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OPTIMIZATION OF V-BENDING PROCESS USING ANSYS

[1]Prafful Kumar Kubde , [2]Dr Rohit Rajvaidya, [3] Dr. Prabhash Jain
[1]Mtech Scholar
[1]Mechenical Department,
[1]BUIT Bhopal, India

Abstract : Sheet metal forming is a vital process in modern manufacturing, extensively used in the automotive and aerospace industries to create components with precise dimensions and minimal defects. This technique involves shaping a flat sheet of metal into a desired form using a punch and die, allowing for the production of complex geometries with high accuracy. In this research, the energy absorption characteristics of copper alloy, Al 1100, and Al 5083 sheet metals with varying thicknesses were investigated through simulations performed using the ANSYS Explicit Solver workbench. The CAD modeling and finite element analysis (FEA) were carried out in ANSYS Design Modeler, focusing on key performance metrics such as Equivalent Stress (Von-Mises Stress), Total Deformation, Internal Energy, and Shear Stress.

To enhance the forming process, the study applied the Taguchi Response Surface Method to optimize the finite element model, concentrating on critical variables like die length and die angle. The optimization process aimed to improve the accuracy and efficiency of the sheet metal forming process by refining these parameters. The simulation results provided detailed insights into stress distribution, internal energy patterns, and deformation behavior for the different materials and thicknesses studied.

The findings from this research offer a comprehensive analysis of the performance of copper, Al 1100, and Al 5083 sheet metals under various forming conditions. By understanding these characteristics, the study contributes to the development of more effective and efficient sheet metal forming processes, which are crucial for meeting the high standards required in industrial applications, particularly in the automotive and aerospace sectors.

Index Terms: **FEA, Sheet Metal Forming, V-Bending Process, Copper Alloy, Al100, Al 5083, ANSYS. **

I. INTRODUCTION

Sand Sheet metal forming is a process in which a thin sheet of metal is formed into a desired shape. In most sheet metal forming processes, the forming apparatus consists of rigid components which normally include a die that has the final required shape, a punch to push the metal sheet into the die cavity and a holder to clamp the specimen during the forming process[1,3]. However, in some sheet metal forming processes, there is no need for the holder and this is known as air bending such as V-bending and U-drawing as shown in Figure 1. Many sheet metals forming operation involves highly non linear deformation processes. In this process lot of elastic strain energy in blank. This energy stored is released when forming pressure is removed.

The existing studies of sheet metal bending are mostly based on the stress i.e., the results are analysed with respect to stress and strain along with forming limit diagram. However, the sheet metal bending can also be investigated using energy absorption characteristics which is based on internal energy absorption.

Through finite element simulation predict the punch load and stress distribution during the V bending process.

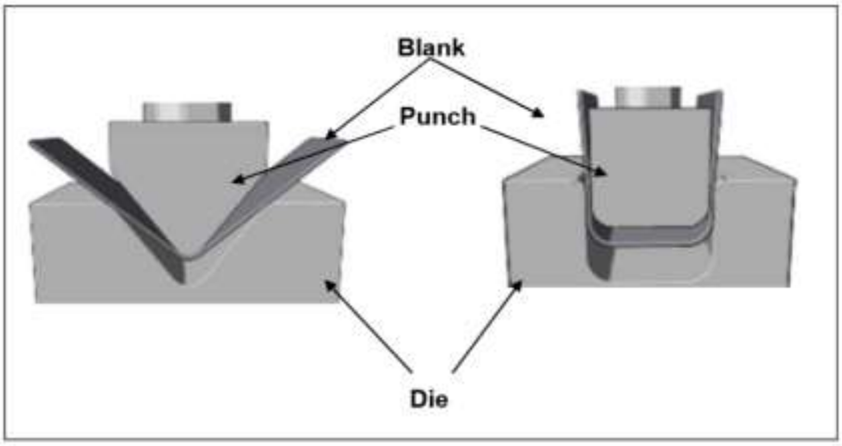


Figure 1: V and U bending sheet metal forming

Sheet metal forming processes are widely used by the automotive and aerospace industries. More than 55% of sheet metal components are produced by press-brake bending in these industries. Press-brake bending is a sheet metal forming process where the sheet is subjected to a bending load and can perform different operations such as V-bending, U-drawing [2], channel die bending and wiping-die bending which is also known as L-bending. It is operated by placing the metal sheet (a blank) over a die and the punch then travels down, pressing the blank into the die cavity. In this thesis, wiping-die bending is termed L-bending.

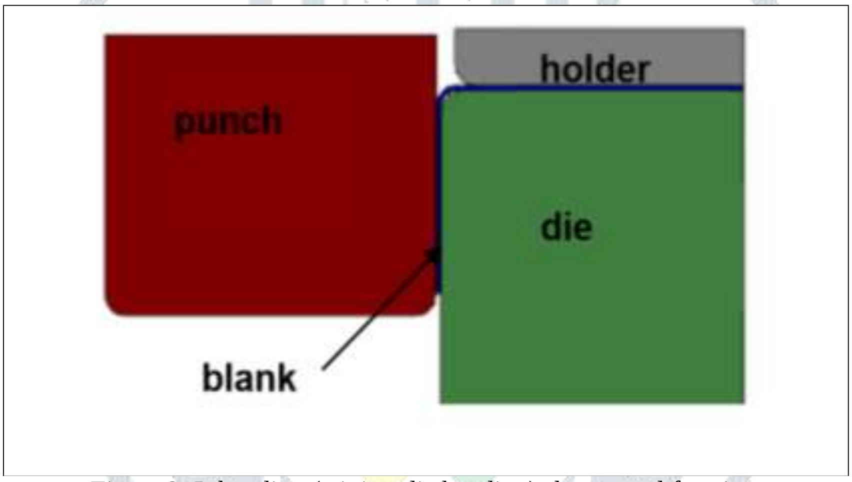


Figure 2: L-bending (wiping-die bending) sheet metal forming

Sheet drawing-forming is another kind of sheet metal forming process. In this operation, the sheet is subjected to a drawing (stretching) force in addition to the bending force, due to a holder that clamps the specimen. Figure 3 illustrates the principle of the U-drawing sheet metal forming process[2,4-6]. Figure 3 shows an example of the drawing sheet forming process for a complex part. The current project investigates spring back after the common L-bending and U-drawing processes. This is because both processes involve severe deformation of a blank and secondly only one metal forming rig is required to study both processes[7,9].

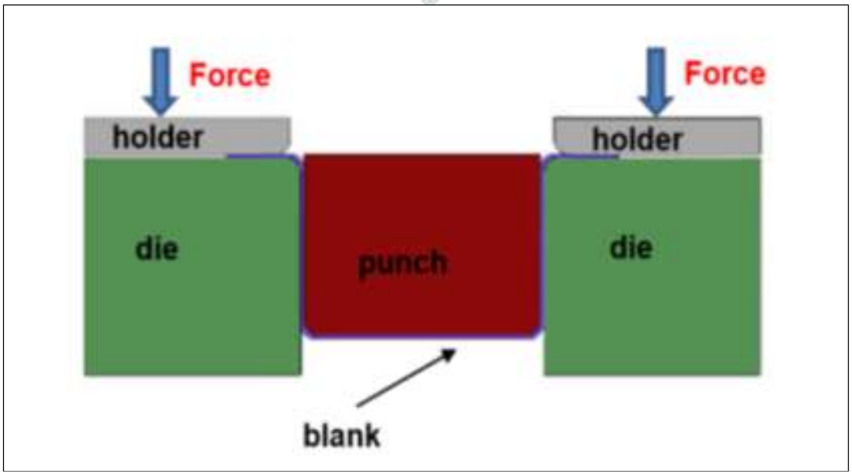


Figure 3: U- drawing sheet metal forming

As a result of the need to reduce fuel consumption for economic and environmental purposes, the automotive industry has made a considerable effort to replace the conventional sheet materials with high strength aluminium and steel. This leads to a decrease in vehicle weight which in turn reduces the CO2 emissions. However, the often low formability and/or substantial springback of high strength material are technical difficulties that the manufacturing engineers must overcome. The springback affects the quality of the final product, making the designing of forming tools more difficult and expensive[2,5].

Background

Many sheet metals forming operation involves highly non linear deformation processes. In this process lot of elastic strain energy in blank. This energy stored is released when forming pressure is removed [1]. This is undesirable defect is popularly known as spring back. This is undesirable due to following reason:-

i. This defect tends blank towards original geometry of blank thus forfeiting purpose of forming.

ii. Prediction of springback is very difficult and hence poses lot of constraints on die designer.

Many researchers have made attempts to predict spring back using finite element simulation using different codes. Many researchers have simulated several sheet metal forming processes like deep drawing, V bending ,hydro forming for optimization of various parameters associated with sheet metal forming.

Panthi, S.K. et al. [2] used analyzed elastic recovery in sheet metal bending with the help of finite element simulation. This study examined the effect of load on spring b back with varying thickness and die radius.

Bahloul R.et al. [3] used finite element simulation for the prediction of punch load and stress distribution during the wiping-die bending process. Here numerical simulation was mofelled using elastic plastic theory coupled with Lemaitre's damage approach. They used ABAQUS for finite element simulation. The punch load and stress distribution was be predicted in view of optimization using response surface methodology (RSM) based on design of experiments.

Guo, Y.Q.et.al.[4] studied the influence of friction forces under punch and blank holders. They studied optimization of the initial blank contour and deep drawing .

Papeleux, L.et.al. [5] investigated the impact of various parameters on spring back in a 2D draw bending [5]. Lee C.H.et.al.

[6] commented on capability of Finite element simulations for prediction of blank shapes and strain distributions in sheet metal forming. They developed algorithm which is applied to cylindrical cup drawing, square cup drawing and oil pan drawing. Their work demonstrates close accuracy of numerical results.

Karafillis, A.P. and Boyce, M.C. [7] suggested need of appropriate design of tooling and binder shape together. They used finite element methodology to analyze this manufacturing process. The tooling for the purpose was numerically designed using the algorithm with input from finite element methodology. Tooling was then manufactured using CNC machines. This tooling was found to be producing accurate parts showing efficiency of finite element methodology.

II. Proposed Method

The CAD model of die and sheet metal is developed using ANSYS design modeler with the dimensions specified .

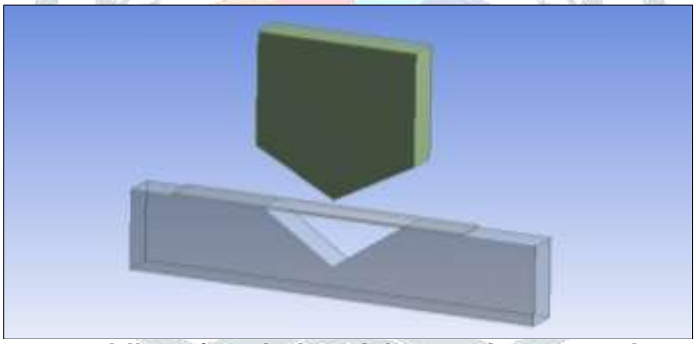


Figure 4: CAD modelling of punch, die and sheet metal in ANSYS design modeler

The CAD model of punch, die and sheet metal is developed in ANSYS design modeler with dimensions as given below.

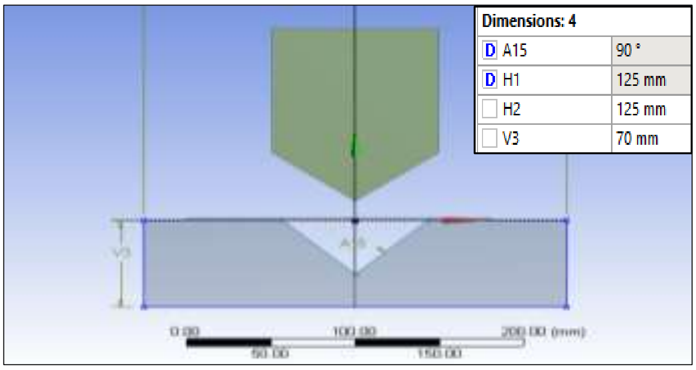


Figure 5: Dimensions of die

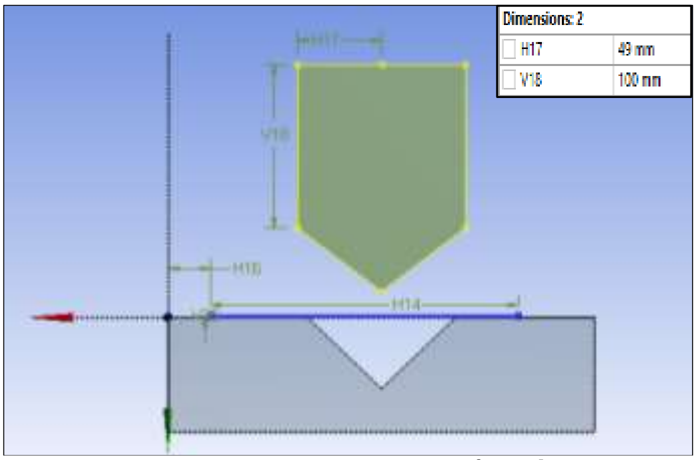


Figure 6: Dimensions of punch

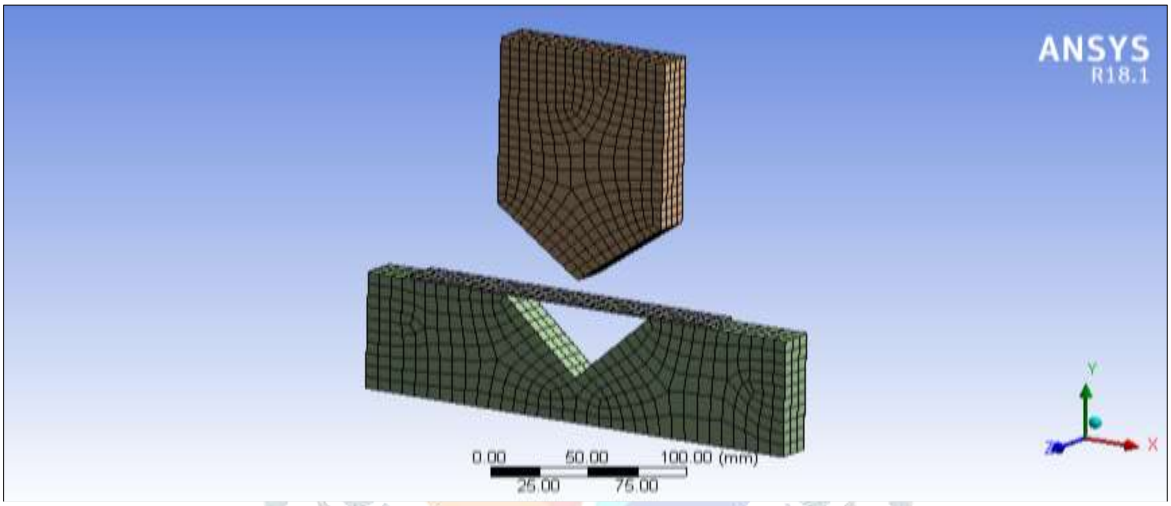


Figure 7: Meshed model of punch, die and sheet metal

The model is meshed using medium relevance and with hexahedral elements as shown in figure above. The transition is set to smooth. The number of elements generated is 2147 and number of nodes generated is 3259.

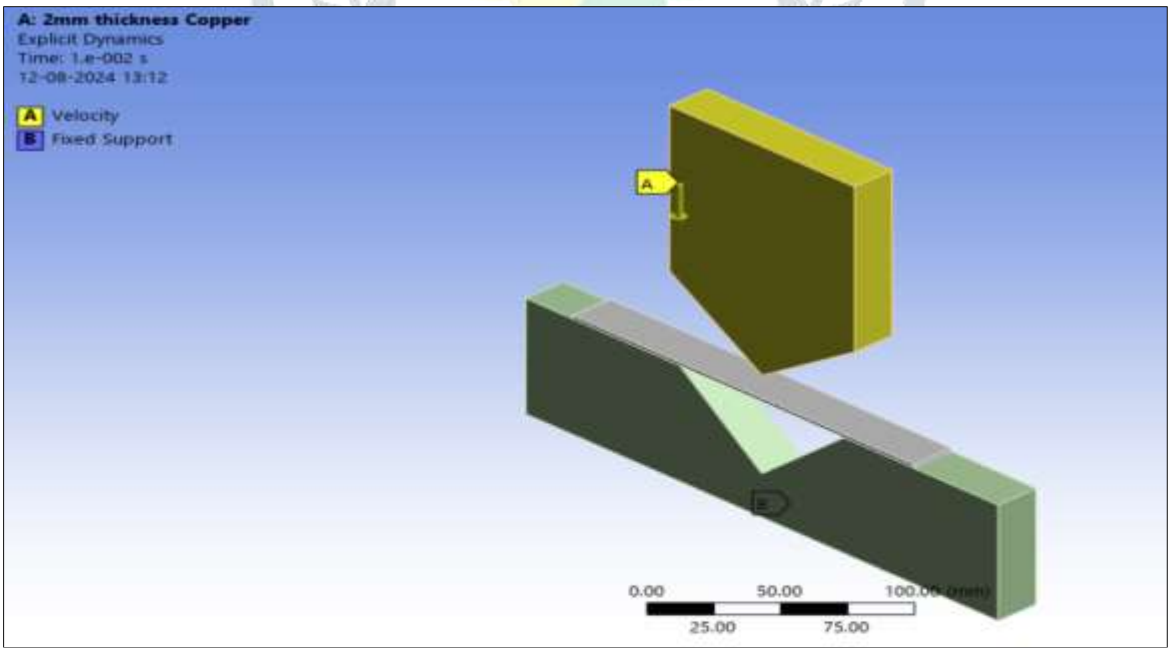


Figure 8: Loads and boundary condition

The initial velocity of 5m/s is applied on punch in downward direction as shown by yellow color and base of die is applied with fixed support. The contact pair between sheet metal and die is defined with frictional of μ=.1

Table 1: Material properties of copper alloy

	A	B	C	D	E
1	Property	Value	Unit		
2	Material Field Variables	Table			
3	Density	8300	kg m^-3		
4	Isotropic Elasticity				
5	Derive from	Young'...			
6	Young's Modulus	1.1E+11	Pa		
7	Poisson's Ratio	0.34			
8	Bulk Modulus	1.1458E+11	Pa		
9	Shear Modulus	4.1045E+10	Pa		
10	Specific Heat	385	J kg^-...		

.Result Discussion

The stiffness matrix is formulated using minimum total potential energy formulation. For the current problem a linear spring of k stiffness is considered and an external force (F) is applied at the right. The spring deformation is given by Δ.

The work done by the single force is

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

$$U = ½\ K\ \Delta_x^2$$

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

$$\Pi = ½\ K\ \Delta_x^2 - \Delta_x * F_x$$

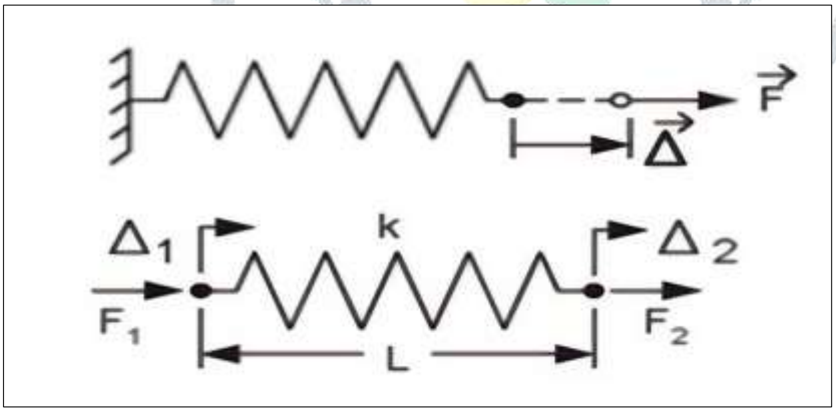
Equation of equilibrium is obtained by minimizing this total potential energy with respect to the unknown displacement, Δ. Thats,

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

This gets simplified to below given equation which is well known equilibrium equation for leaf spring

$$K\ \Delta_x = F$$

The system is considered as spring and the potential energy is minimized along with application of displacement constraint.



$W = \Delta.\ F$

$U = ½\ K\ \Delta_x^2$

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

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

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

Figure 9: Classic and general leaf spring element

The response surface optimization technique used for optimization is optimal space filling design. Space-filling designs (SFDs) in the context of DOE refer to the arrangement of experimental points in a way that ensures the entire experimental space is uniformly covered. The objective is to minimize the gaps in the design space, ensuring that no region is left under-explored. This approach is particularly useful in computer experiments where the underlying relationship between the input variables and the response is complex, nonlinear, or unknown. Optimal space-filling designs are critical in DOE for several reasons:

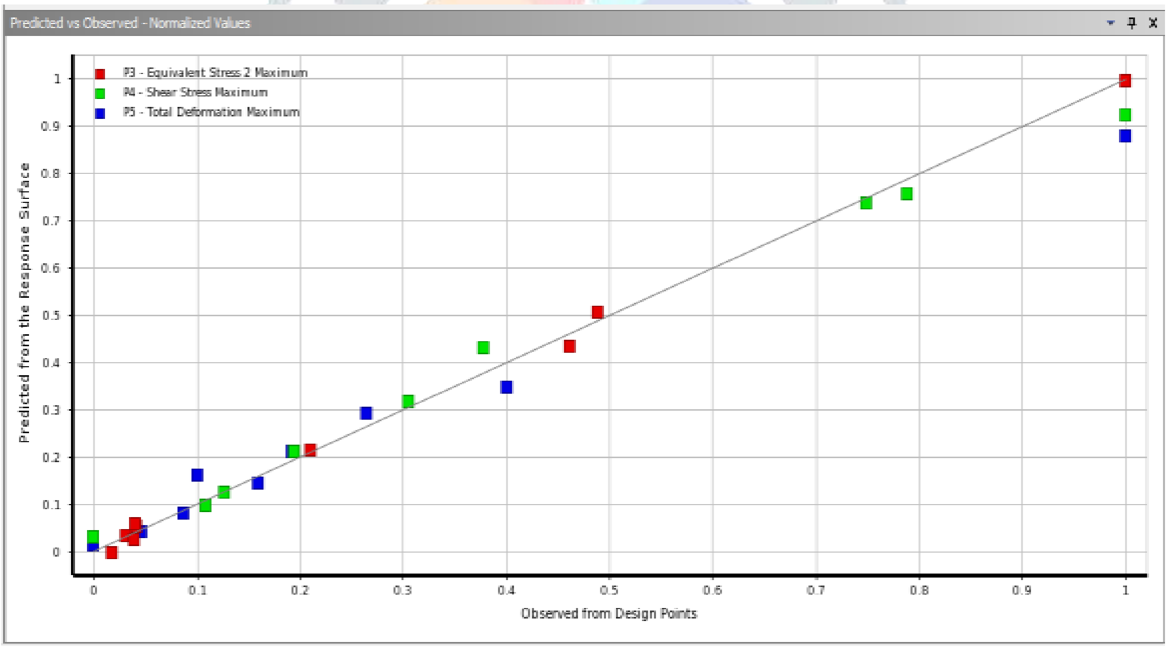
- **Exploration of Unknown Spaces:** When the response surface is unknown or cannot be easily approximated, SFDs help in thoroughly exploring the design space, capturing variations in the response across different regions.
- **Robustness:** SFDs ensure that the design is robust to variations in input variables. This robustness is particularly important in optimization problems where sensitivity to inputs needs to be minimized.
- **Efficiency:** Optimal SFDs reduce the number of experimental runs required to achieve a given level of precision. By uniformly covering the design space, SFDs allow for efficient sampling, leading to accurate models with fewer experiments.

Table 2: Design points generated using DOE optimal space filling design

Table of Output A2: Design Points of Design of Experiments					
A	B	C	D	E	F
S.No	**P1 - die-angle (degree)**	**P2 - die length (mm)**	**P3 - Equivalent Stress 2 Maximum (MPa)**	**P4 - Shear Stress Maximum (MPa)**	**P5 - Total Deformation Maximum (mm)**
1	90.889	124.333	89.673	1493.062	36.788
2	91.778	124.778	117.694	1841.287	36.501
3	89.111	125.444	630.131	4023.536	38.919
4	90.444	125.222	104.996	2116.501	36.870
5	88.667	124.111	664.260	3899.365	36.383
6	89.556	124.556	323.944	4704.014	37.398
7	90.000	125.889	116.769	2473.898	37.054
8	91.333	125.667	115.750	1898.308	36.604
9	88.222	125.000	1287.918	2707.376	36.639

Table 3 : Maximum and minimum value of design parameters

S.No.	Name	Calculated Minimum	Calculated Maximum
1	**P3 - Equivalent Stress 2 Maximum (MPa)**	**89.67**	**1287.91**
2	**P4 - Shear Stress Maximum (MPa)**	**1493.06**	**4704.01**
3	**P5 - Total Deformation Maximum (mm)**	**36.38**	**38.91**



Graph 1: Goodness of fit curve

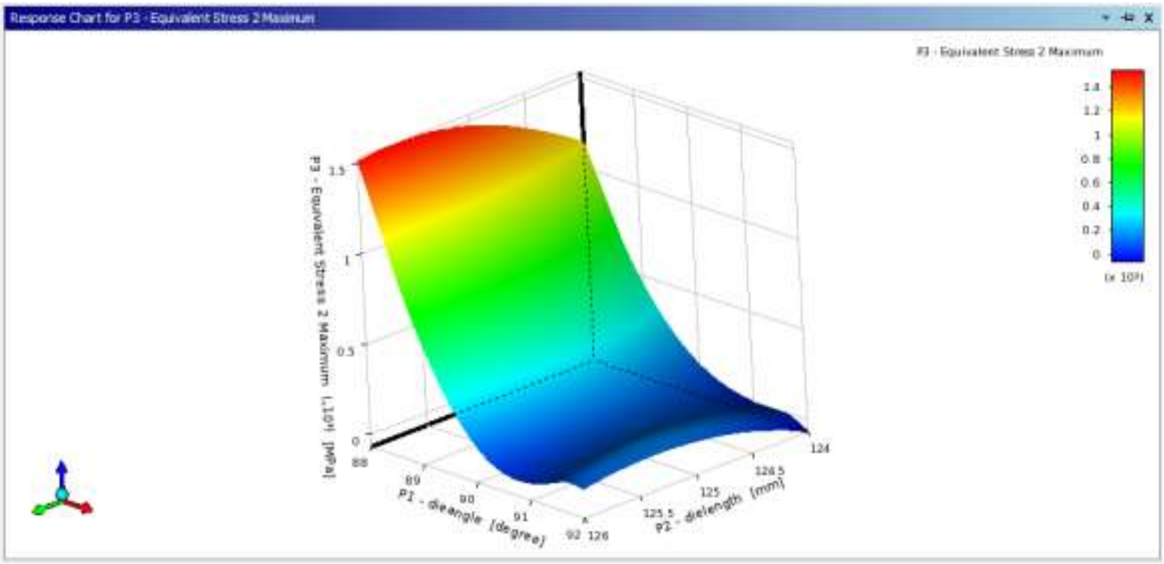
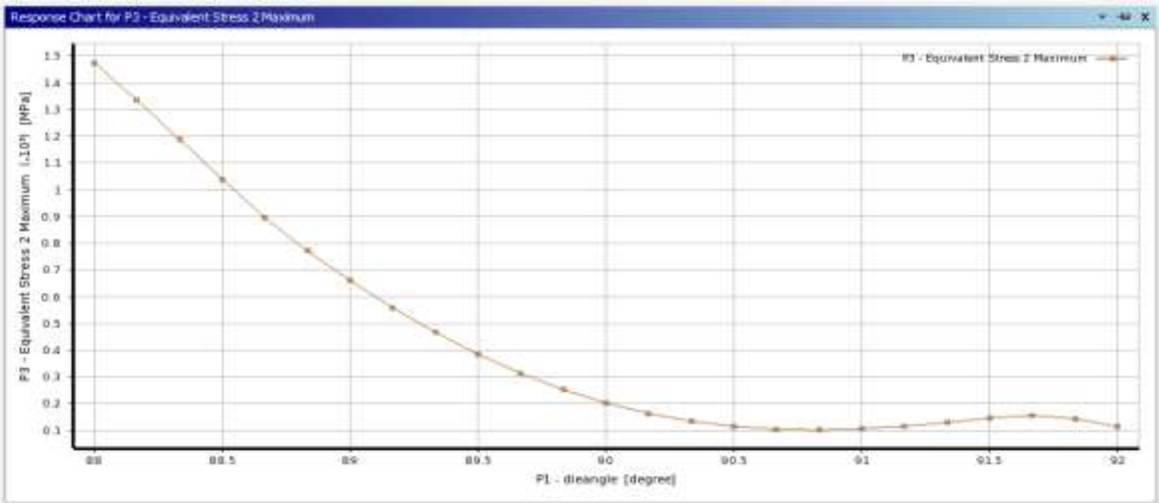


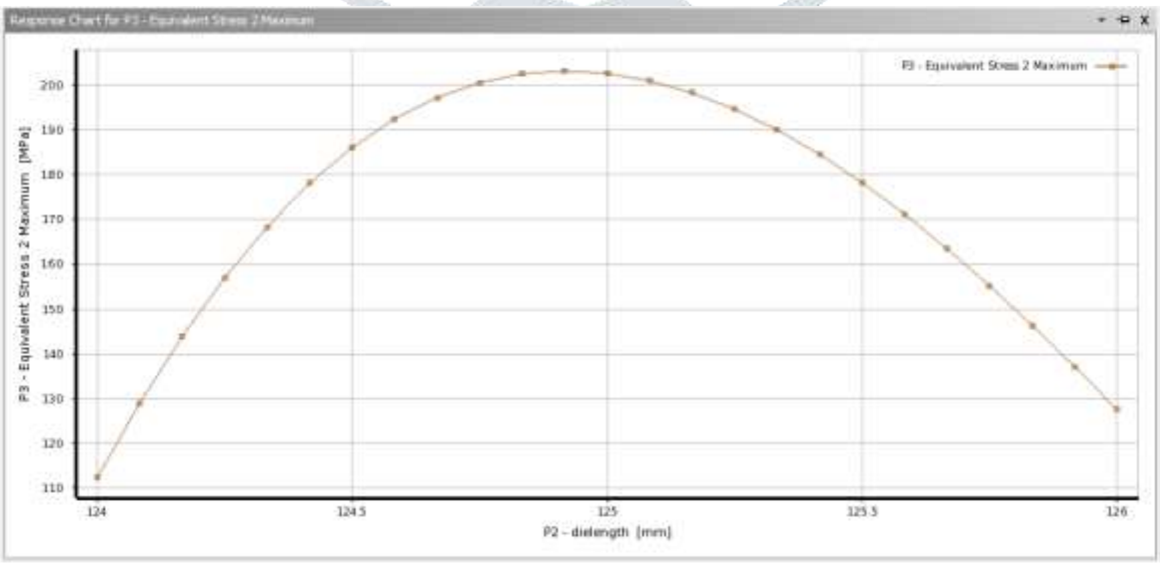
Figure 10: 3D response surface plot of equivalent stress

The 3D response surface plot generated for equivalent stress shows high values of equivalent stress for die angle ranging from 88^0 to 89^0 and die length ranging from 124mm to 126mm. The minimum equivalent stress is observed for die angle ranging from 89.5^0 to 92^0 and die length ranging from 124mm to 126mm.



Graph 2: Equivalent stress vs die-angle

The variation of equivalent stress with die angle is shown in Graph 2 above. The curve shows linear decrease in equivalent stress up to 90.5^0 and becomes constant thereafter.



Graph 3: Equivalent stress vs die length

The variation of equivalent stress with die length is shown in Graph 3 above. The curve shows initial increase in equivalent stress and reaches maximum value at 124.8mm die length.

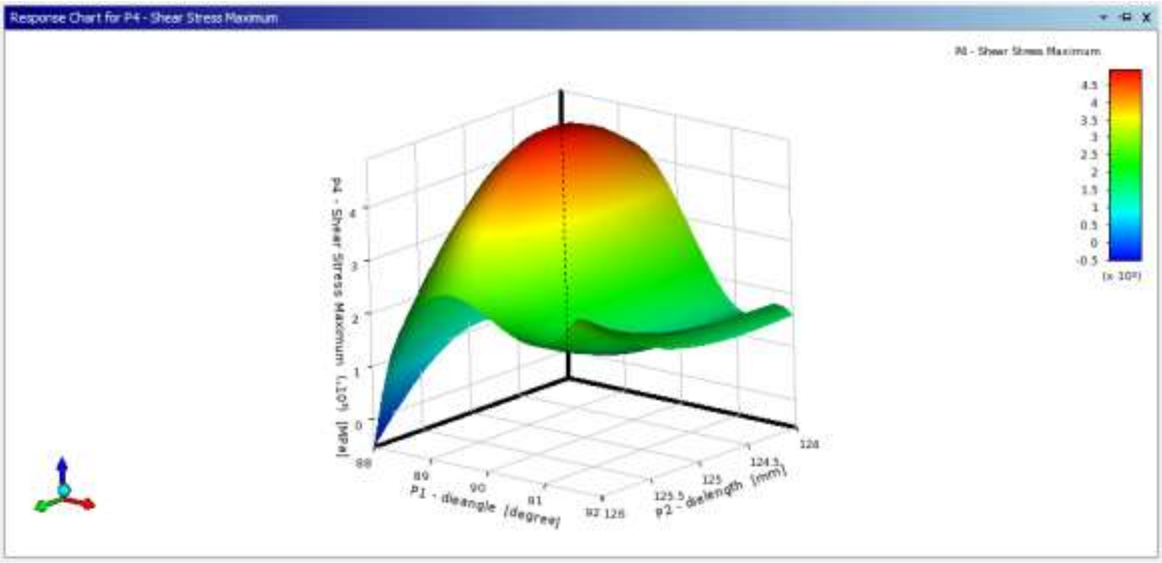
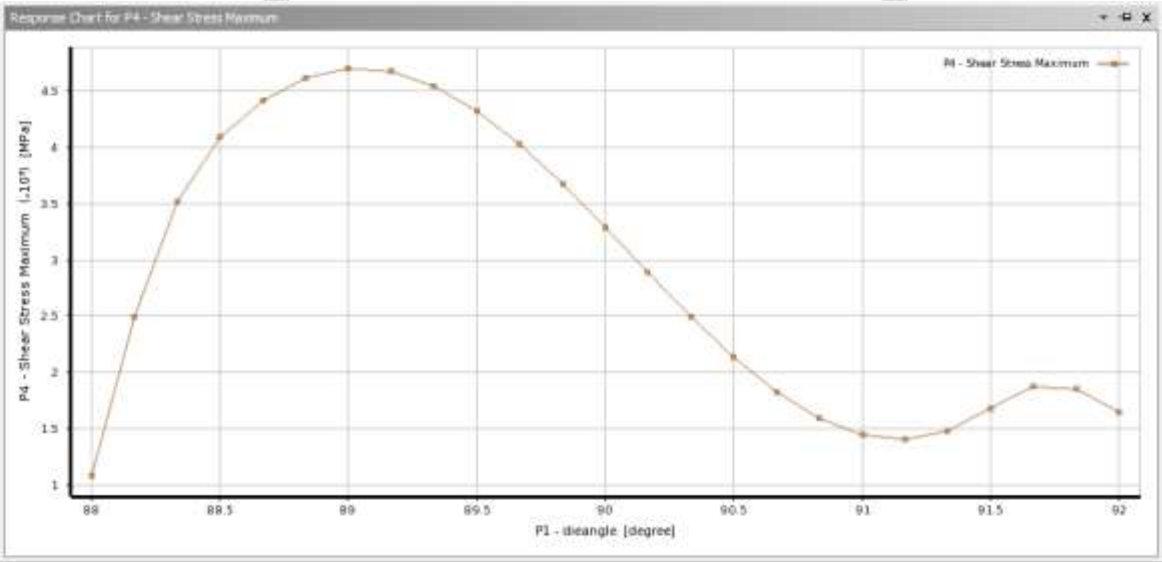


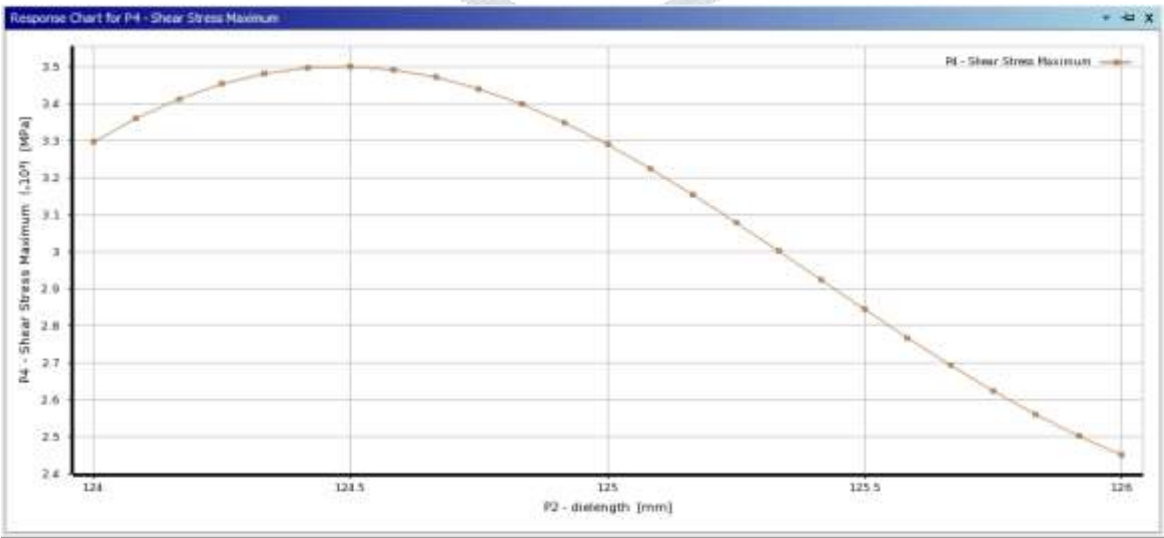
Figure 11: 3D response surface plot of shear stress

The 3D response surface plot generated for shear stress shows high values of shear stress for die angle ranging from 88.5^0 to 91^0 and die length ranging from 125.5mm to 124mm. The minimum shear stress is observed for die angle ranging from 88^0 to 89^0 and die length ranging from 125mm to 126mm.



Graph 4: Shear stress vs die angle

The variation of shear stress with die angle is shown in Graph 4 above. The plot shows increase in shear stress and reaches minimum shear stress at 89^0 die angle.



Graph 5: Shear stress vs die length

The variation of shear stress vs die length is shown in Graph 5.15 above. The plot shows initial increase in shear stress and reaches maximum shear stress at 124.5mm die length. The shear stress then decreases linearly and reaches minimum value at 126mm die length .

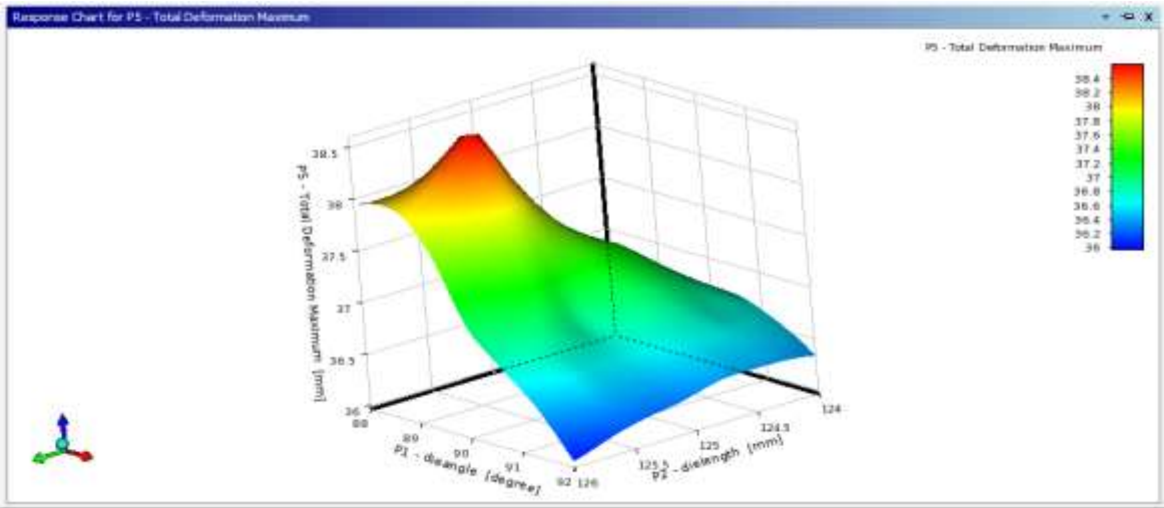
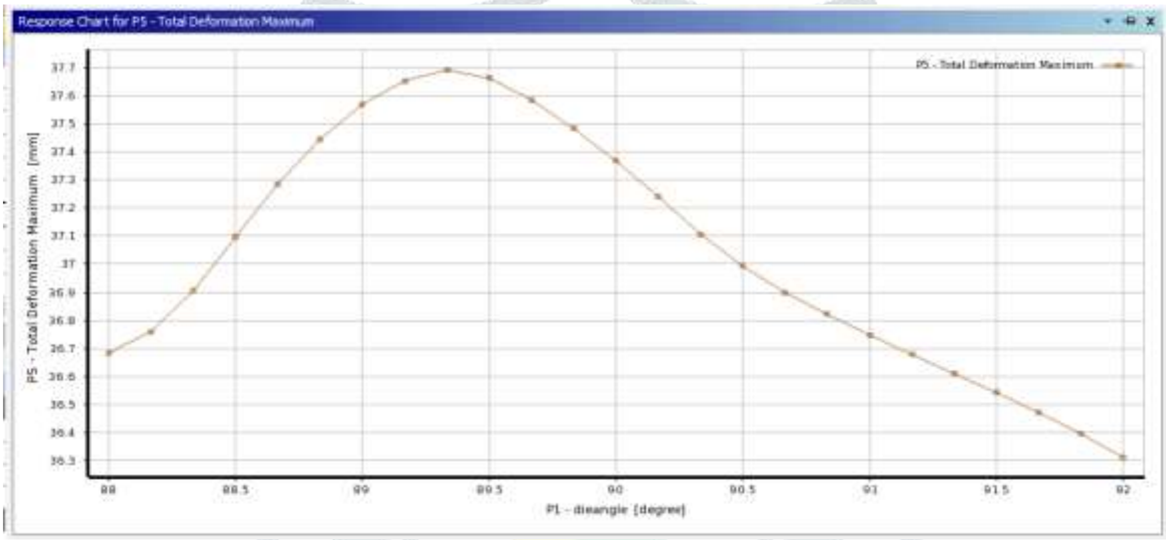


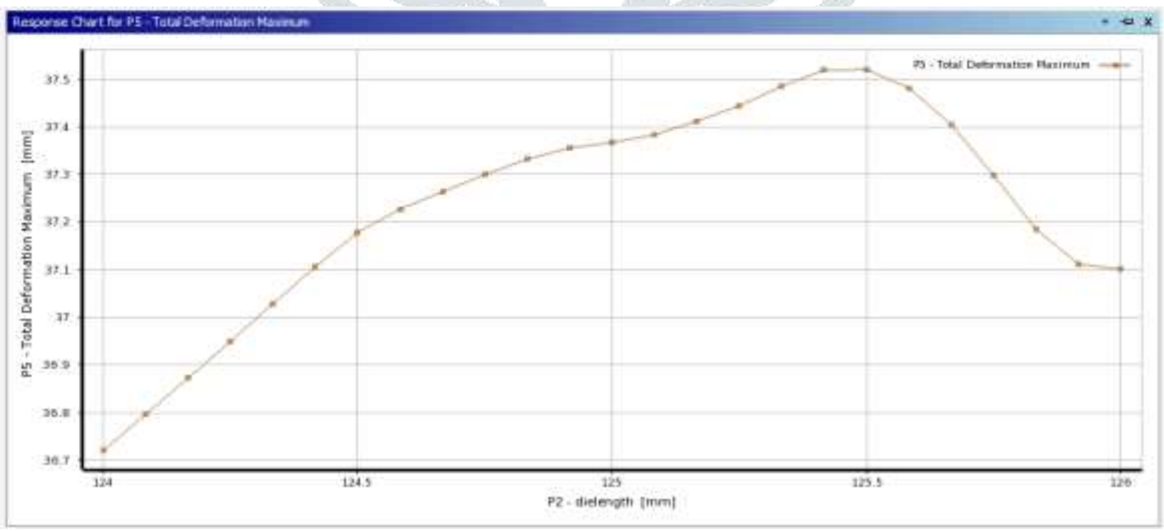
Figure 12: 3D response surface plot of total deformation

The 3D response surface plot generated for total deformation shows high values of deformation for die angle ranging from 88^0 to 88.5^0 and die length ranging from 124mm to 126mm. The minimum deformation is observed for die angle ranging from 90.5^0 to 92^0 and die length ranging from 124mm to 126mm.



Graph 6: Total deformation vs die-angle

The variation of total deformation with die angle is shown in figure 6 above. The curve shows increase in total deformation upto 89.5^0 die angle and then decreases thereafter and reaches minimum value at 92^0 die angle.



Graph 7: Total deformation vs die length

The variation of total deformation vs die length is shown in Graph 7 above. The plot shows constant increase for die length up to 125.5mm die length and then decreases linearly and reaches minimum at 126mm die length.

V. CONCLUSION

In this research, the application of optimal space-filling design (SFD) has been crucial in analyzing the complex response surface associated with sheet metal bending. Considering the intricacies of sheet metal forming, where material properties, bending angles, and tool geometry significantly impact outcomes, employing an SFD allowed for thorough exploration of the entire parameter space. This approach ensured a uniform coverage of design variables, enabling accurate modeling of the bending process and providing deeper insights into the effects of different parameters on bending quality and precision. The SFD minimized the risk of missing critical factors by covering all possible interactions, thus contributing to the development of more robust and efficient bending processes while reducing the number of experimental runs required.

Key findings include:

1. The 3D response surface plot for equivalent stress reveals high stress values for die angles between 88° and 89° and die lengths of 124mm to 126mm, with minimum stress observed for die angles between 89.5° and 92° and the same die length range.
2. The shear stress plot shows high stress values for die angles from 88.5° to 91° and die lengths of 125.5mm to 124mm, while minimum shear stress occurs for die angles between 88° and 89° and die lengths of 125mm to 126mm.
3. Total deformation is highest for die angles ranging from 88° to 88.5° and die lengths of 124mm to 126mm, with minimum deformation observed for die angles between 90.5° and 92° and similar die lengths.
4. Equivalent stress shows negative sensitivity to die angle and positive sensitivity to die length, with die angle having a more significant impact (85.44% sensitivity) than die length (5.65% sensitivity).
5. Shear stress shows positive sensitivity to die angle and negative sensitivity to die length, with die angle again having a greater influence (70.073% sensitivity) compared to die length (21.11% sensitivity).
6. Total deformation displays negative sensitivity to die angle and positive sensitivity to die length, with die angle exerting a stronger effect (46.77% sensitivity) compared to die length (26.38% sensitivity).

These results underline the importance of die angle and die length in optimizing sheet metal bending processes, with die angle playing a more critical role across all measured parameters..

REFERENCES

[1] Forcellese, A., Fratini, L., Gabrielli, F. and Micari, F., 1996. Computer aided engineering of the sheet bending process. Journal of Materials Processing Technology, 60(1-4), pp.225-232.

[2] Panthi, S.K., Ramakrishnan, N., Pathak, K.K. and Chouhan, J.S., 2007. An analysis of springback in sheet metal bending using finite element method © 2017, IRJET | Impact Factor value: 5.181 |ISO 9001:2008 Certified Journal | Page 2731 (FEM). Journal of Materials Processing Technology, 186(1), pp.120-124.

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

[4] 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.

[5] Papeleux, L. and Ponthot, J.P., 2002. Finite element simulation of springback in sheet metal forming. Journal of Materials Processing Technology, 125, pp.785-791.

[6] Lee, C.H. and Huh, H., 1998. Blank design and strain estimates for sheet metal forming processes by a finite element inverse approach with initial guess of linear deformation. Journal of materials processing technology, 82(1), pp.145-155.

[7] 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.

[8] 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.

[9] Shinde, R.A., Patil, B.T. and Joshi, K.N., 2016. Optimization of Tube Hydroforming Process (without Axial Feed) by Using FEA Simulations. Procedia Technology, 23, pp.398-405.

[10] Joshi, M.K.N., Patil, B.T. and Satao, M.S., 2014. Optimization of Variation in Wall Thickness of a Deep Drawn Cup using Virtual Design of Experiments. Optimization, 4(5).

[11] Chan, W. M., H. I. Chew, H. P. Lee, and B. T. Cheok. "Finite element analysis of spring-back of V-bending sheet metal forming processes." Journal of materials processing technology 148, no. 1 (2004): 15-24.

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

[13] R. Venkat Reddy, Dr T.A. Janardhan Reddy, Dr. G.C.M. Reddy, "Effect of Various Parameters on the Wrinkling In Deep Drawing Cylindrical Cups", International Journal of Engineering Trends and Technology- Volume3 Issue1- 2012.

[14] Najmeddin Arab, Abotaleb Javadimanesh, "Theoretical and Experimental Analysis of Deep Drawing Cylindrical Cup"; Journal of Minerals and Materials Characterization and Engineering, 2013, 1, 336-342

[15] Fereshteh-Saniee F, "A comparative estimation of the forming load in the deep drawing process"; J Mater Process Technol 2003; 140:555–61.

[16] Jyhwen Wang, Amit Goel, Fengchen Yang, Jenn-Terng Gau;"Blank optimization for sheet metal forming using multi-step finite element simulations"; International Journal Advance Manufacturing Technology; volume-40 (2009); pp-709-720.

[17] T. S. Yang,R. F. Shyu;" The design of blank's initial shape in the near net-shape deep drawing of square cup"; Journal of Mechanical Science and Technology; volume-21 (2007); pp-1585-1592.

[18] A. R. Joshi, K. D. Kothari, Dr. R. L. Jhala, "Effects Of Different Parameters On Deep Drawing Process"; International Journal of Engineering Research & Technology (IJERT) Vol. 2 Issue 3, March – 2013 ISSN: 2278-0181.

[19] JaisinghAmit, Narasimhan K., Date P.P., Maiti S.K., Singh U.P. "Sensitivity Analysis of a Deep Drawing Process for Miniaturised Products", Journal of Material Processing Technology, vol. 147, pp 321-327, 2004.

[20] TommerupSoren, Endelt Benny "Experimental Verification of a Deep Drawing Tool System for Adaptive Blank Holder Pressure Distribution", Journal of Material Processing Technology, Vol. 212 pp 2529- 2540, 2012

[21] Volk Mihael, NardinBlaz, DolsakBojan, "Application of Numerical Simulations in the Deep-Drawing Process and the Holding System with Segments' Inserts", Journal of Mechanical Engineering, vol. 57, Issue No. 9, pp 697-703, 2011.

[22] Zhao S.D., Zhang Z.Y., Zhang Y., Yuan J.H. , "The Study on Forming Principle in the Process of Hydro-Mechanical Reverse Deep Drawing with Axial Pushing Force for Cylindrical Cups", Journal of Materials Processing Technology, vol. 187-188, pp 300-303 2007.

[23] 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

[24] Yang T.S. "Investigation of the Strain Distribution with Lubrication During the Deep Drawing Process", Tribology International, vol. 43, pp 1104–1112, 2010.

[25] Liu Qiqian, Lu Cheng, Fu Wenzhi, TieuKiet, Li Mingzhe, Gong Xuepeng "Optimization of Cushion Conditions in Micro Multi-Point Sheet Forming" Journal of Material Processing Technology, vol.212, pp 672-677, 2012.

[26] Molotnikov A., Lapovok R., Gu C.F., Davies C.H.J. Davies, Estrin Y., "Size Effects in Micro Cup Drawing", Material Science and Engineering, vol. 550, pp 312- 319, 2012

[27] Kandil Anwar "An Experimental Study of Hydroforming Deep Drawing", Journal of Material Processing Technology, vol.134, pp 70-80, 2003

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