MULTI RESPONSE OPTIMISATION FOR SINGLE CYLINDRICAL CUP DRAWINGS AT SINGLE STAGE USING ANN

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Abstract
There are mainly two methods of deep drawing analysis: experimental and analytical/numerical. Experimental analysis can be useful in analyzing the process to determine the process parameters that produce a defect free product, and the analytical/numerical modeling can be used to model and analyze the process through all stages of deformation. In the presented study, simulation of the drawing process for determining strain distribution pattern in the drawn component for a particular displacement is explained. Research work involved in the prediction of life of stripper of compound die using artificial neural network (ANN) is presented. The parameters affecting life of stripper of compound die are investigated through FEM (Finite Element Method) analysis and the critical simulation values are determined.

Keywords: *ANN, FEM, MATLAB*

1.0 Introduction:
Production of high quality products in a short time and at low cost is an ultimate goal in manufacturing. Deep drawing is one of the most popular metal forming methods available to manufacturers. In deep drawing, a flat blank of sheet metal is shaped by the action of a punch forcing the metal into a die cavity. The use of numerical simulation could contribute towards the development and optimization of the process, leading to significant economic and technical gains. The application of the finite element method to the numerical simulation of the deep-drawing process has evolved in a significant way in the course of the last few years. Many of the problems associated with numerical simulation of this process have been solved or at least are better understood. Reviewing the various literature available on simulation of drawing, it is understood that most of the research work are focused on drawing of cylindrical product. Relatively a few research work has been done for finite element simulation conical product.

The cup drawing is a basic deep drawing process. Thus, understanding the mechanics of the cup drawing process helps in determining the general parameters that affect the deep drawing process. There are mainly two methods of analysis; experimental and analytical/numerical. Experimental analysis can be useful in analyzing the process to determine the process parameters that produce a defect free product. However, experimental work is usually very expensive and time consuming to perform. On the other hand, the Analytical/Numerical modeling can be used to model and analyze the process through all stages of deformation. This approach is less time consuming and more economical than experimental analysis. In the present study, an incremental Analytical/Numerical modeling approach is developed. The model analyzes the stresses and strains in the cup drawing process.

2.0 Literature review:

Dai et al. (2000) reported about the axially symmetrical forming of SPIF was examined theoretically and experimentally and the technique to attain more even metal flow deformation was discussed. The authors proved that point by point movement of tool can control flowing of metal and different strain distribution can be produced by different forming locus. By loading the low stiffness and low deformation area first and decrease the time of loading on the boundary area where the splitting occurs easily can be optimized the forming locus

Ji and Park (2008) attempted about the feasibility of incremental forming technique to magnesium alloys at warm temperature. Finite element method also carried out to realize the deformation characteristics. Hemispherical ended tool was used to form incrementally using CNC machines. The sheet formability were analysed by plane-strain and by axi-symmetric stretching tests at 200C, 1000C, 1500C, 2000C and 2500C temperatures. It was found that increase in temperature increases the formability. The results show that forming limit curve for different temperatures is more or less straight line and parallel to one another.

Franzen et al. (2009) reported that the possibility of employing the single point incremental forming technology for commercial PVC sheets and formability limits were evaluated for this process as function of major operating parameters. The authors conducted this test under normal room temperature with 2mm, 3mm as sheet thickness and the tool diameters about 10 mm and 15 mm with above said two process parameter the formability of the sheets were investigated. Thinner sheet sizes are more sensitive to wrinkles and twisting of the sheet al. ong the tool path direction and lead to failure due to thinning

Petek et al. (2010) developed online system to identify the fracture of the material at the time of incremental forming. The proposed online system was is based on investigation of the shape of the forming force time series using skewness and statistical predictors and also verified with many tests using different work material, shapes, thicknesses and various process parameters

Ambrogio and Luigino Filice (2011) presented methods to increase part accuracy by back drawing methods and multi stage forming of sheet metal. For this study Aluminium Alloy and DC04 Deep Drawing Steel are experimented with sheet thickness and tool step as varying parameter remaining parameters kept constant. Back drawing approach method reduced 15-25% dimensional deviation and incremental forming steps could increase accuracy.

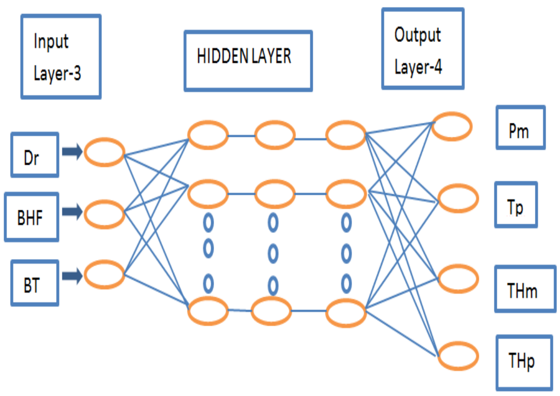
Reddy A. C. S. et. al. (2015), Anova results reveal that BHF has most significant parameter 56.98%, followed by punch nose radius 30.12% the die shoulder radius has lower effect on maximum thickness variation

3.0 Methodology:

Predictive Model using Artificial Neural Network

The semi empirical models developed in preceding sections using the influence of process parameters on the formed cups based on the assumptions that the each of the variables considered are independent and the linear relationship exists among them. However, such a situation is considered to be very ideal in any real application. As has been pointed our earlier, artificial neural network (ANN) is expected to address such situations. This section shall be dealing with application of ANN for the modeling of the process with the same experimental data collected so far.

An ANN has the ability to relearn to improve its performance with new available data. Once the ANN is adequately trained, it can generalize to similar cases which it has never seen. The architecture of a general three layered feed forward neural network model. It has three input parameters as Die radius in mm, BHF in N and blank thickness in mm. while four output parameters. The neural network considered is fully connected in the sense that every unit belonging to each layer is connected to every unit belonging to the adjacent layer.



Architecture of a General Three Layered Feed Forward Neural Network Model

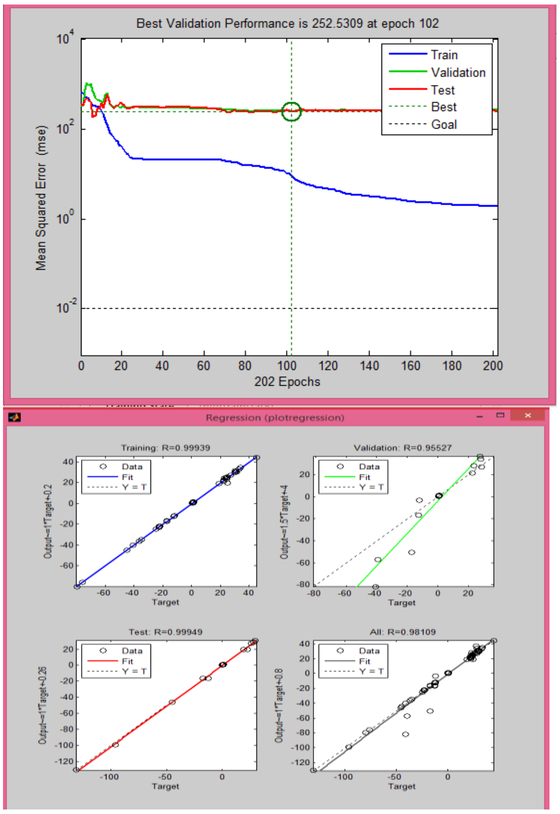
An ANN computer program is developed using MATLAB 2010. Out of 27 trials, the experimental results corresponding to 9 samples, randomly selected, are used for training the model and remaining 18 are used for testing and validation as per the proportion mentioned above.

Damage Values after Each Die Pass For Different Die Radius

No. of Drawing Die	Max. Principal Stress			
	Die radius of 4mm	Die radius of 5mm	Die radius of 6mm	Die radius of 7mm
1	199	169	178	203
2	161	122	155	172
3	122	94	96.74	111.2
4	65.5	50.7	31.1	67.4
5	11.79	14.5	4.85	4.28

4.0 Results:

It is found that the sum square error (R^2) of the network corresponding to training data, test data and validation data individually, with different learning parameters. The marked circle shows optimum number of iteration where R^2 values of three categories of data approximately matches with each other and gives the best R^2 value for these individual categories and their combined effect.



a.

b.

Figure above Influence of Iteration Limit on Sum Squared Error and Regression Curves regression for individual data set

In order to assess the accuracy of ANN estimations, the regression curves are plotted for estimated and experimental data (3 categories, individually and together) of all performance parameters and formability characteristics together and are shown in Figure 4.b As mentioned before, the criterion R was selected to evaluate the networks to find the best activation function and number of neuron. The regression values (R^2) is found to be 0.98109 for complete data set. The correlation coefficient close to unity indicates that ANN is capable of generalizing relationship between input variables and output parameters reasonably well.

The results show that the training algorithm of the optimum point (Circled) found at epoch 4 and got satisfactory R^2 values nearest to 1 for predicting performance parameters and formability characteristics. A high prediction capability was achieved for both training and testing data sets of output parameters. Therefore, the ANN appears to have a high generalization capability.

Using weights and biases of trained ANN model, output parameters (performance parameters and formability characteristics) can be predicted. The experimental and predicted values (using ANN) for each performance parameters and formability characteristics are plotted and are shown in thesis. Thinning % maximum (Pm), Thinning % minimum (Tp), Thickness maximum (Thm) and Thickness minimum (Thp) formability characteristics 0f correlation coefficients for at the training stage are found to be 0.99939, 0.95527, 0.99949, and 0.98109 respectively. The correlation coefficients close to unity for all output parameters indicate good accuracy of the models developed. Thus, ANN models can be used to predict formability of single stage drawing of cylindrical cup adequate accuracy.

As all performance parameters and formability characteristics considered are equally important, a multi-parametric optimization approach is expected to provide breakthrough in single stage drawing of cylindrical cup into reality.

Comparison of analytical result and ANN predicted result with maximum principal stress.

Output of FEM analysis, analytical result and ANN result of stripper

Stresses in stripper in [MPa]			
Max. principal	Min. principal stress in [MPa]	Analytical results (Number of cycles)	ANN predicted results (Number of cycles)
-4.2406	-23.395	1439531	1466235
-3.8123	-22.117	1402566	1423188
-3.3841	-20.84	1369125	1399202
-2.9558	-19.562	1329223	1369334
-2.5276	-18.284	1298178	1335125
-2.0993	-17.006	1243669	1300987
-1.6711	-15.728	1202885	1280156
-1.2429	-14.451	1160359	1235998
-0.8146	-13.173	1133699	1199006
-0.3863	-11.895	1096126	1161086
0.0487	-10.617	1059879	1136105
0.4701	-9.339	1021003	1100036
0.8983	-8.061	999128	1069364
1.3266	-6.784	969169	1031698
1.7549	-5.506	943789	1012256

An ANN model has been developed for prediction of cylindrical cup. The methodology used for prediction of life of cylindrical cup has been described briefly. The proposed ANN model is capable of accomplishing the tedious and time-consuming task of prediction of cylindrical cup in a very short time period. The model has been tested successfully on various stripper designed in sheet metal industries. A sample run on a typical stripper demonstrated the usefulness of the proposed model.

Multi response optimization

The single parameter optimization is applicable when system performance is counted only on the bvasis of one repsonse or among many one particular response function is most dominant. However, in the present work, all the response functions are important, though having varrying weightages. Hence multi objective, multi parametric optimization is required to be done. In this work it is porposed to use Utility concept along with Taguchi.

Preference scale construction

The preference scale is constructed for all parameters. For BTE, it as shown as follows,

$$P_{BTE} = 14.66 \times \log \left[\frac{X_{BTE}}{7.46}\right]$$

Weights of quality characteristics

The decision maker has to assign weights. Normally, every parameter is assigned equal weights, here eight output parameters are analyzed, and hence weight of 1/4 is equally assigned to each response.

$$Pm = Tp = THm = THp == 1/4$$

Utility value calculation

The utility value of each experiment is calculated using following equation,

$$U(n, R) = Pm \times Wm + Tp \times Wp + THm \times Wthm + THp \times Wthp$$

Where, n = trial number, 1, 2……..9

R = replication number, 1, 2, 3, 4

Analysis of the data and determination of optimal setting of parameters

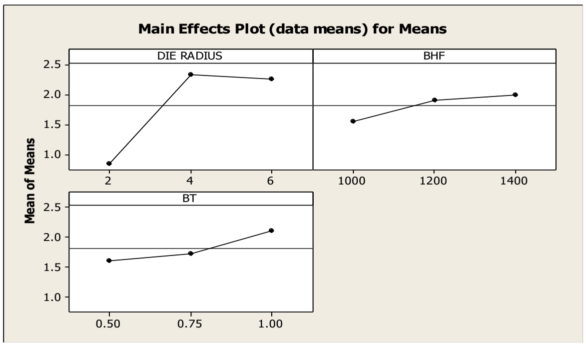
Utility values are analyzed for mean response and signal to noise ration. Since utility is higher is better is selected then,

$$S/N = -10 \log10\left(\frac{1}{n}\sum_{i=1}^{n}\frac{1}{Y{i^2}}\right)$$

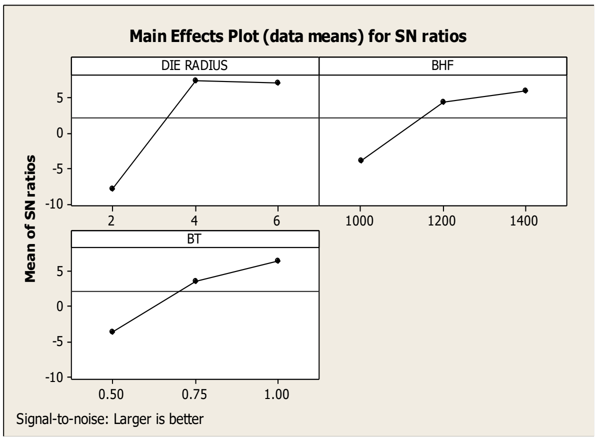
Where, y_j= value of the characteristics at observation j;

The corresponding S/N ratios using utility values as single response and the condition "higher is better" are found by

The main effect plots for individual variable for combined response function are shown in Figures. Considering larger the better criteria, values of different variables for combined optimum response, based on S/N ratio, are shown in Table. The below plots define highest mean value plots in terms of data means and optimal characteristics.



a. Means



b. S/N Ratio

Figures show Main Effect Plot of Parameters on Means and S/N Ratio of Utility Overall Value

Table shows Optimum values on S/N Ratio basis

Variables			S/N ratios
Die radius	**BHF**	**Bt**	
4	1400	1	7.355

Die radius contributes maximum i.e. 47.04% in optimum response followed by blank holding force c (16.93%), and blank thickness (16.45%), The confirmation test for the optimal parameter setting with its selected levels was conducted to evaluate the response characteristics for single stage drawing of cylindrical cup. The maximum error between the actual and predicted values is 2.43%. It may be attributed to the manual setting of compression ratio and least count of digital measuring equipment.

Confirmatory Test

The confirmation test for the optimal parameter setting with its selected levels was conducted to evaluate the response characteristics for single stage drawing of cylindrical cup. Optimum performance and best formability characteristics are found at die radius 4, BHF 1400, and blank thickness 1 mm. Test is conducted Table shows the comparison of the experimental results with predicted values of responses. The maximum error between the actual and predicted values is 1.56 %. It may be attributed to the manual setting of compression ratio and least count of digital measuring equipment.

Actual and Predicted values

Trial	Dr	BHF	Bt
	4	1400	1

Sr. No	Response	Actual	Predicted	% error	For the above trial, confirmatory test is conducted and actual results are compared with predicted results
1	Pm	24.4	25.01	2.4391	
2	Tp	127.49	129.07	1.2242	
3	Thm	1.125	1.139	1.23	
4	Thp	0.7756	0.789	1.6984	

Conclusions:

- The model developed using an Artificial Neural Technique predicts input-output relationship for all performance parameters and formability characteristics with highest accuracy as it takes care of non-linear behaviour.
- The non-linearity occurs mainly due to following reasons;
  i) Uncertainty in interaction effect of input variables in different situations leading to formation of unexpected defects,
- ANN provides a single model with virtual hidden algorithm considering training, testing and validating data together and helps to predict all performance parameters and formability characteristics in a single iteration.
- The correlation coefficients for Thinning % maximum (Pm), Thinning % minimum (Tp), Thickness maximum (Thm) and Thickness minimum (Thp) at the training stage are found to be 0.99939, 0.95527, 0.99949, and 0.98109 respectively. The coefficients close to unity indicate good accuracy of the models.
- The model can be used to predict output data cylindrical cup without further experimentation

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