DETERMINATION OF MORE INFLUENCING PARAMETER OF DEEP DRAWING OF SHEET METAL USING RESPONSE SURFACE REGRESSION

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Abstract—*The main aim of this paper is to find the more dominant parameter of deep drawing, out of two parameters namely DR (Die Radius) and BHF (Blank Holding Force). In order to accommodate these two parameters simultaneously, FE models of sheet metals are generated by varying the Die Radius (DR) and BHF (Blank Holding Force). These generated FE models are analyzed using FE Explicit Dynamics analysis LS DYNA by varying DR and BHF in FE models to determine the Vonmises stress of the sheet metals. Non-linear response surface regression analysis was carried out to fit response surface for vonmises stress obtained from FE numerical analysis results taking the DR and BHF as input variables. From the regression analysis, it is found that Die Radius is more dominant factor than Blank Holding Force.*

Keywords—Sheet metals –Deep Drawing- Vonmises Stress, Die Radius (DR), BHF (Blank Holding Force) – FE Explicit Dynamics analysis LS DYNA

1. INTRODUCTION

Deep drawing process is a sheet metal forming process where a punch is utilized to force a flat sheet metal to flow into the gap between the punch and die surfaces. As a result, the sheet metal or blank will deformed into desired shape like cylindrical, conic, or boxed-shaped part and also complex parts which normally require redrawing processes by using progressive dies. Deep drawing is a popular selection due to its rapid press cycle times. Its capability of producing complicated shaped and geometries with low labours requirement is also an advantage in manufacturing industries. A few examples of deep drawing applications that is widely use nowadays include beverage cans, automotive bodies, aircraft panels and sinks. The important variables which affect the formability of sheet metal in deep drawing process can be divided into two categories: Material and friction factors; and tooling and equipment factors. With the right and proper selection of these variables, the formability of the material can be process at its optimum result and reducing the defects in deep drawing process like fracture, wrinkling and earing. Sheet metal forming process is used for both serial and mass production. Their characteristics are high productivity, highly efficient use for material, easy servicing machines, the ability to employ workers with relatively less basic skills and other advantageous economic aspects. Part that made from sheet metal has many attractive qualities: Good accuracy of dimension, adequate strength, light weight and a broad range of possible dimensions. One of the most common outcomes in deep drawing process is a cup fractures that occur at the bottom of the cup shell. This cup fracture is cause by many parameters like blank holder force (BHF), blank diameter, friction between punch and blank, normal anisotropy of material, blank thickness and many more. Mark Colgan et al (1) analysed numerically and experimentally the influence affecting parameters deep drawing. F. Fereshteh-Saniee et al (2) studied the forming load in the deep drawing process analytically, numerically and experimentally and concluded that all the methods of values are close to the FEA analysis value. Mayavan.T et al (3) studied the formability of low carbon steel sheets using deep drawing and they were found that thickness variations of the deep drawn steel sheet were less. R. Padmanabhana et al (4) studied the major affecting factor of deep drawing process experimental and statistical method and there were concluded that the blank holding force having major affecting factor and the die radius also has the same affecting process of deep drawing and they were noted that tearing of cup due to less punch nose radius. M.T. Browne et al (5) studied, optimizing the variables using DOE method and compared the optimum levels with the experimental results and found that the optimum parameters to provide the least variation in wall thickness distribution are, top-ram pressure, 70 kN; blank-holding pressure, 18 kN; and speed 100 mm/min. F. Ayari et al (6) conducted the parametric study of finite element analysis of square cup deep drawing and analysed the influencing parameters of deep drawing process. Juraj HUDÁK, (7) studied the analysis of forces in deep drawing process and they were concluded that decreasing the drawing ratio caused maximal drawing force growth until dup breaking force. H. Gharib et al (8)optimized the blank holding force in cup drawing and found that the Optimization of the BHF scheme needs to be carried out on other cup models in order to determine the validity of the linear relation between the BHF function slope and intercept with the drawing ratio R. Venkat Reddy et al (9) Effect of Various

Parameters on the Wrinkling In Deep Drawing Cylindrical Cups and they were found that the height of the wrinkles is reduced by increasing the blank holding force, decreasing friction, increasing the tools edge radius and reducing deep-drawing depth all together in one operation. To the best of the knowledge of authors none of the work compares the effect of die radius and Blank Holding Force. Hence in the present work in order to determine more dominate parameter out of two geometrical parameters namely Die Radius (DR) and Blank Holding Force (BHF).

2. MATERIAL PROPERTIES:

Table 1 Material Property

S.no	Property	Value
1	Young's modulus (E)	6.9 X 10^4 N/mm^2
2	Mass density (ρ)	2.7 X 10^{-9}
3	Poisons ratio (μ)	0.3
4	Strength coefficient (k)	412.4
5	Hardening exponent (n)	0.255

The material properties assigned to blank sheet is shown in table 1 and the material properties assigned to remaining are considered as rigid and the schematic view of the model is shown in Fig 1.

3. MODELING:

Following assumption/options are used during the analysis.

- The sheet metal is in plane strain conditions along the flange width direction
- In Plane stress conditions along the sheet thickness direction
- The sheet metal is homogeneous and isotropic
- The sheet metal follows the power hardening law and Von Mises yield criterion
- Planes normal to the sheet surface remain planes during the deformation process

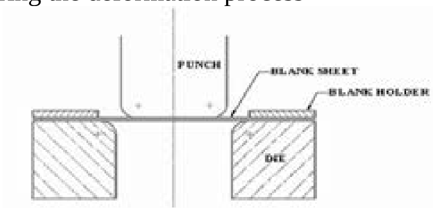

Fig 1 Schematic view

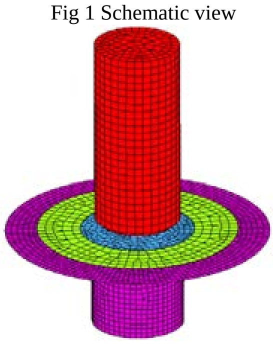

Fig 2. Finite element model

4. RESPONSE SURFACE REGRESSION MODELING

Since the study is about the determination of more dominant parameter out of two parameters namely DR (Die Radius) and BHF (Blank Holding Force), both the parameters are considered as independent variables and hence L9 Orthogonal Array is selected for this study. The numerical results obtained by varying DR (x1) and BHF (x2) are fitted to quadratic polynomial model using MINITAB 17.

$$Y = \beta_o + \beta_1 x_1 + \beta_2 x_2 + \beta_{11} x_1^2 + \beta_{22} x_2^2 + \beta_{12} x_1 x_2$$

Where Y is predicted response, here it is Spring Back Angle (SBA) which is defined as spring back angle (θ) = tan-1 [(X2 –X1) / (Y2 - Y1)] of thin sheet metal and $\beta_o, \beta_1, \beta_2, \beta_{11}, \beta_{22}, \beta_{12}$ is model co-efficient parameters.

5. RESULTS AND DISCUSSIONS

The coded values (-1, 0, 1) of L9 orthogonal array for the two parameters taken for study are shown in Table.1 with their actual parameter values (experimental values). The experimental levels for each variable are taken from ref Gyadari Ramesh et al (2013). Accordingly DR is varied as 2 mm, 4 mm and 6 mm and the BHF is varied as 10000 N, 11000 N and 12000 N.

The Vonmises stress (S) values is obtained from FE Explicit Dynamics analysis in LS-DYNA by varying DR and BHF in FE models are given in Table 1 which are used as input response parameter for response surface regression modeling. The regression analysis is carried out using MINITAB 17 software taking DR and BHF as input parameters and a second order polynomial type regression equation is fitted with values of correlation co-efficient (R^2) and adjusted correlation co-efficient (R^2 adj) are 99.64% and 99.3% respectively and the fitted equation are given in equation (2). Correlation co-efficient (R^2) is a measure of degree of fit i.e., how close the data are to the fitted regression line. If R^2 approaches unity, the better the model fitted with the actual data.

S=(169-(20.92*DR)+(0.0502*BHF)+(2.788*DR*DR)
-(0.000002*BHF*BHF)- (0.000800*DR*BHF)) (2)

The corresponding ANOVA Table is presented in Table 3. From this table it can be noted that fitted model is a statistically significant model (as P value < 0.05) with 95% confidence level.

TABLE: 2 EXPERIMENTAL VALUES FROM FEA

Coded Values		Real Values		SBA Values	
				Thickness = 2 mm	
DR (x_1)	BHF (x_2)	DR (x_1) mm	BHF (x_2) N	Experimental	Predicted
-1	-1	2	10000	413.3	424.3120
-1	0	2	11000	418.9	430.9120
-1	1	2	12000	419.3	433.5120
0	-1	4	10000	391.3	399.9280
0	0	4	11000	391.9	404.9280
0	1	4	12000	390.3	405.9280
1	-1	6	10000	386.8	397.8480
1	0	6	11000	389.2	401.2480
1	1	6	12000	386.4	400.6480

Thus, the data are fitted well with the proposed quadratic polynomial model. From Table 1 it can be noted that there is a good agreement between experimental values and predicted values.

Table: 3 ANOVA Table for the response surface regression model

Source	Degree of Freedom (DF)	Adjusted Sum Square (Adj SS)	Adjusted Mean Square (Adj MS)	F – value	P – value	F - table
Regression	5	1594.37	318.873	10.86	0.001	9.01
DR	**1**	**45.59**	**45.590**	**38.23**	**0.017**	**10.13**
PR	1	10.35	10.350	0.12	0.104	10.13
DR*DR	1	248.65	248.645	0.02	0.001	10.13
PR*PR	1	8.82	8.820	1.32	0.123	10.13
DR*PR	1	10.24	10.240	14.63	0.105	10.13
Error	3	5.81	1.938			
Total	8	1600.18				

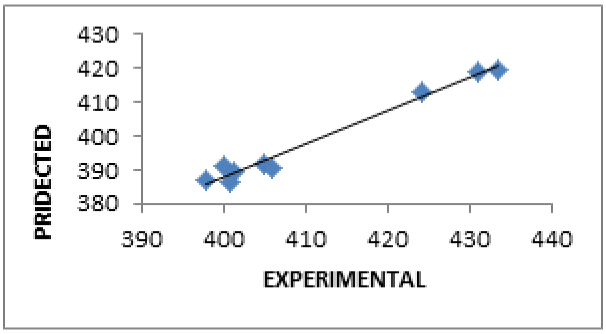

Fig.3Experimental vs. predicted values plot

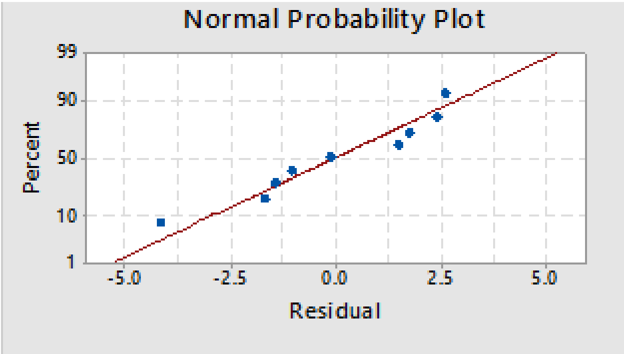

Fig.4 Normal probability plots of residuals

The normal probability plots of residuals for present regression models are shown in Fig.4.The points in the plot should generally form a straight line if the residuals are normally distributed. Since in the present model, the residuals falls near the straight line, there is no indication of non- normality of experimental results.

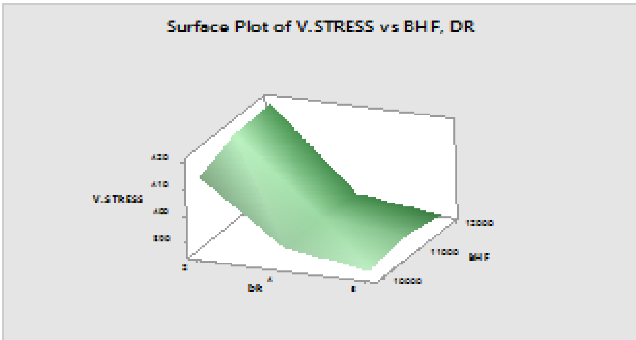

Fig.5 Response surface plot showing the effect of DR and BHF on STRESS

The Fig.5 shows 3D Response surface of the fitted model. It can observed in the Table.3 of ANOVA that the F-value of DR is more than that of BHF implies that DR is more dominate parameter than BHF.

6. CONCLUSIONS

The following conclusions are derived from the response surface regression modeling of Vonmises stress on sheet metal having varied DR and BHF in the given range.

•For this sheet metal deep drawing analysis the effect of influencing parameters namely DR & BHF is meager and the maximum variation Stress value is 433.5120and minimum 397.8480.

•The regression ANOVA analysis indicates that more dominate factor is DR because of its dimensional variational of fitted equation and average rate effect of DR and BHF on Stress is clearly indicates that more dominate factor is DR that is die radius is more dominate factor than blank holding force (BHF).

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