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Explicit Dynamic Analysis Of Sheet Metal Forming

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Abstract : Sheet metal forming is a process that is now widely utilised in the automotive and aerospace sectors. The forming process is an old industrial technique in which metal is shaped using a punch and die to turn a flat sheet of material into the desired shape and dimension. Using the ANSYS Explicit Solver workstation, the current study evaluated the energy absorption properties of Al- alloys with various sheet thicknesses. ANSYS software is used for CAD modelling and finite element analysis (ANSYS design Modeler). For the material, graphs of Equivalent Stress (Von-misses Stress), Total Deformation, Internal Energy, and Shear Stress are created.

I.Introduction

Out of all the manufacturing process like casting, forming, cutting, joining, sheet metal forming, deep drawing, etc…., sheet metal forming is one of the most adaptable technique used by the manufacturing industries for the production processes. In this technique the work piece is converted into desired shape with no failure or any kind of defect. The formability is different for different materials. Here in this paper we are taking Al-1100 and Al-5083 materials. The parameters like shear stress, internal energy, equivalent stress and total deformation are analyzed using ANSYS explicit solver. The analysis is using a internal energy absorption method to evaluate the results.

Key words: ANSYS, sheet metal forming, CAD, FEM

II.Literature Review

[1] Chung, K and Shah, k required a precise explanation of the behavior of anisotropic material. The results were achieved by utilizing the six component Barlat anisotropic yield function.**[2] joshi, patil and Satao** has performed a optimization of wall thickness variations of the deep drawn cup by combing experimental technique and methodology for the finite element. This approach was dubbed an experimental virtual design. Their research addresses the influence on wall thickness varies in the cup drawing by means of finite element modeling of the radius, metal sheet thickness and blank holding force.**[3] Tommerupet** Researched that the impact on stress route in the stress during the forming process was studied using the blank holder pressure.**[4] jaisinghet.al.** he has recommended that the largest effect on the dilution strain, rubber coefficient, plastic strain ratio is on the blank holder strength. The exponent for strain- hardening is BHF.**[5] Yang et al.** the friction co-efficient, strain distribution has been studied by modeling deep drawing process by integrating the FEM elastic plastic code with a friction model. Numeric findings for the flim thickness and strain distribution are consistent with the experimental results. **Liu Qiqianet. al. [6]**Micro multi-point cushion forming simulation. A finite element model incorporating the influence of the size was created to simulate a micro multi-point formation process.

III.Objectives

Existing sheet metal bending research is mostly centred on stress, with results analysed in terms of stress and strain, as well as a forming limit diagram. However, energy absorption characteristics based on internal energy absorption can be used to examine sheet metal bending. Using ANSYS explicit dynamics, the current study analyses the influence of various design factors such as thickness and punch radius.

IV.Modeling Of Finite Element Analysis

Finite element formulation

A minimal total potential energy formulation is used to create the stiffness matrix. A linear spring with k stiffness is used in this issue, and an external push or pull effect (F) is applied to the right. The change in dimensions of a spring is determined by Δ.

The work accomplished by a single force is

$$W = \Delta . F = \Delta_x * F_x = u\,F$$

$$U = \frac{1}{2} K \Delta_x^2$$

Therefore, the total potential energy (Π) for the loaded spring is

$$\Pi = \frac{1}{2} K \Delta_x^2 - \Delta_x * F_x \quad (5.2)$$

By lowering total potential energy in relation to an unknown displacement, the equation of equilibrium is established, Δ. That is,

$$\frac{\partial \Pi}{\partial \Delta x} = 0 = \frac{2}{2} K \Delta_x - F_x \quad (5.3)$$

This is reduced to the equation below, which is a well-known leaf spring equilibrium equation.

$$K \Delta_x = F$$

The system is modelled as a spring, with the potential energy reduced and a displacement limit applied.

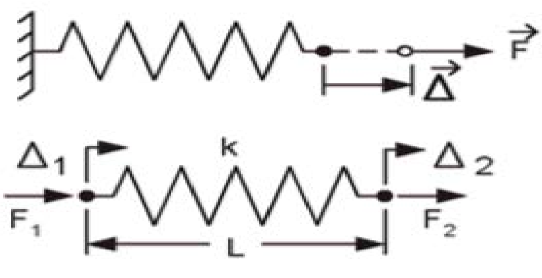


Figure 1: classic and general leaf spring element

$$\{\Delta\}^T = [\Delta_1\ \Delta_2]$$

$$\{F\}^T = [F_1\ F_2]$$

$$W = \{\Delta\}^T\{F\}^T$$

Finite element Simulation

The CAD model of die and sheet metal is developed using ANSYS design modeler with the dimensions specified in literature [4].

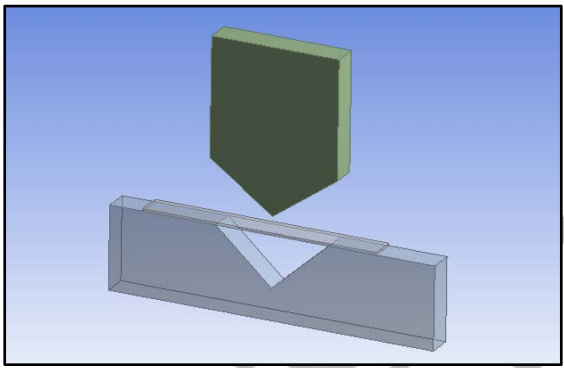
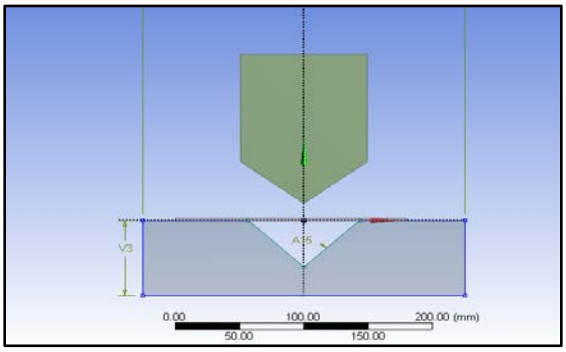
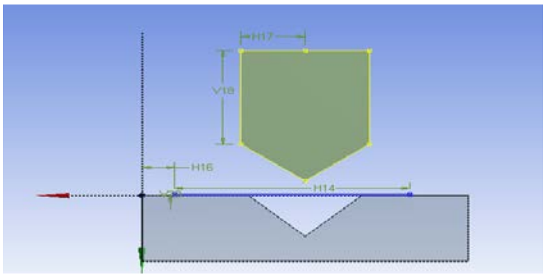


Figure 2: CAD modeling of die, punch and sheet metal using ANSYS design modeler.



Dimensions: 4	
D A15	90 °
D H1	125 mm
H2	125 mm
V3	70 mm

Figure 3: Dimension of Die



Dimensions: 2	
H17	49 mm
V18	100 mm

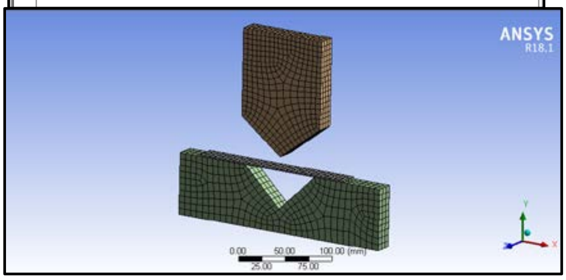


Figure 4: Hexa-hedral Meshing of the model.

As indicated in the picture above, With medium importance and hexahedral components, the model is mesh able. The changeover is designed to be as seamless as possible. The total number of elements and nodes produced is 2147 and 3259, respectively.

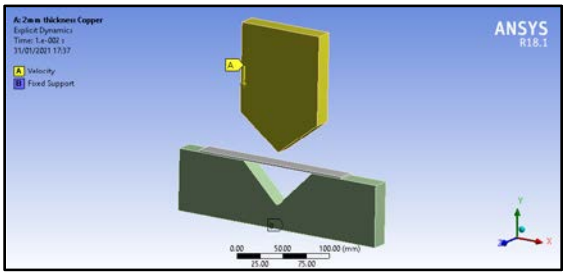


Figure 5: Loads and Boundary Conditions.

On the bottom punch the starting speed of 5.0m/s is applied, as illustrated in yellow and with fixed support the base of a die. With a frictional value of μ=.1 the contact pair between sheet and dying is defined.

Material And Material Properties

Here we are using alloys of Aluminium like Al-1100 and Al-5083 for analysis and simulation process. Aluminium is the most commonly used and commercially available metal. It's light weight and high strength-to-weight ratio make it a good choice for everything from aircraft to flashlights to jigs to just about anything else you can make out of metal.

	A	B	C	D	E
1	Property	Value	Unit		
2	Material Field Variables	Table			
3	Density	2707	kg m^-3		
4	Specific Heat	884	J kg^-1 C^-1		
5	Steinberg Guinan Strength				
14	Shear Modulus	2.71E+10	Pa		
15	Shock EOS Linear				
16	Gruneisen Coefficient	1.97			
17	Parameter C1	5386	m s^-1		
18	Parameter S1	1.339			
19	Parameter Quadratic S2	0	s m^-1		

Figure 6: material properties of Al-1100.

	A	B	C	D	E
1	Property	Value	Unit		
2	Material Field Variables	Table			
3	Density	2700	kg m^-3		
4	Specific Heat	910	J kg^-1 C^-1		
5	Johnson Cook Strength				
14	Bulk Modulus	5.833E+10	Pa		
15	Shear Modulus	2.692E+10	Pa		

Figure 7: material properties of Al-5083.

V. Results And Discussions

Finite element analysis of Al-1100

The deformation plot and equivalent stress plot is obtained at different time intervals for 2mm Al-1100 and Al-5083 alloys. For a 2.0mm Al 1100 thickness metal sheet, the deformation plot and equivalent stress plot were obtained at various time intervals. The maximum deformation of 1.2450mm is exhibited in the deformation curve of Al-1100 sheet metal at 0.3 mili seconds in the picture below.

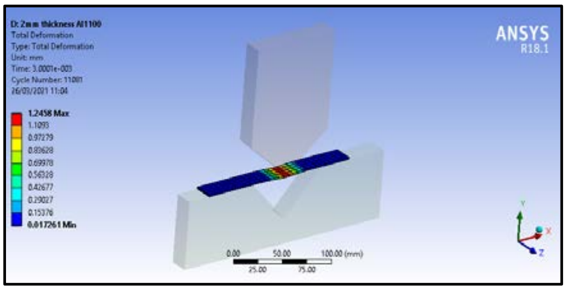


Figure 8: Deformation at 0.3 ms

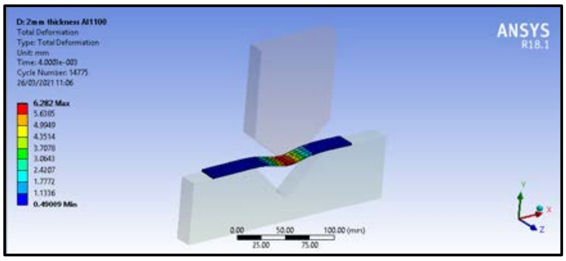


Figure 9: deformation at 0.4 ms

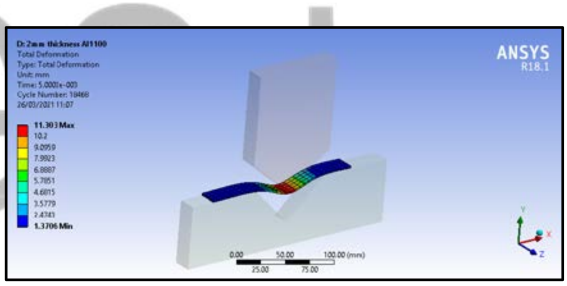


Figure 10: deformation at 0.5 ms

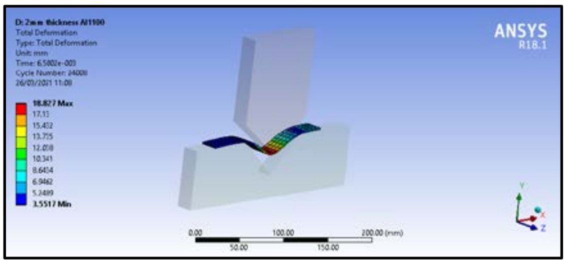


Figure 11 : deformation at 0.65 ms

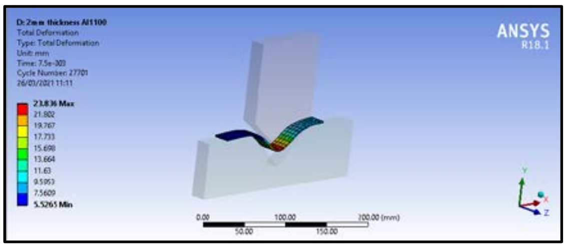


Figure 12: deformation at 0.75 ms

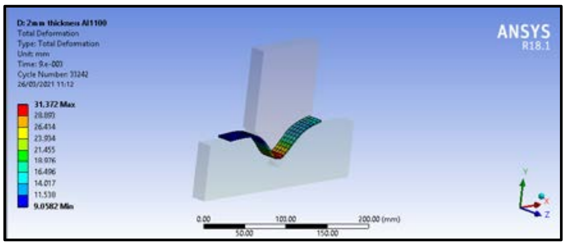


Figure 13: deformation at 0.9 ms

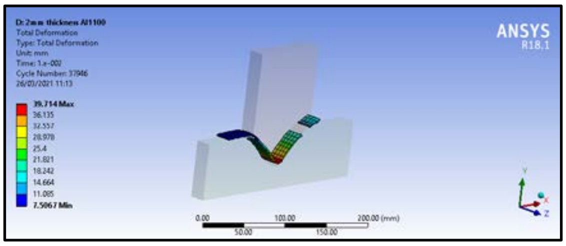


Figure 14: deformation at 10 ms

The maximum deformation of 6.2820mm is seen in the deformation curve of Al-1100 sheet metal at 0.4 mili seconds (see picture above). Figure 10 illustrates a deformation curve of Al 1100 sheet metal at 0.5 mili seconds, with a maximum displacement of 11.3030mm. The maximum deformation of 18.8270mm is seen in the deformation curve of Al-1100 sheet metal at 0.65 mili seconds (see picture above). Figure 12 illustrates a deformation curve of Al-1100 sheet metal at 0.75 mili seconds, with a maximum deformation of 23.8360mm. The greatest deformation of 31.3720mm is seen in the deformation curve of Al-1100 sheet metal at 0.9 mili seconds (see picture above). Figure 14 illustrates a deformation curve of Al-1100 sheet metal at 10 mili seconds, with a maximum deformation of 39.7140mm.

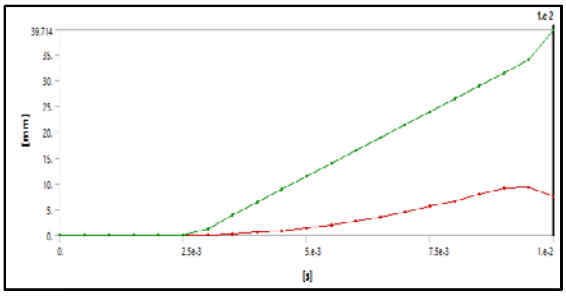


Figure 15: deformation vs time curve for Al-1100 material.

The deformation vs time graph shows linear increase from the time the tool makes 1st contact with Al-1100 sheet. The deformation increases linearly and reaches greatst value of 39.7140mm by the end of simulation.

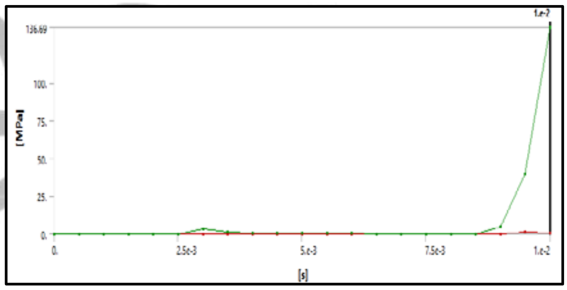


Figure 16: equivalent stress vs time curve for Al-1100 material

The equivalent stress increase is shown in figure 16 above. The graph shows steep increase in equivalent stress and reaches greatest stress in very short time interval. The equivalent stress behaviour is very different from deformation behaviour. The maximum equivalent stress reaches to 136.690MPa at the point of total deformation of Al 1100 sheet.

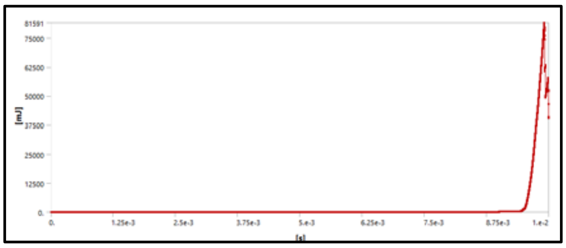


Figure 17: internal energy vs time curve for Al-1100 material.

The shear stress and internal energy exhibit an equal stress pattern. The internal energy grows sharply and with shear stress the same pattern is observed. At the end of the bending process, the highest shear stress is 81,591mega joules and 40892mega joules.

Finite element analysis of Al-5083N

The deformation plot ,equivalent stress ,shear stress and internal energy are evaluated with different time intervals with respect to time. For a two milimeters Al 5083 thickness metal sheet, the deformation plot and equivalent stress plot were obtained at various time intervals. The deformation curve of Al-5083 sheet metal at 0.3 mili seconds, which displays a maximum deformation of 1.2470mm.

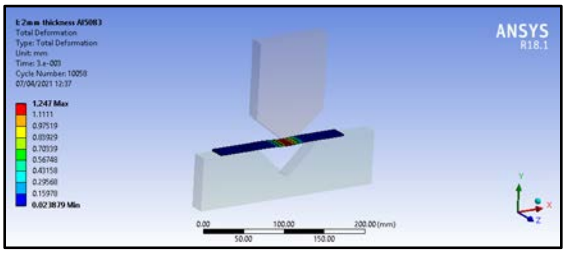


Figure 18: deformation at 0.3 ms

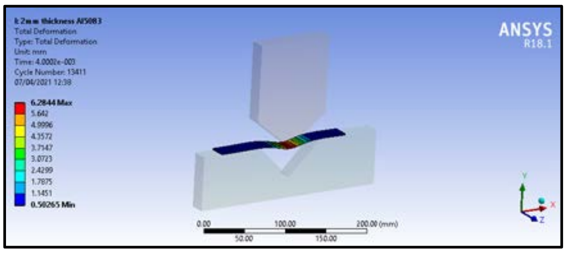


Figure 19: deformation at 0.4 ms

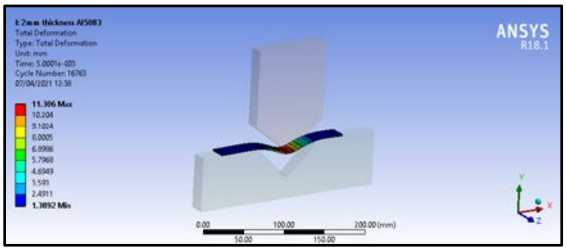


Figure 20: deformation at 0.5 ms

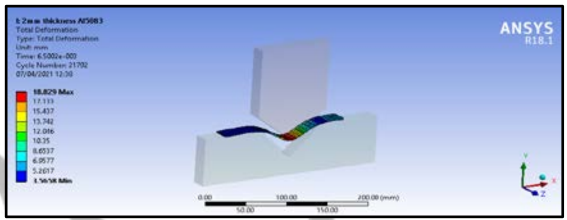


Figure 21: deformation at 0.65 ms

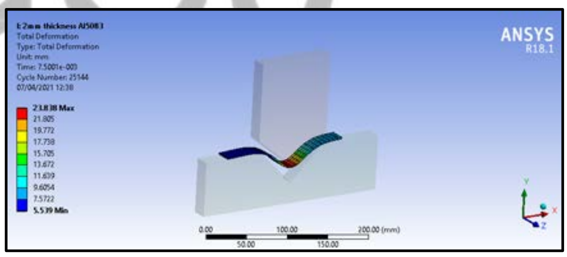


Figure 22: deformation at 0.75 ms

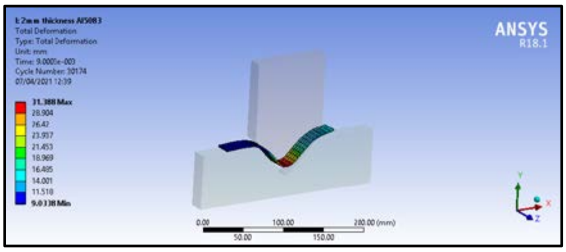


Figure 23: deformation at 0.9 ms.

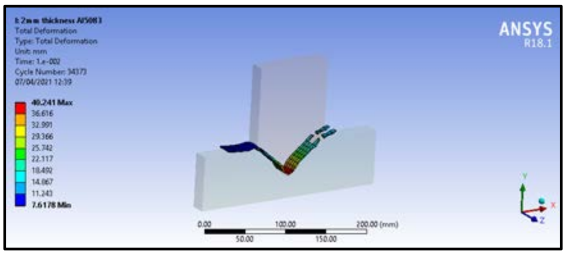


Figure 24: deformation at 10 ms.

The deformation curve of Al-5083 sheet metal at 0.4 mili seconds, which displays a maximum deformation of 6.2840mm, is given in the picture above. Figure 20 illustrates a deformation curve of Al-5083 sheet metal at 0.5 mili seconds, with a maximum deformation of 11.3060mm. The maximum deformation of 18.8290mm is seen in the deformation curve of Al - 5083 sheet metal at 0.65 mili seconds (see picture above). The maximum deformation of 23.830mm is seen in the deformation curve of Al-5083 sheet metal at 0.75 mili seconds (see picture below). The maximum deformation of 31.3880mm is seen in the deformation curve of AL-5083H116 sheet metal at 0.9 mili seconds (see picture above). Figure 24 illustrates a deformation curve of Al-5083 sheet metal at 10 mili seconds, with a maximum deformation of 40.2410mm.

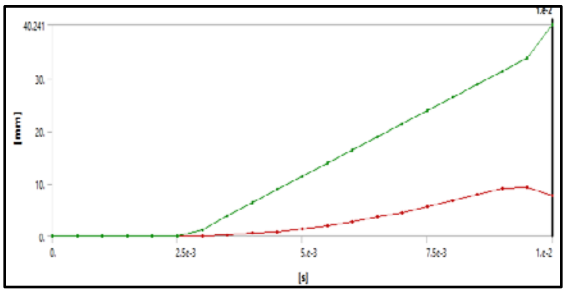


Figure 25: deformation vs time curve for Al-5083 material.

The deformation vs time graph shows linear increase from the time the tool makes 1st contact with Al-5083 sheet. The deformation increases linearly and reaches peak value of 40.2410mm by the end of simulation.

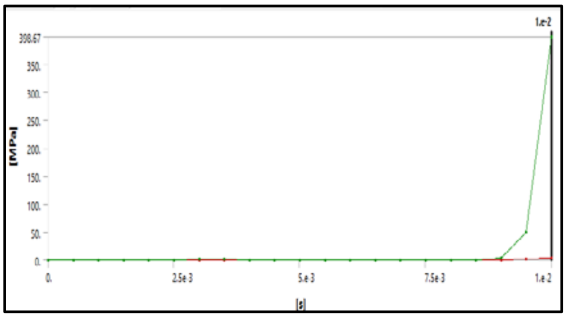


Figure 26: equivalent stress vs time curve for Al-5083 material.

The equivalent stress increase is shown in figure above. The graph shows steep increase in equivalent stress and reaches maximum stress in very short time interval. The equivalent stress behaviour is very different from deformation behaviour. The maximum equivalent stress reaches to 398.670MPa at the point of total deformation of Al 5083 sheet.

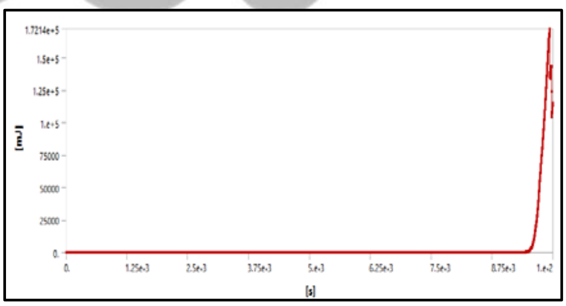


Figure 27: internal energy vs time curve for Al-5083 material.

The shear stress and internal energy tend to be the same as the corresponding stress. The internal energy is sharply increasing and the same pattern with shear stress is seen. The highest energy recorded for shear stress is 172140 mJ and 114920 mJ at the conclusion of the bending phase.

Comparison between Al-1100 and Al-5083 for different thicknesses

For 2mm thickness

Materials	Internal Energy (in joules)		Shear Stress (in Mpa)		Total Deformation (in M)		Equivalent Stress(Von- Mises) (in pa)	
	Max	Min	Max	Min	Max	Min	Max	Min
AL-1100	81.591	0	53.761	-77.096	0.039714	0.0075067	136.69 Mpa	632.71 Kpa
AL-5083 H116	172.14	0	225.93	-205.64	0.040241	0.0076178	398.67 Mpa	4392.8 Kpa

Figure 28: tabulation of 2mm thickness of al-1100 and al-5083

For 3mm Thickness

Materials	Internal Energy (In joules)		Shear stress (In Mpa)		Total Deformation (in M)		Equivalent Stress (Von- mises) (In Pa)	
	Max	Min	Max	Min	Max	Min	Max	Min
AL-1100	171.11	0	98.885	-93.153	0.041163	0.0061828	174.54 Mpa	712.3 Kpa
AL-5083 H116	431.86	0	234.97	-256.7	0.04173	0.0051089	461.21 Mpa	2.4967 Mpa

Figure 29: tabulation of 3mm thickness

For 4mm Thickness

Materials	Internal Energy (In Joules)		Shear Stress (In Mpa)		Total Deformation (In M)		Equivalent Stress (Von- mises) (In Pa)	
	Max	Min	Max	Min	Max	Min	Max	Min
AL-1100	321.76	0	86.802	-84.203	0.041742	0.0054369	191.97 Mpa	1.6191 Mpa
AL-5083H116	847.05	0	232.07	181.21	0.043259	0.0054774	484.43 Mpa	3.1149 Mpa

Figure 30: tabulation of 4mm thickness

From the above comparison table analysis, we conclude as the increase in the thickness of the sheet metal the internal energy of the sheet metal also increases. The effect of shear stress is increases up to 3mm thickness of sheet in these three materials but some how in 4mm thickness sheet of Al-1100 and Al-5083H116 the shear stress is decreasing. The negative sign indicates that the minimum shear stress is acting in the negative direction of the forced applied axis. As the thickness increasing the deformation for these materials are increasing. In all the three cases Al-5083H116 has the maximum deformation and copper has the minimum deformation. It is found that the Al-5083 having maximum equivalent stress(Von-mises stress), which means the Al-5083 have the maximum yield or fracture value than the other . So for the same applied load conditions the other two materials are fractured before the copper material is fracture.

VI. Conclusion

In the current analysis the shear stress, equivalent stress, deformation and internal energy evaluated using explicit dynamics at different time intervals. The analysis conducted enable us to determine the location and magnitude of stresses, pattern of internal energy. The shear stress and equivalent stress is lower till deformation occurs and then increases suddenly when deformation is restricted by die.

References

[1]. Bahloul, R., Mkaddem, A., Dal Santo, P. and Potiron, A., 2006. Sheet m etal bending optimisation using response surface method, numerical simulation and design of experiments. International journal of mechanical sciences, 48(9), pp.991-1003.

[2]. Guo, Y.Q., Batoz, J.L., Detraux, J.M. and Duroux, P., 1990. Finite element procedures for strain estimations of sheet metal forming parts. International Journal for Numerical Methods in Engineering, 30(8), pp.1385-1401.

[3]. Karafillis, A.P. and Boyce, M.C., 1996. Tooling and binder design for sheet metal forming processes compensating springback error. International Journal of Machine Tools and Manufacture, 36(4), pp.503- 526.

[4]. Amir Atrian, Faramarz Fereshteh-Saniee;"Deep drawing process of steel/brass laminated sheets"; Composites: Part B; volume- 47 (2013); pp-75-81.

[5]. Chung, K. and Shah, K., 1992. Finite element simulation of sheet metal forming for planar anisotropic metals. International Journal of Plasticity, 8(4), pp.453-476.

[6]. Saniee F. Fereshteh, Montazeran M.H., "A Comparative Estimation of the Forming Load in the Deep Drawing Process", Journal of Materials Processing Technology, vol. 140, pp 555–561, 2003

[7]. Jabbar **Gattmah** "Sheetmetal forming process for various materials using Finite Element Analysis" 1st International Conference on Advances in Mechanical and Mechatronics Engineering , ICAMMEN 2018