Investigate the wrinkling of Al6061 sheet metal forming process by neural network

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***Abstract*—In sheet metal industries, they mostly concentrate to reduce the defect of sheet metal like wrinkling, tearing etc., during sheet metal forming process. The wrinkling of Al6061 is concentrated in this paper. The wrinkle factor of sheet metal is affected by various factors like velocity, cup thickness, sheet metal thickness, friction coefficient. That wrinkle factors of Al6061 is analyzed by ansys. The artificial neural network is train to reveal the geometrical criteria of wrinkling. The back propagation neural network is use to feed the set of geometrical variables as its inputs. After train the experimental data, applied the new data to get the new prediction value of wrinkling.**

Keywords—Wrinkling, Sheet metal forming,Neural network.

I. INTRODUCTION

During the last decade, there has been a tremendous development of sheet materials and sheet forming technology. The development of new sheet metal forming processes, tooling etc. has up till now to a large extent been based on experience, rules of thumb and trial-error experiments without or with only little use of scientifically based engineering methods. As mentioned above, experience is not enough, and trial-error experiments are very expensive with regard to both money and time. There is therefore great need for the development of both theoretical and experimental engineering methods which enable the problems to be tackled effectively; this is necessary to reduce production cost and to reduce the lead time between design and production the demands required from the sheet metal processes are increasing both with regard to the tolerance requirements of the finished part and with regard to the complexity (e.g. near net shape forming). To meet these requirements, a detailed knowledge about the material properties, the friction conditions and the forming process is needed. This knowledge can only be obtained by using advanced theoretical and experimental engineering methods.

Metal forming includes a large group of manufacturing process in which plastic deformation is used to change the shape of metal work pieces, deformation results from the use of a tool. Usually called a die in metal forming, which applies stresses that exceed the yield strength of the metal. The metal therefore deforms to take a shape determined by the geometry of the die. Sheet metal working processes are forming and related operations performed on metal sheets, strips, and coils. The surface area-to-volume ratio of the starting metal is high; thus, this ratio is a useful means to distinguish bulk deformations from sheet metal processes. In this sheet metal forming processes there are number of forming process like wise forging, bending, stretching, extrusion, drawing, rolling, deep drawing.

Deep drawing technology is used in a wide range of production processes. For example, it is used by the automotive industry to manufacture car parts; it is also used for making household items such as stainless steel kitchen sinks. The deep drawing process is a process to manufacture a product from sheet metal. During the deep drawing process an

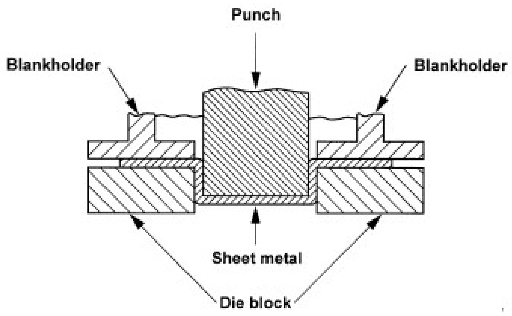

Fig.1 Schematic Diagram of Deep Drawing

initially flat blank is clamped between the die and the blank holder after which the punch moves down to deform the clamped blank into desired shape

Useful tools to study the influence of these parameters are numerical models like the finite element method. To develop the finite element program in order to better satisfy the requirement for industrial applications of the deep drawing process. Numerical investigations of the deep drawing of square cups have been carried out using the finite element method.

Deep drawing is a more complex form of sheet metalworking than cuttings are bending, and more things can go wrong. A number of defects can occur in a drawn product some of wrinkling, tearing, surface scratches. In sheet metal industries, the ability to predict and avoid surface failures, such as wrinkling, is of great importance. Wrinkling often appears as surface defects in the form of small waves or folds. The initiation and growth of wrinkles in sheet metal forming processes are influenced by many factors such as the stress state the mechanical properties o f the sheet material the geometry of the body and the contact conditions.

It is difficult to analyze wrinkling growth considering these factors because the effect of the factors are very complex and the wrinkling behavior may show a wide variation for small deviation of the factors. Wrinkling research has interested many scholars for along period. Great efforts have been put on in the prediction of wrinkling initiation during sheet forming processes. In sheet metal forming, it is vital to strictly prevent surface defects like wrinkling so as to ensure dimensional accuracy and acceptable aesthetics. It is difficult to define criteria for describing the stability in metal forming. Therefore, an understanding of the factors governing the formation and growth of wrinkles is of prime importance in the successful forming.

Neural network is a nonlinear dynamic computational system where, rather than relying on a number of predetermined assumptions, data is used to form the model. The technique is therefore potentially capable of handling the noisy and approximate data that are typical in the domain of failure risk analysis. When using neural networks, developers of models do not need to deal with the assumptions which are imposed by statistics and which limit their modeling ability. Much research has been conducted to apply neural network technology to some sort of prediction problems such as forecasting the machining behavior and tool wear. There exist many different architectures and learning algorithms for neural network models Most successful applications utilize the three layer back propagation design, In such a model, when the input neurons receive data (in our case the geometrical variables), a calculation is performed at each neuron, with a subsequent signal sent to each connected hidden neuron, which in turn passes a signal teach output neuron.

The output layer then performs the evaluation (in our case the estimation of the occurrence of Wrinkle free).The neural network learns by using training data. Input Variables are supplied and the resultant output is compared with the desired output. The network then adjusts the interconnection weights between layers. This process is repeated until the network performs well on the training set. The network can then be assessed on data not included in the training set, the validation data, to estimate its performance.

The outputs of the network model in processing this data set, compared with the target values, represent a kind of objective assessment of the quality of the model. A neural network model was constructed and trained by the above datum series obtained from the Numerical Results. The minimization of wrinkle free is identified as the characteristic parameter since it reflects the changes of friction coefficient, thickness and material properties. Model was applied to unknown data to perform the investigation of the occurrence of wrinkling as well as to examine.

Here we investigate the Al6061 alloy wrinkling by using neural network. The Al6061 alloy is using in automotive industries to produce the automotive components.

II. FEA SIMULATION

A. Performing FEA simulation

FEA simulation is mainly performed to get the teaching data for the neural network. More emphasis is given to the thickness and frictional coefficient. Various sets of friction coefficient, cup height and thickness are used as the training cases. For each combination of friction coefficient, cup height and sheet thickness, no of iterations are performed in the FEM simulations. The simulation characterized by the minimum wrinkle is chosen as the teaching set for the neural network.

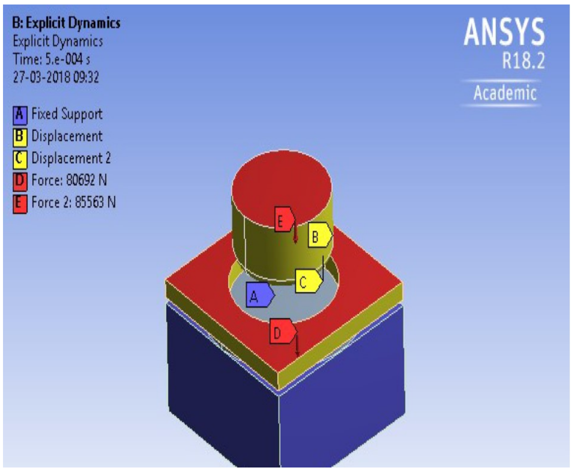

Fig.2 Boundary Conditions

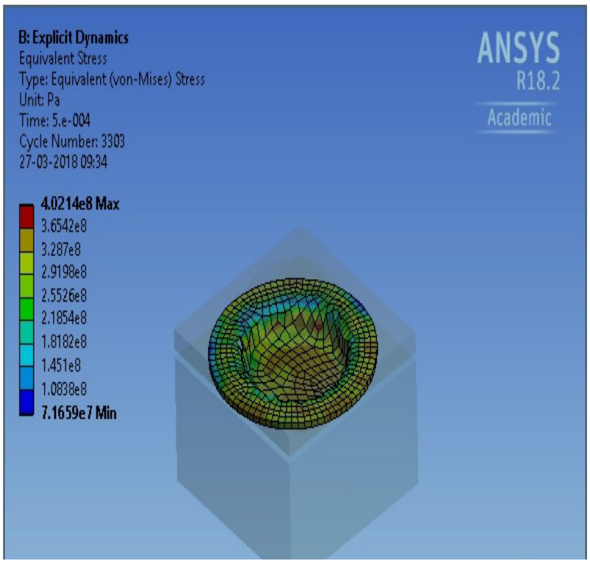

Fig.3 Equivalent Stress

B. Wrinkle factor

The wrinkling percentage is find out by Journal of Materials Processing And Technology 53(1995) 759-780. (Failure and Wrinkling Criteria and Mathematical Modelling of Shrink and Stretch Flanging Operation in Sheet Metal Forming).

The wrinkle is occur when the maximum compressive strain not exceed the limit strain.

III. TRAING THE NEURAL NETWORK

Initially random weights are assumed for each neuron. When provided with certain inputs, based on the weights the inputs are processed through each layer and the output is produced at the output layer. The output is checked with the desired output to calculate the Mean Square Error (MSE). The MSE is given by

$$MSE = \frac{1}{Q * N_o} * \sum_{m=1}^{Q} \sum_{n=1}^{N_o} (d_n[m] - y_n[m])^2$$

MSE is back propagated through the network to alter the weights. New outputs are obtained based on the altered weight and the outputs are checked with the desired output to calculate MSE. Again MSE is back propagated and this process continues until MSE is reduced to certain level. The weights associated with each neuron obtained after error reduction are the final weights. This process of obtaining the final weights is called the training of the network.

The data's from the numerical simulation are used as training set for the network. Total of 50 sets of simulation data's are used. Sheet thickness, Friction coefficient, Young's Modulus and poisons ratio are used as input values. Punch force and percentage of punch stroke are used as output values.

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A. Trained Input Data Sets

punch velocity	cup height	sheet thickness	friction coefficient	wrinkle factor
50	15	3	0.05	1.02
50	15	2.5	0.05	2
50	15	2	0.05	4.95
50	15	2	0.05	9
50	15	2.4	0.05	8.8
60	15	3	0.05	7.42
60	15	1	0.05	12.12
60	15	1.1	0.05	15
60	14.5	1.25	0.05	13.32
60	14.5	1.5	0.05	13
100	14.5	1.54	0.05	4
100	14.5	1.7	0.05	3.9
100	15	1.9	0.05	7.98
100	15	1.9	0.05	8
100	15	1.94	0.05	6.42
80	15	2	0.05	10
80	15	2	0.05	5
80	15.1	2.2	0.05	3.5
75	15.4	2.2	0.05	3
75	15.5	2.5	0.05	2.5
75	15.5	2.7	0.05	2.8
60	15.5	2.7	0.05	3.5
60	15.5	3	0.05	3.2
50	15	0.9	0.05	16
50	15	0.9	0.05	13.1
55	15	0.9	0.05	14.89
55	15.5	1	0.05	10
60	15.5	1.5	0.05	8.7
60	15	1.5	0.05	8.5
60	15.5	1.5	0.05	8.8
65	15	2	0.05	1.8
65	15	2.5	0.05	1.5
70	15.5	2.5	0.05	1.2
75	15.5	2	0.05	1
75	15	2.5	0.05	1.1
75	15.5	2	0.05	1.07
75	15	2.5	0.05	2
75	15	2	0.05	3.5
80	15	2.5	0.05	2.12
80	15.5	2	0.05	2.3
85	15.5	2.5	0.05	2.12
85	15	3	0.05	0.12

B. Predicted values

Punch velocity	Cup height (mm)	Sheet thickness (mm)	Friction coefficient	Wrinkle factor (%)
70	25.6	0.9	005	6.59
120	25.6	0.9	0.05	3.48
100	25.0	0.9	0.05	0.85
100	25.2	0.9	0.05	0.27
100	25.6	0.85	0.05	2.72
100	25.6	1.4	0.05	5.47
100	25.6	0.9	0.035	8.54
100	25.6	0.9	0.06	0.32

The effect of various factors such as thickness, cup height, friction co efficient, punch velocity, affecting wrinkling are shown through graphs.

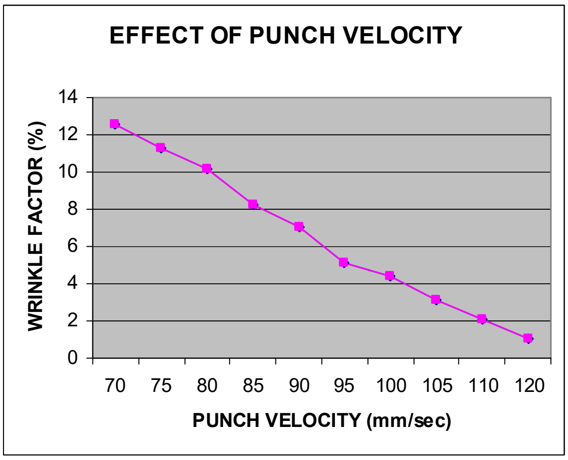


Fig.4 Punch velocity Vs wrinkle factor

From the above graph it's known that the punch velocity will be increased the wrinkle will be reduce

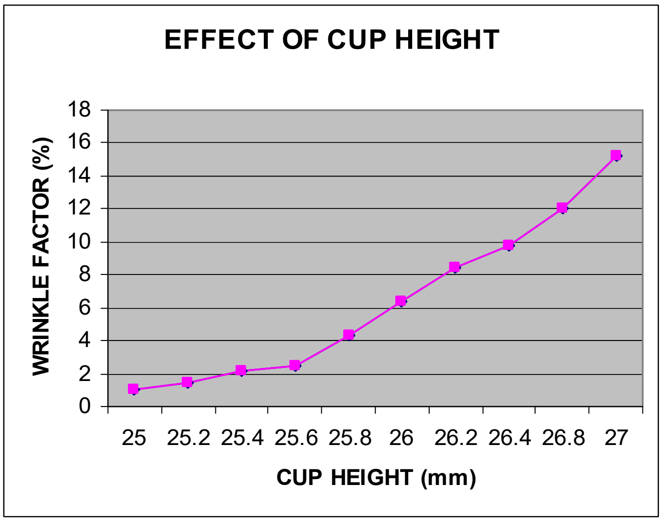


Fig.5 Cup height Vs wrinkle factor

From the above plot, it's known that the wrinkle effect is found to be more with the increase of cup height.

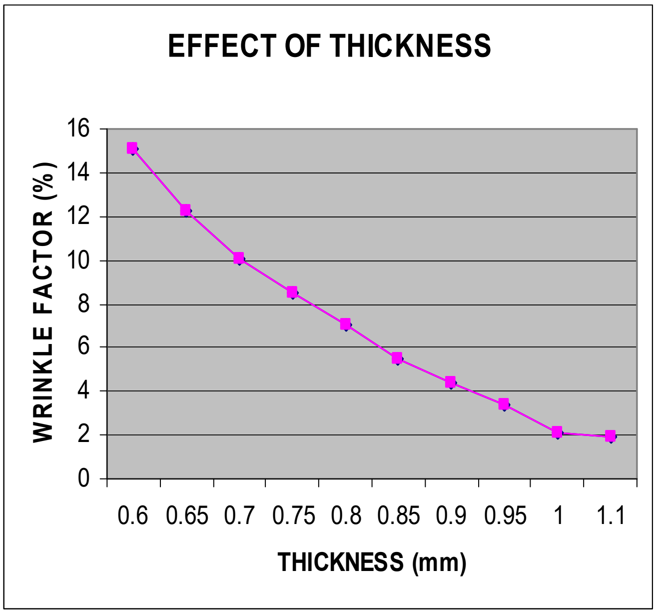
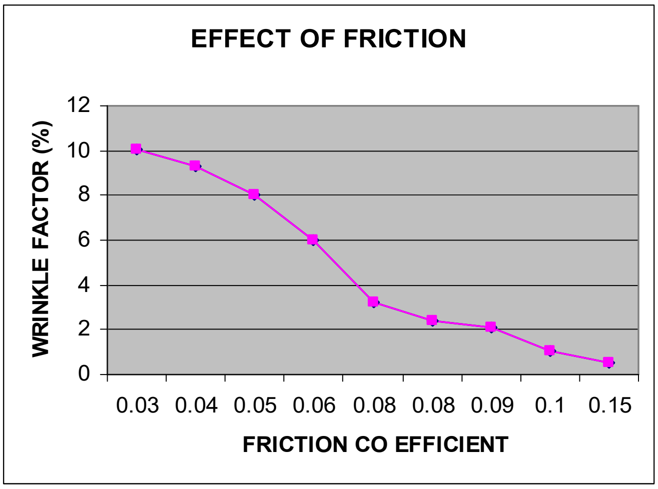


Fig.6 Thickness Vs wrinkle factor

The above plot shown that the increase in the sheet thickness will reduce the wrinkling



From the above graph known that the wrinkling will decrease by the increase of friction co efficient.

III.CONCLUSION

Wrinkling analysis of deep drawing process in Al6061 was attempted. The problem was modeled in two dimensional one. Parameters like blank sheet thickness, punch velocity, co efficient of friction, blank holder force, cup height are taken for analysis. Here the blank holder force kept a constant value. One factor at a time analysis is used to predict the various parameters. A neural network control system for prediction of wrinkling in deep drawing process of aluminum is proposed in this paper. Influences of variations in sheet thickness, cup height, punch velocity and lubrication conditions are examined. The following results are the major conclusions from the analysis.

The results shows that,

- There is a reduction in wrinkle, when the punch velocity is increased.
- Wrinkle is found to be more, when the cup height is increased.
- Wrinkle was reduced, when the sheet thickness is increased.
- Wrinkle was reduced, when the co efficient of friction is increased.

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