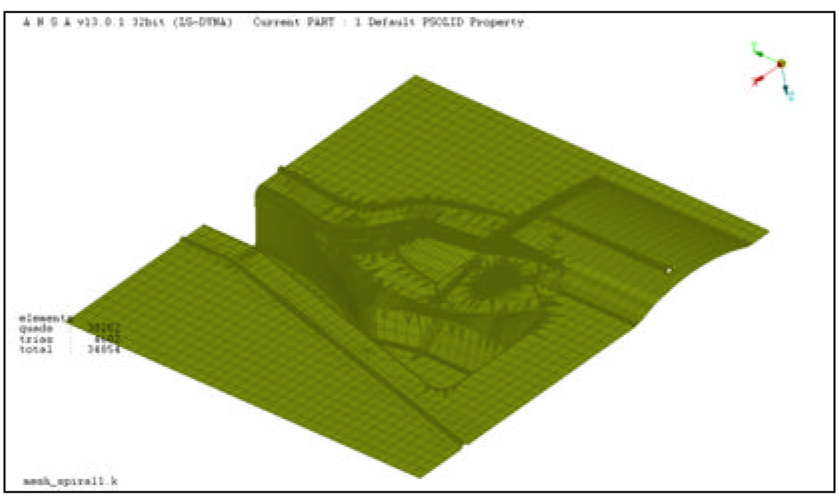

Figure 1- FE-Model of Die with all features captured in detail

Following is the setup shown in Figure 2 for the simulation. The Die & Punch is considered as the rigid ones and work piece is considered as the Linear – Elastic – Plastic.

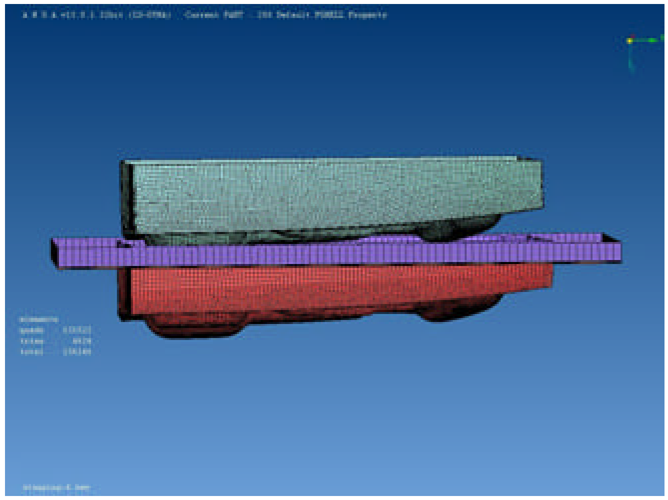

Figure 2- FE Model setup

CONTACTS DEFINED

In this set up there are contacts defined at 4 locations and at all the places the contact which has been used is *Contact_forming_One_Way_surface_to_surface which has been specifically created with a viewpoint of metal forming simulation.
There are 4 locations where these contact pairs are defined and they are.

1. Contact between Punch and die
2. Contact between Die and Blank
3. Contact between die holder and blank
4. Contact between die holder and blank

3. MATERIAL PROPERTIES

There are 2 types of materials used for the whole set up.
Mat18-Mat Power Law Plasticity for Blank.
Mat20-Rigid for Punch, Die, Blank holder.

The material Properties for Aluminium 6061are given tabulated below in Table 1

Table 1: Material Properties of Aluminium 6061

Density	2.6989 g/cc
Youngs Modulus	68 GPA
Poissons Ratio	0.32
Co Efficient of Friction	0.18
Strength Hardening Co Efficient	1538.4
Yield Stress	241 Mpa
Ultimate Tensile Strength	290 Mpa

4. LOADING AND BOUNDARY CONDITIONS

BOUNDARY CONDITIONS

For any Finite element analysis to get a good result its quite essential to define proper constraints and boundary conditions. A proper boundary condition definition ensures that we get a proper result. Basically while defining the boundary condition we try to simulate the FE analysis in a way, which resembles the actual physical process. So in a way resembling actual process we try to replicate the same in the FE model by constraining or arresting some Degrees of Freedom.

In the present case we are constraining all the nodes of die along all 6 degrees of freedom by following this step we are making the die a perfectly rigid. We are also ensuring that the Punch is free to move in all direction so as the blank.

LOADING CONDITIONS

INITIAL VELOCITY OR PUNCH VELOCITY

Here we will be applying the loads to the model set up in 2 ways. The first is the initial velocity or the punch velocity. In this load condition we will be applying the velocity on all the nodes present on the punch along z-axis. Based on specific requirement we will be turning on the velocity and acceleration displacement card. We will be describing the Load CASE ID (LCID) in order to specify the motion value v/s time. We also will be defining a load scale factor.

HOLDER FORCE

The second loading condition which we are going to apply on this model is the clamping holding force or simply know as holding pressure. This we will be applying on the holder, which encircles the blank, which is getting formed. Here also we will be applying a load curve to pre describe the motion pattern in terms of time steps.

5. RESULTS AND DISCUSSIONS

I. EFFECT OF VARIATION OF THICKNESS OF THE BLANK

- **We will be varying the thickness of the blank from 0.75 mm to 1.50 mm with an increment of 0.25mm**
- **The other parameters that will be constant during this iteration will be.**
- **Clamp Force = 500000 N & Ram Velocity = 1500 mm/sec**

Displacements plots with the variation in the thickness of the blank are shown below:

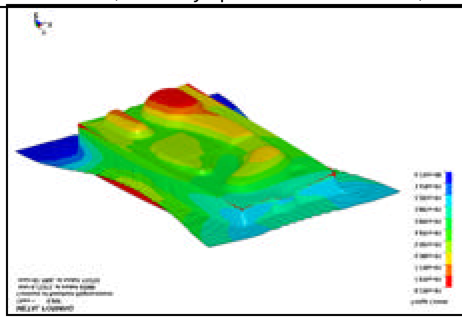

Figure 3 - For Thickness 1.00 mm

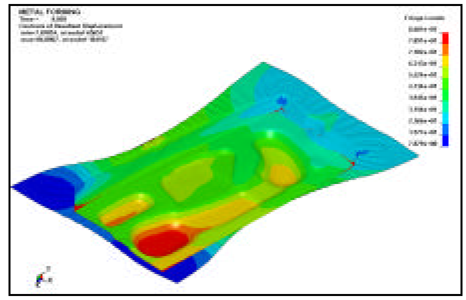

Figure 4- For Thickness 1.00 mm

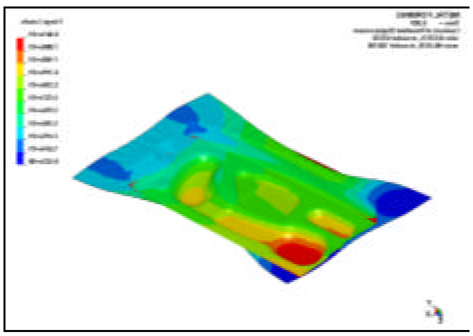

Figure 5 - For Thickness 1.25 mm

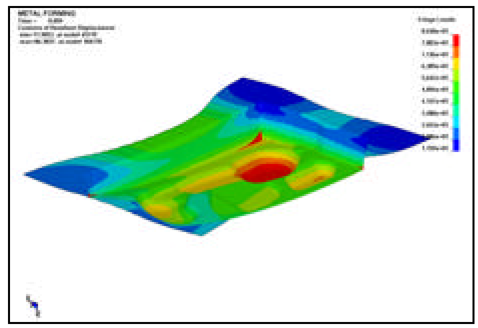

Figure 6 - For Thickness 1.50 mm

Table 2: Comparative results with the variation of the thickness of the blank

Thickness (mm)	Von-Mises Stress (N/mm2)	Pressure (N/mm2)	Plastic Strain	Max.Shear Stress (N/mm2)	Displacement (mm)
0.75	2885.61	631.45	2.79	1666.00	87.20
1.00	2567.19	608.10	2.54	1482.01	86.81
1.25	2537.69	652.786	2.48	1462.83	86.61
1.50	2709.26	630.05	2.61	1555.46	86.30

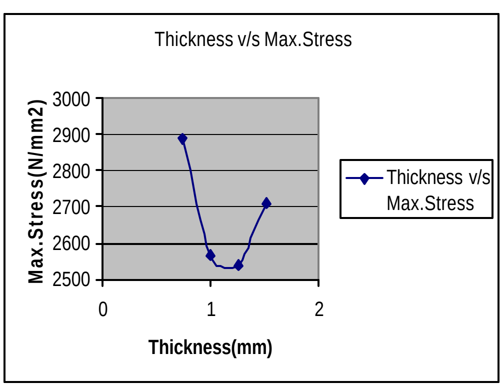

Figure 7- Thickness v/s Max.Stress

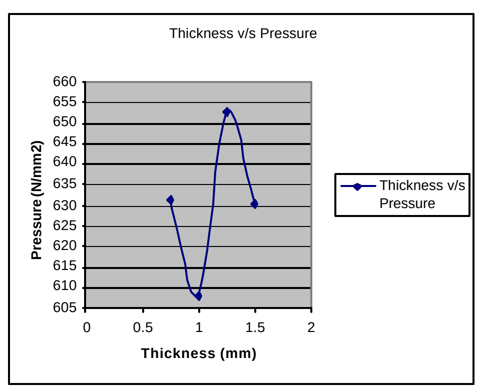

Figure 8 - Thickness v/s Pressure

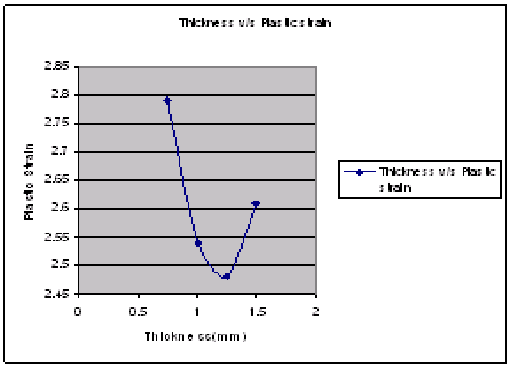

Figure 9 - Thickness v/s Plastic Strain

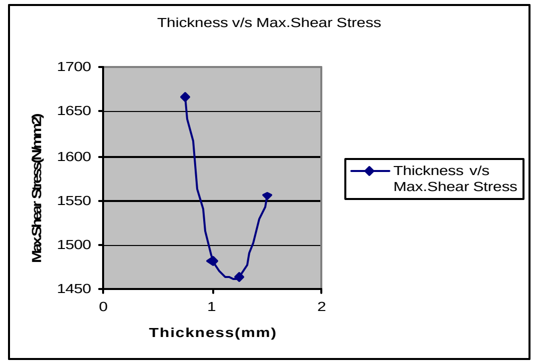

Figure 10- Thickness v/s Max.Shear stress

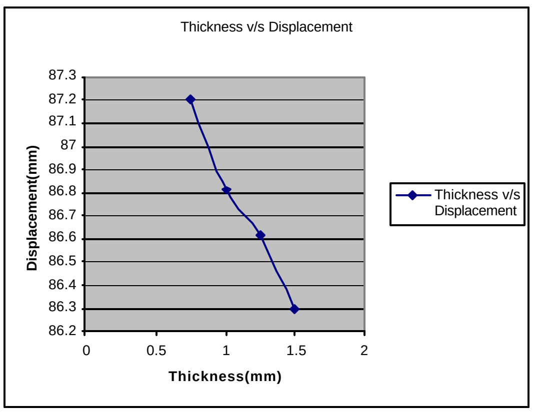

Figure 11 - Thickness v/s Displacement

DISCUSSION ON OBTAINED RESULTS

? From the Fig 7 it's evident that at lower thickness of the blank the von-mises stress will be more, but subsequently as the thickness increases there will be reduction in the von-mises stress considerably. But again once this stage is crossed the stress will again increase even if we increase the thickness of the blank, perhaps this might be due to spring back effect or another cause might be increase in the thickness will result in more bending stress

? From Fig 8 its evident that pressure various heavily with thickness of the blank. To start with as the thickness gets increased the pressure will considerably reduce but soon this trend will gets reversed and there will again be increase in the pressure with the increase in thickness. But in the next subsequent steps these trend continues to exist

? From the Fig 9 it's evident that at lower thickness of the blank the Plastic Strain will be more, but subsequently as the thickness increases there will be reduction in the plastic strain considerably. But again once this stage is crossed the strain will again increase even if we increase the thickness of the blank, perhaps this might be due to spring back effect or another cause might be increase in the thickness will result in more bending stress.

? From the Fig 10 it's evident that at lower thickness of the blank the Max. Shear stress will be more, but subsequently as the thickness increases there will be reduction in the shear stress considerably. But again once this stage is crossed the stress will again increase even if we increase the thickness of the blank, perhaps this might be due to spring back effect or another cause might be increase in the thickness will result in more bending stress

- From the Fig 11 it's quite evident that the resultant displacement will reduce considerably with the increase in the thickness of the blank.

II. EFFECT OF VARIATION OF CLAMP HOLDING FORCE

We will be varying the thickness of the blank from 350 N to 550 N. The other parameters that will be constant during this iteration will be.

- Blank Thickness = 1.5 mm
- Ram Velocity = 1500 mm/sec

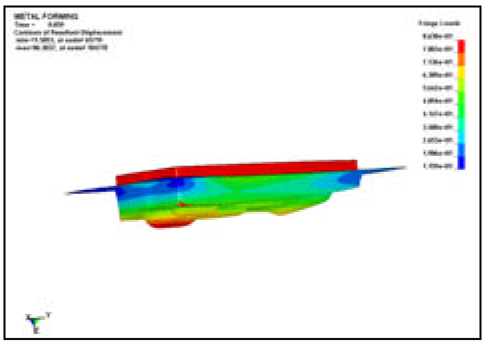

Figure 12 - For Clamp holding force of 350KN

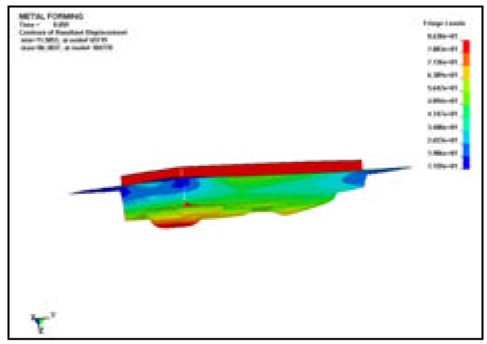

Figure 13- For Clamp holding force of 400KN

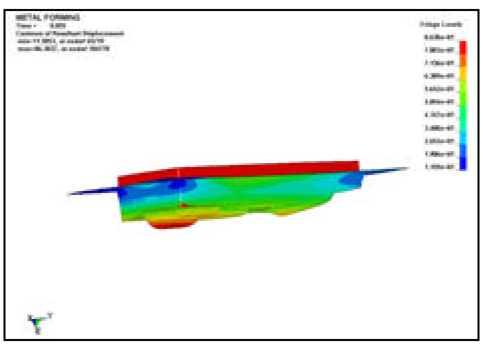

Figure 14 - For Clamp holding force of 500KN

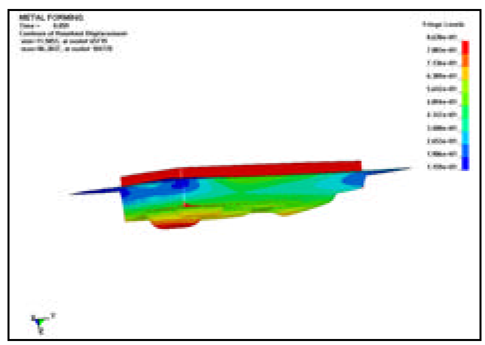

Figure 15- For Clamp holding force of 550KN

Table 3: Comparative results with the variation of the Clamp holding forces of the blank

Clamp Holding Force (N)	Von-Mises Stress (N/mm2)	Pressure (N/mm2)	Plastic Strain	Max.Shear Stress (N/mm2)	Displacement (mm)
350000	2709.26	630.05	2.61	1555.46	86.30
400000	2709.26	630.05	2.61	1555.46	86.30
500000	2709.26	630.05	2.61	1555.46	86.30

550000	2709.26	630.05	2.61	1555.46	86.30

III. EFFECT OF VARIATION OF RAM VELOCITY

- We will be varying the velocity of the ram from 1000 mm/s to 1500mm/s
- The other parameters that will be constant during this iteration will be.
  - Blank Thickness = 1.5 mm
  - Clamp Holding Force = 500 N

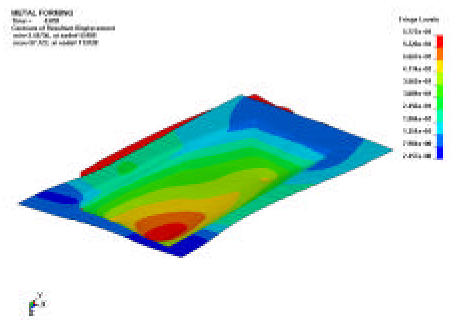

Figure 16 - For ram velocity of 1000mm/s

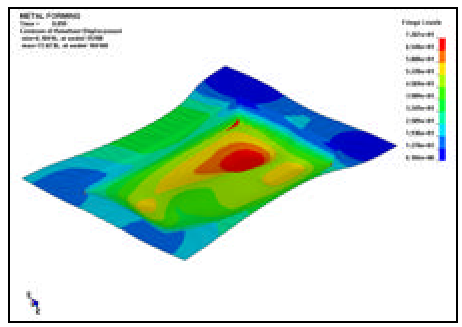

Figure 17- For ram velocity of 1250mm/s

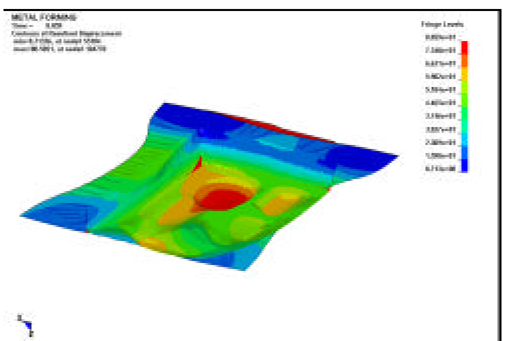

Figure 18 - For ram velocity of 1400mm/s

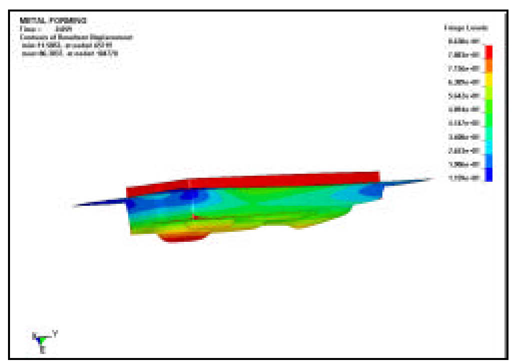

Figure 19- For ram velocity of 1500mm/s

Table 4: Comparative results with the variation of the ram velocity

Ram Velocity (mm/s)	Von-Mises Stress (N/mm2)	Pressure (N/mm2)	Plastic Strain	Max.Shear Stress (N/mm2)	Displacement (mm)
1000	1627.67	448.10	1.31	934.90	57.73
1250	2467.66	550.30	2.32	1377.55	72.08
1400	2632.81	510.16	2.50	1503.73	80.60
1500	2709.26	630.05	2.61	1555.46	86.30

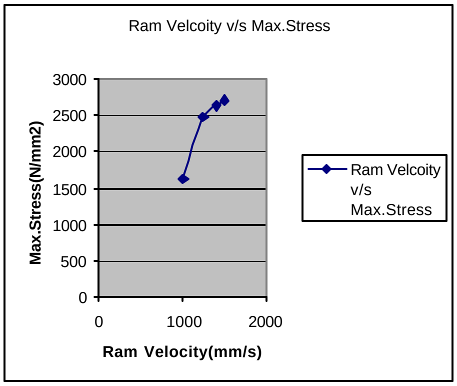

Figure 20- Ram Velocity v/s Max Stress

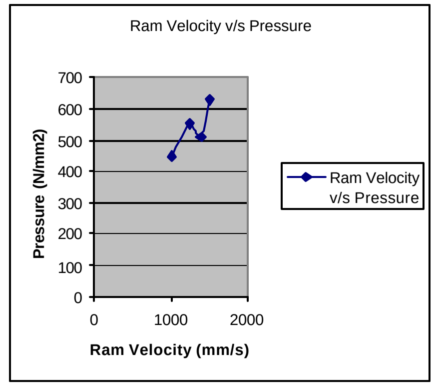

Figure 21- Ram Velocity v/s Pressure

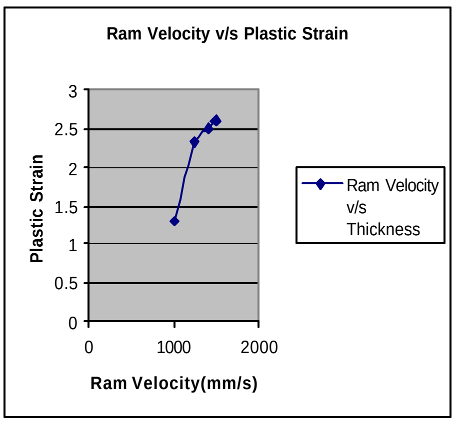

Figure 22 - Ram velocity v/s Plastic Strain

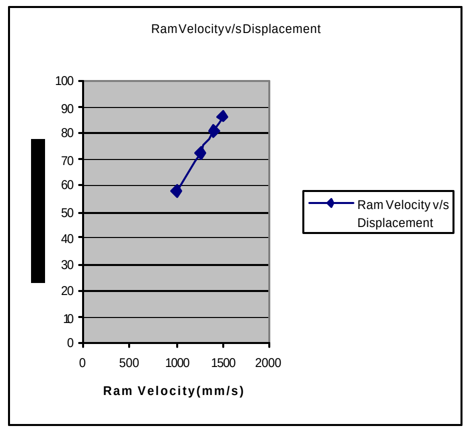

Figure 23- Ram velocity v/s Displacement

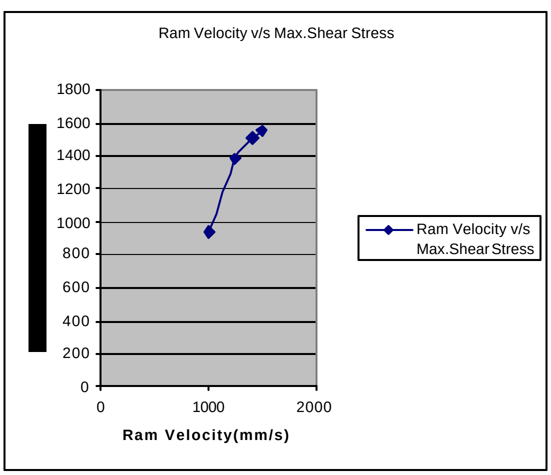

Figure 24 - Ram velocity v/s Max Shear Stress

DISCUSSION ON OBTAINED RESULTS

? From the Figure 20 it's evident that as the ram velocity increases the max stress also increases

- From Figure 21 its evident that pressure various heavily with Ram velocity .To start with as the ram velocity gets increased the pressure will considerably increase but soon this trend will gets reversed and there will be reduction in the pressure with the increase in velocity. But in the next subsequent raise of velocity the pressure will also increase
- From the Figure 22 its quite evident that as the ram velocity increases the plastic strain also increases
- From the Figure 23 it's evident that with increase in ram velocity the displacement also increases.

- From the Figure 24 its evident that as the ram velocity increases the max shear stress also increases

PLOTS FOR THE ENERGY ASSOCIATED WITH THE PROCESS

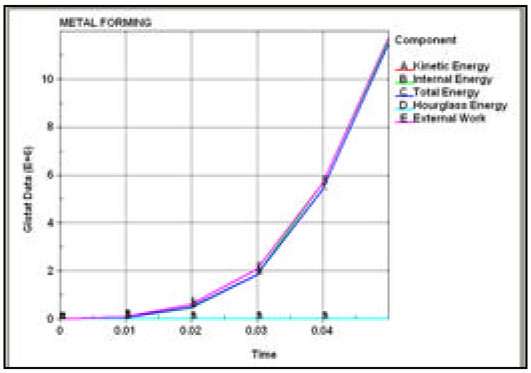

Figure 25- Energy Plot obtained during the variation of the thickness

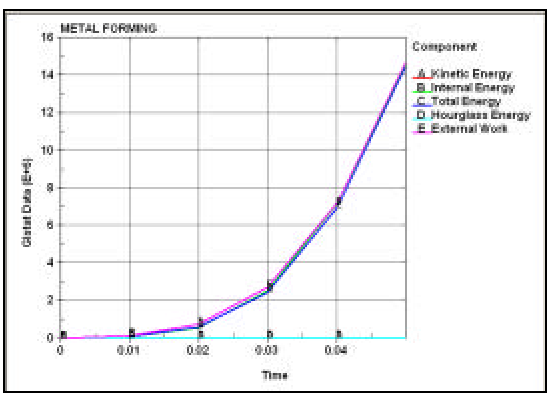

Figure 26-Energy Plot obtained during the variation of Clamp holding Force

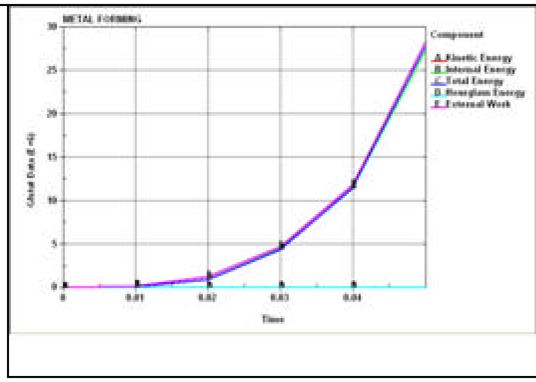

Figure 27- Energy Plot obtained during the variation of Ram Velocity

DISCUSSION ON THE OBTAINED ENERGY PLOTS

The energy balance of a system in an impact is governed by the law of conservation of energy. The Law of Conservation of Energy states that energy within a body or a system can neither be created nor destroyed, but it may only be converted from one form into another, but the total amount of energy never changes.

In case of an impact the kinetic energy possessed by the system in motion is converted into potential energy, sound energy and heat energy. The majority of the converted energy is the potential energy. The amount of this deformation is called the dynamic crush of a vehicle. In other words, the total kinetic energy is absorbed by the seat belt and the dummy, since the energy must be conserved.

Kinetic energy is the work input and internal energy is the work output. Kinetic is the energy possessed by the system in motion and is directly proportional to the product of square of the velocity and mass of the entire system. Internal energy is the energy absorbed by the system and is directly proportional to the product of force and deformation. The energy balance of the entire system for the baseline simulation is shown in the figures.
Hour Glass energy is a mathematical phenomenon which acts in a system during the stamping process.

From the Overall view of the energy plots we can see that the energy system is well balanced as all the energies are closely associated with each other.

6. CONCLUSIONS

1. The Thickness of the material which is getting formed has a major impact on the stresses (Both von-mises as well shear stress). Normally stress will decrease with increase in the thickness of the material but due to the spring back effect and due to high bending stress in high thickness of the blank the thickness of the material the stresses may increase even with if we increase the thickness of the material

2. The thickness of the material have a unique effect on pressure, generally we can see a both positive and negative variation of the pressure with the increase in the thickness of the material
3. The Thickness of the material which is getting formed has a major impact on the Plastic strain. Normally strain will decrease with increase in the thickness of the material but due to the spring back effect and due to high bending stress in high thickness of the blank the thickness of the material the strain may increase even with if we increase the thickness of the material
4. The increase in the thickness of the material reduces the resultant displacement
5. The Clamp holding force bears no effect on the stresses, strains, displacements and pressure, even though we vary holding force all these factors remains unchanged.
6. The Increase of ram velocity significantly increases the stress (Both von-mises and Max.Shear) and its proportional.
7. The Increase in ram velocity also increases the plastic strain
8. The ram velocity when it get increased the resultant displacement also increases
9. The ram velocity have a unique effect on pressure, generally we can see a both positive and negative variation of the pressure with the increase in the ram velocity
10. The pressure increases proportionately with the increase in the ram velocity
11. The overall energies associated with the stamping process are well balanced

7. RECOMMENDATIONS FOR THE FUTURE WORKS

1. Finite element method makes it possible to study the effect of different materials used in the Stamping process and their performance can be evaluated and improved.
2. The spring back effect which occurs during the stamping process can be simulated
3. The overall process of Simulation can be automated for repetitive steps using ANSA and LS-Dyna scripting tools
4. The FEA results can be correlated with real-time test results
5. More study can be done on the energies involved and associated with the overall forming process

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