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ARTIFICIAL NEURAL NETWORK APPLICATION IN CYLINDRICAL BENDING PROCESS.

Dipali P. Pandya[1] , Harit K. Raval[2]
[1]Lecturer (Mech) Nirma Uni. Ahmedabad.
[2] Professor (Mech) S.V.N.I.T. Surat

Email: dipali.pandya@nirmauni.ac.in[1] , hkr@med.svnit.ac.in[2]

ABSTRACT
The cylindrical section are back born of fabrication industry, as it is used to prepare the skeleton of pressure vessel, reactors etc. Spring back is the serious problem in air V bending and three roller bending processes. To overcome this problem there exist number of different analytical methods. Among many such analytical method FEM has proven its application for the manufacturing process, however it cannot be used for the online controlling the spring back, as it takes very long time for prediction. In order to get optimum solution of spring back ANN can be used. In present work an attempt has been made to use Neuro solution 4.3 for the ANN applying to cylindrical bending process. Effect of network parameters on Mean Square Error for prediction of spring back was studied. The result of ANN model was compared with Experimental and analytical results. The result was found in good agreement.

INTRODUCTION
The roll bending process is an efficient technique for forming a metal plate into a cylindrical shape. It is widely used in metal forming industry. There are many different types of roll benders available to plate bending manufacturers, including for example, the three-roll pyramidal model or a four roll symmetric model. A three-roll plate-bending machine belongs to the category of heavy-duty machines that can roll the plate into cylinders and cone. Its important applications are in the manufacture of cylindrical tanks, boiler equipment, fuel tanks for launch vehicles, space application programmers and special containers

Considerable amount of literature is available on industrial and academic research on the plate bending process. M. Inamdar1, P. P. Date1, U. P. Singh [2] discusses the development of an ANN which can be used to train and later to predict the springback, as well as the punch travel, to achieve the desired angle in a single stroke in an air V bending process. M.V. Ingmar, P.P. Date,[3] describes the development of an ANN based on back propagation (BP) of error. The architecture, established using an analytical model for training consisted of 5 input, 10 hidden and two output nodes (punch displacement and spring back angle). The five inputs were angle of bend, punch radius/thickness ratio, die gap, die entry radius, yield strength to Young's modulus ratio and the strain hardening exponent, n. The effect of network parameters on the mean square error (MSE) of prediction was studied. The ANN was subsequently trained with experimental data generated from over 400 plane strain bending experiments using combinations of two punch radii, three die radii and three die gaps and five different materials. Updating of the learning rate and the momentum term was found to be beneficial. Testing of the ANN was carried out using experimental data not used during training. It was found that accuracy of predictions depended more on the number of training patterns used than on the ANN architecture.

Research work on roller-bending reported in literature mainly focuses on ANN application in different processes .In the presented work ANN applied to cylindrical bending process. The result of ANN model was compared with experimental results.

NOMENCLATURE

α	Momentum
η	Learning rate
R	Radius of curvature (before spring back in mm)
R_f	Radius of curvature (after spring back in mm)
U	Top Roller position (mm)
E	Young's modulus (N/mm2)
K	Strength coefficient (N/mm^2)
r_t	Radius of top roller (mm)

t Plate thickness (mm)

n Strain hardening exponent

ANN MODELING FOR 3- ROLLER CYLINDRICAL BENDING PROCESS USING NERO SOLUTION S/W.

INTRODUCTION

A multi layer perception was developed using neuro solution and used for the prediction of spring back. The BP was initially trained using an analytical model (that correlated well with experimental data) and subsequently with experimental data. Testing was performed on experimental data [7]. For the cylindrical bending data was already generated analytically and experimentally [9]. .Stuttgart Neural Network Simulator (SNNS)software package was already used [9] to predict the spring back and top roller position .After finding a new version of ANN called NEURO SOLUTION all this generated data was tested and simulate the result of SNNS and NEURO SOLUTION. Though both the software operating method is different and good results were found compared to SNNS Operating with Neuro Solution , Out of 999 data 15% data had taken for cross validation and 5% data had taken for testing. The section that follows describes the modeling of ANN for three roller bending process and brings out its capabilities.

INPUTS TO ANN

The major parameter s influencing the spring back were identified to be [1,5, 9]

1. Radius of curvature R_f
2. Sheet thickness t
3. Width of the sheet w
4. Strain hardening exponent n
5. Flow stress constant k
6. Young's modulus E
7. Top roller radius R_t
8. Bottom roller radius r
9. Center distance between rollers a

Effect of other parameters like friction etc. are having comparatively minor influence on spring back were not consider as an input to ANN. The above nine input parameter have been combine in to six parameters for easy functioning which are namely,

1. Radius of curvature R_f
2. Ratio of sheet thickness to the width(t/w)
3. Strain hardening exponent(n)
4. Ratio of Flow stress constant Young's modulus(K/E)
5. Ratio of Top roller radius to Sheet thickness(R_t/2t)
6. Ratio of Bottom roller radius to Center distance between rollers(r/a)

OUTPUTS TO ANN

The following two parameters of interest were the output of ANN [1,4, 7,9]

1.Top roller position U

2.Spring back (R_f-R)

BACK PROPAGATION NEURAL NETWORK

Neural networks are mathematical models composed by several neurons arranged in different layers, linked through the variable weights. These weights are calculated by an itrerative method during the training process when the network is fed with a large amount of training data, input and output pairs that represent the pattern attempting to be modeled. On account of this , Neural networks are non-linear analysis tools. The relationships among the influence variables in bending and spring back have a non- lineal character with multiple interactions [3,5]. Commonly, a one layer neural network is sufficient to accurately model any type of continuous function if it is provided by a sufficient number of hidden nodes. This universality property [8] is applied for function approximation, which fits with the target of the variables that want to be predicted. Therefore for this work , a multilayer perceptions with one layers using a back propagation (BP) algorithm , widely used for general engineering applications, is chosen [6].

ANN ARCHITECTURE

As mention above nine different inputs and four out puts are given to ANN. Consider the ten hidden nodes and single layer feed forward Neural Network, Network architecture is become as follows (Refer fig.1).

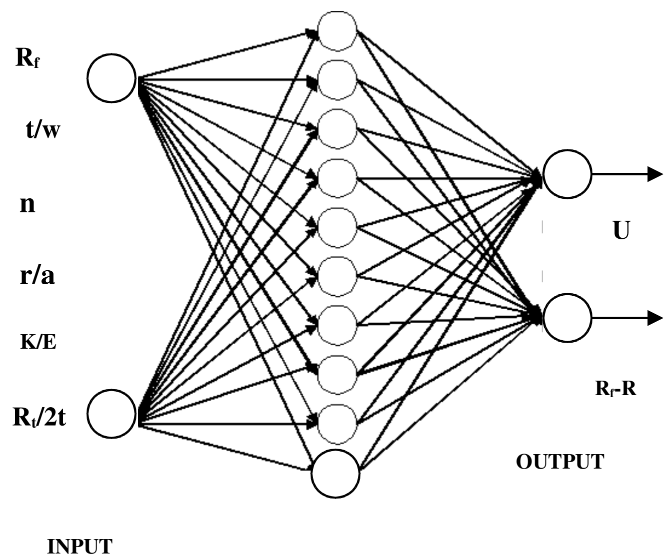

Fig.1 Network Architecture

TRAINING OF ANN

For this case study will be broach under a supervised learning strategy, which means that for all the input patterns ,the objective out puts are known and batch pattern training style is chosen. The training set construction represents a key point of the network generalization property [8], especially for avoiding the over fitting problem. For avoiding it , the early stopping technique is used considering the three data sets:

training ,validation and testing. The training set for training and weight adjustments. The validation set to refine the network by early stopping technique. And finally the testing data set an unseeing set during the training that is used to determine the network performance by an error computation.

RESULT AND DISCUSSION

The results obtained under the present work are reported .ANN applied to the Cylinder for prediction of spring back , top roller position and it found to be good agreement.

Here Neuro Solution version 4.3 is used which was found by Curt Lefebvre and Jose Principle. NEURO SOLUTION based on the back propagation learning algorithm with momentum term is used. Network parameter such a Learning rate (η), Momentum(α), no of hidden nodes in hidden layer(n), no of hidden layers and activation functions were chosen based on the parametric study reported in the literatures [5] .The parametric study was intended to obtain the optimal parameters for faster convergence of data and minimum MSE. For **cylindrical bending** six non dimensional parameters were selected as an input to ANN based on the literature . ANN was trained with the experimental data up to 40000 epochs . While training, to arrive at optimal parameter , parametric variation was under taken, varying one parameter at once and keeping other parameter constant . The parametric variation was selected based on the effect of it on MSE as reported in literature [3,4,7]. Subsequently network was tested with that experimental data which was not used during training [4,7]. After testing , ANN results were compared with experimental results for the % of error in top roller position and spring back.

OPTIMUM PARAMETER VALUES FOR THE ANN ARCHITECTURE

Table.1Optimal parameter values for ANN architecture from parametric study(in cylindrical bending)

Sr.No	Parameter	Data Normalized as a whole set
1	Number of Inputs	6
2	Number of out puts	2
3	Number of hidden nodes	10
4	Number of hidden layers	1
5	Momentum	0.7
6	Learning rate	0.6
7	Activation function	Sigmoidal
8	Normalized range	0.1 to 0.9

TESTING RESULT OF ANN

Testing result clearly shows Table 2, R value is nearly about to 1 which co relate desired out put to the ANN predicted output. Also the graph shows desired out put and ANN out put result is coincide with each other.

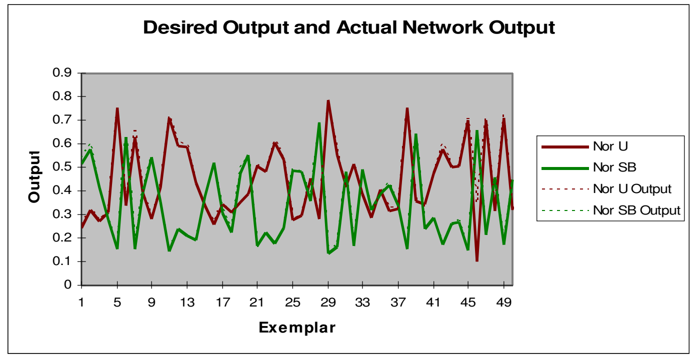

Fig.2 Desired out put and ANN predicted output.

Table.2 Co relation between desired output and ANN output

Performance	*Nor U*	*Nor SB*
MSE	0.001300787	0.000171284
NMSE	0.051246056	0.006673003
MAE	0.012019119	0.010353748
Min Abs Error	0.000149022	0.000746634
Max Abs Error	0.245628053	0.027423743
R	0.975263229	0.997166663

SENSITIVITY ANALYSIS RESULT

From the fig.3 can be clearly understand the effect of each input parameter on output. Ratio of flow stress constant to young's modulus(k/E) shows the maximum sensitivity on top roller position and spring back compare to other input parameters in cylindrical bending .

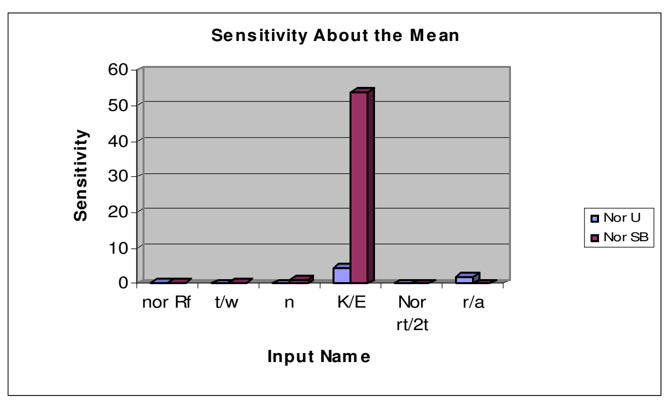

Fig.3 Effect of each input parameter on output (cylindrical bending)

CONCLUSION

The ANN, based on the Back Propagation algorithm with updating term and Learning rate is capable of predicting the within 5% error for cylindrical. Model under consideration is suitable for the upper and lower range of variables as mentioned in table 3.

Table3 lower and upper range of variables for cylindrical bending.

SR. NO	VARIABLE	LOWER RANGE	UPPER RANGE
1	Final radius of curvature	350 mm	3780 mm
2	Thickness , t	5 mm	14 mm
3	Width w	66 mm	197mm
4	Center distance ,a	375 mm	470 mm
5	Material flow constant , k	520.909 mm	1018.870 mm
6	Young's modulus E	$210000 N/mm^2$	
7	Top roller radius Rt	94 mm	
8	Bottom roller radius, r	81.5 mm	
9	Strain hardening exponent, n	0.438	0.695

From the parametric study , training and testing result of the data on cylindrical Bending process using obtained ANN , following conclusion were derived.

- MSE during the training and testing was found to be affected by Normalization of data. Because of this fact ANN can be used only for the range of the input variables for which it has been trained.
- Network parameter like Momentum and learning rate were found to influence MSE, Larger initial values of learning rate leads to the faster decrease in MSE . similar was the case with Momentum parameter. Parametric study indicates that there exists unique combination of Network Parameters like Momentum and Learning rate for MSE. Optimal parameter values are required to be find out by trail and error.
- Empirically it was observed that one got better prediction by increasing the number of training patterns , rather then modifying the ANN architecture.
- Good correlation between the test output of the ANN with the analytical model and experimental results for spring back radius as a function of normalized top roller position (U) and top roller position (U) as a function of final radius of curvature Rf , demonstrating the usefulness of present power low ANN model for the online prediction of spring back and setting of top roller position (U).
- It can be concluded from the normal distribution of the selected plates that reliability of ANN obtained under present study is approximately 95% for cylindrical bending, meaning is to say that 95% of testing results will fall under targeted error of ($\pm$) 5% of error in top roller position and spring back for cylindrical bending in top roller position , spring back

REFERENCES

1. Weilong Hu, Z.R. Wang, "Theoretical analysis and experimental study to support the development of a more valuable roll-bending process". International journal of machine tool and manufacture, 41 (2001)731-747.
2. M. Inamdar1, P. P. Date1, K. Narasimhan2, S. K. Maiti1 and U. P. Singh, "Development of an Artificial Neural Network to Predict Springback in Air Vee Bending" Journal of Advance manufacturing Technology. (2000) 16:376–381
3. M.V. Inamdar , P.P. Date, U.B. Desai1 " Studies on the prediction of springback in air vee bending of metallic sheets using an artificial neural network" Journal of Materials Processing Technology 108 (2000) 45-54
4. Dhaval Bhatt , Chinmay Desai, H.K. Raval and A.K. Dave ,"prediction of the spring back in air V- bending ANN for the real material behavior (power law)", 6th Internation conference on Engineering Design and Automation, Aug4-7,2002,hawai.
5. A.Forcellese, F. Gabrielli ,R. Ruffini "Effect of the training set size on spring back control by neural network in an air bending process" Journal of Material processing Technology ,1998.
6. M.Luisa Garcia- Romeu and Joaquim Ciurana "Spring back and Geometry Prediction – Neural Network Applied to the Air Bending Process. Dept. of mechanical engineering and industrial construction , Univercity of Girona.
7. Piyush P. Gohil, " Simulation and Experimental investigation on three roller plateBending process", M.E. Dissertation report submitted to South Gujarat University , 2002
8. Mehrotra ,K Mohan, C.K.Ranka "Elements of Artificial Neural Networks",MIT Press, Cambridge,Mass, 1997.
9. A.H. Gandhi, "Simulation of three roller plate Bending process for real material behavior using Artificial Neural Network-: A Parametric study", M.E. Dissertion report submitted to South Gujarat University , 2003.