

# ARTIFICIAL NEURAL NETWORK BASED SIMULATION FOR PIERCING OPERATION

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**ABSTRACT:** In this paper a neural network-based approximation method is used to predict optimized punch entry during piercing operation. Five materials are used with varying thicknesses and punch diameters for experimentation against optimal punch entry as a measure during piercing. Rigorous experimentation was carried out and the tabulated data is used for the numerical simulation using Artificial Neural Network. Figurative mathematical model is initiated to reveal the nature of Neural Network. Scaled conjugate gradient algorithm is considered as optimization algorithms for ANN, which performs well with diversified topologies. Coefficient of correlation ( $R = 0.997$ ) with the sum of square error in the range of (0.001-0.01) reflecting a better approximation of dependent variable.

**Key words:** Piercing, Punch entry, Neural network, Diverse topologies, Coefficient of correlation

## 1. INTRODUCTION

Sheet metal piercing process consists in separating a blank from a sheet by the punch. It is the combination of plastic flow and ductile fracture. Initial study pertaining to metal shearing [1] was an revolutionary start to understand the concept, shearing which further extensively examined [2] for crack formation in piercing operation. Numerous experimental studies [3,4] discussed the various affecting parameters like cutting clearance, thickness of sheet and tool diameter during shearing of the metal sheets. The exhaustive study of Johnson and Slater [5,6] discusses the phenomenon involved in the blanking operation have been well known for a longer duration. They have given a schematic representation of punch force verses punch penetration diagram which elaborates the different phases associated with cutting action. In their study they clearly define that the maximum punch force is strongly related to the plastic flow and it does not depend on initiation & propagation of fracture. Piercing is one of the most widely used sheet metal operation which leads to plastic shearing followed by the creation and propagation of cracks (Figure 1). Since few decades, so many researchers have been devoted to the modeling of piercing/blanking process. Earlier Atkins [7] and Zhou and Wierzbicki [8] concerned the development of some analytical models. These simple models can be used to estimate the punching force but unable to investigate the other phenomenon. Goijaerts, A. M, et all [9] is focused on the description of ductile fracture initiation, which is required to predict product shapes in the metal blanking. Hambli [10] compare the numerical results obtained in case of blanking with Gurson & Lemaitre damage model in describing the initiation and propagation of cracks during the process evolution. Due to rapid change in technology the need of changing process specification is getting more importance, which leads to aim, decrease of lead time in

production. Therefore optimization of punch entry is one such task which helps to reduce machining time, damages of cutting edges of punch and die block.

## 2. PUNCHING PROCESS

In the piercing process, deletion of sheet is carried out through the shearing process between the punch and die. Phases of cutting in the shearing process as illustrated using Figure 1. The cutting action is started by the contact between the punch and sheet. Onwards, the elastic deformation starts. Once the yield strength of the sheet is reached, plastic deformation occurs. Pressure at the cutting edge continues to increase and the shearing starts. After the shear strength of the sheet is exceeded, the crack is formed and the sheet will be separated [6]. The resulting sheared edge consists of the rollover zone, burnish zone, fracture zone, and burr. The rollover zone is formed due to plastic deformation. The burnish zone is a smooth area that is created during the shearing process. The fracture zone is created after the crack formation. Actual cutting point is noticed in between the length of fracture zone. Burr formation is influenced by the wear state of the tools and clearance.

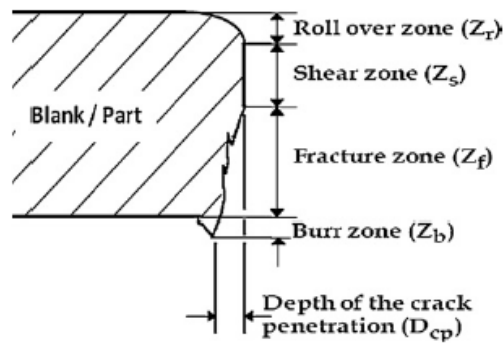


Figure 1. Geometric parameters of the blanked edge

## 3. EXPERIMENTAL SETUP AND MEASUREMENT

In the presented study, piercing experiments are performed by using a precision hydraulic press with 100-ton capacity. A simple die with removable die bushes is used during the experimentation. Photograph of die loaded press is shown in figure 2. Five materials are used for experimentation with varying thicknesses. To note the actual punch entry during experimentation, entry washers of different thicknesses ranges between 0.1 to 8 mm are added to setting stoppers of the die. The optimum punch entry at the fracture point is recorded.



Figure 2. Photograph of the simple die loaded on the used press

Five materials namely Steel CR, Copper, Brass CuZn 40, Aluminum and Galvanized Iron, thicknesses between 0.2 to 4 mm and punch diameters range between 10-30 mm (with an increment of 5mm) were used for piercing operation.



Figure 3. Photograph shows varying thicknesses of sheet metals and punches

Cutting force and Cutting clearance was calculated accordingly. Entry of the punch was noted each time when sheave (ranges between 0.1 to 8 mm) placed between setting stoppers was removed. Optimum entry at the point of fracture is noted and used for validation. The specific objective of the present investigation is to perform numerical simulation of piercing operation using artificial neural network (ANN). Investigation also provokes to find the error between the experimental and simulated results.

#### 4. NEURAL NETWORK MODELING

An artificial neural network (ANN) is a soft computing intelligent technique, based on biological methods of information processing. It is a form of computation inspired by the structure and function of the brain. As the family grew, most of the new models were designed for non-biological applications, though much of the associated terminology reflects its origin. The trade-off for the neural network flexibility is that the synaptic weights of a neural network are not easily interpretable. Thus, if one is trying to explain an underlying process that produces the relationships between the dependent and independent variables, it would be better to use a more traditional statistical model. However, if model interpretability is not important, one can often obtain good model results more quickly using a neural network (Figure 4). An ANN model can accommodate multiple input variables to predict multiple output variables.

#### 5. FEEDFORWARD NEURAL NETWORK

A multilayer perceptron (MLP) is a deep, artificial neural network. It is composed of more than one perceptron. They are composed of an input layer to receive the signal (L), an output layer that makes a decision or prediction about the input, and in between those two, an arbitrary number of hidden layers (M) that are the true computational engine of the MLP. The structure depicted in Figure 5 is known as feed forward architecture because the independent variables nodes in the network from input layer are connected in forward direction with hidden layer nodes and further connected to the output layer without any feedback loops.

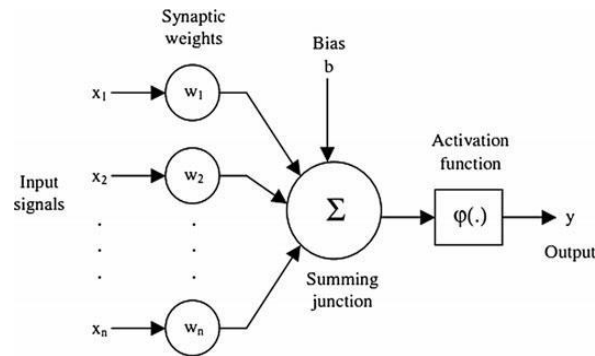


Figure 4. Neuron model and three-layer neural network structure

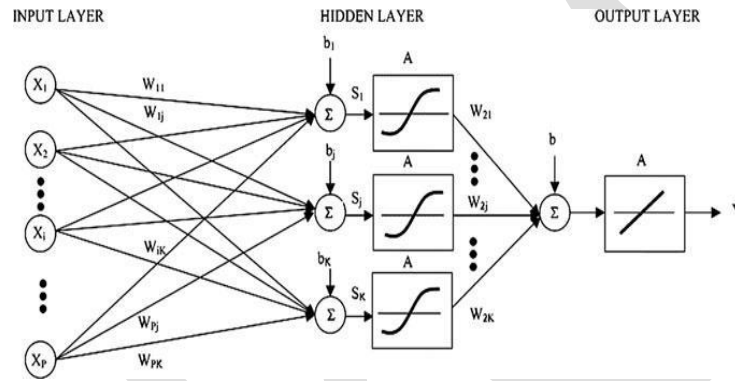


Figure 5. Three-layer neural network structure

- I. The input layer contains the independent variables.
- II. The hidden layer contains unobservable nodes or units. The value of each hidden unit is weighted sum of input and synapses constricted through nonlinear transfer function; the scrupulous form of the function is contingent upon the network type and upon user-controllable stipulations.
- III. The output layer comprises the dependent variables. Each output unit is some function of the hidden units.

## 6. ANN Modeling

An experimental means for determining an appropriate topology for solving a particular problem involves the training of a larger-than-necessary network and the subsequent removal of unnecessary weights and nodes during training. This approach, called pruning, requires advance knowledge of initial network size, but such upper bounds may not be difficult to estimate. An alternative means for determining appropriate network topology involves algorithms which start with a small network and build it larger; such algorithms are known as constructive algorithms.

## 7. RESULTS AND DISCUSSION

To investigate the strength of training algorithm for an MLP based ANN equalizer, the simulation results were obtained evaluating various test parameters. Training an ANN involves gradual reduction of the error between ANN output and the target output. ANN performance, regression plot and network performance plot measured by MSE error with the training number for one of the material is

presented in figure 6. Coefficient of correlation in all materials is closed to 0.997 which is an excellent indication for prediction of correct punch entry after ANN simulation. The maximum error seen is between 0.001-0.01 for any point. It is observed from figure 6 that, amongst 10-50 training cycles, the curve stabilizes for all simulated materials, which predicts that the ANN has been sufficiently trained.

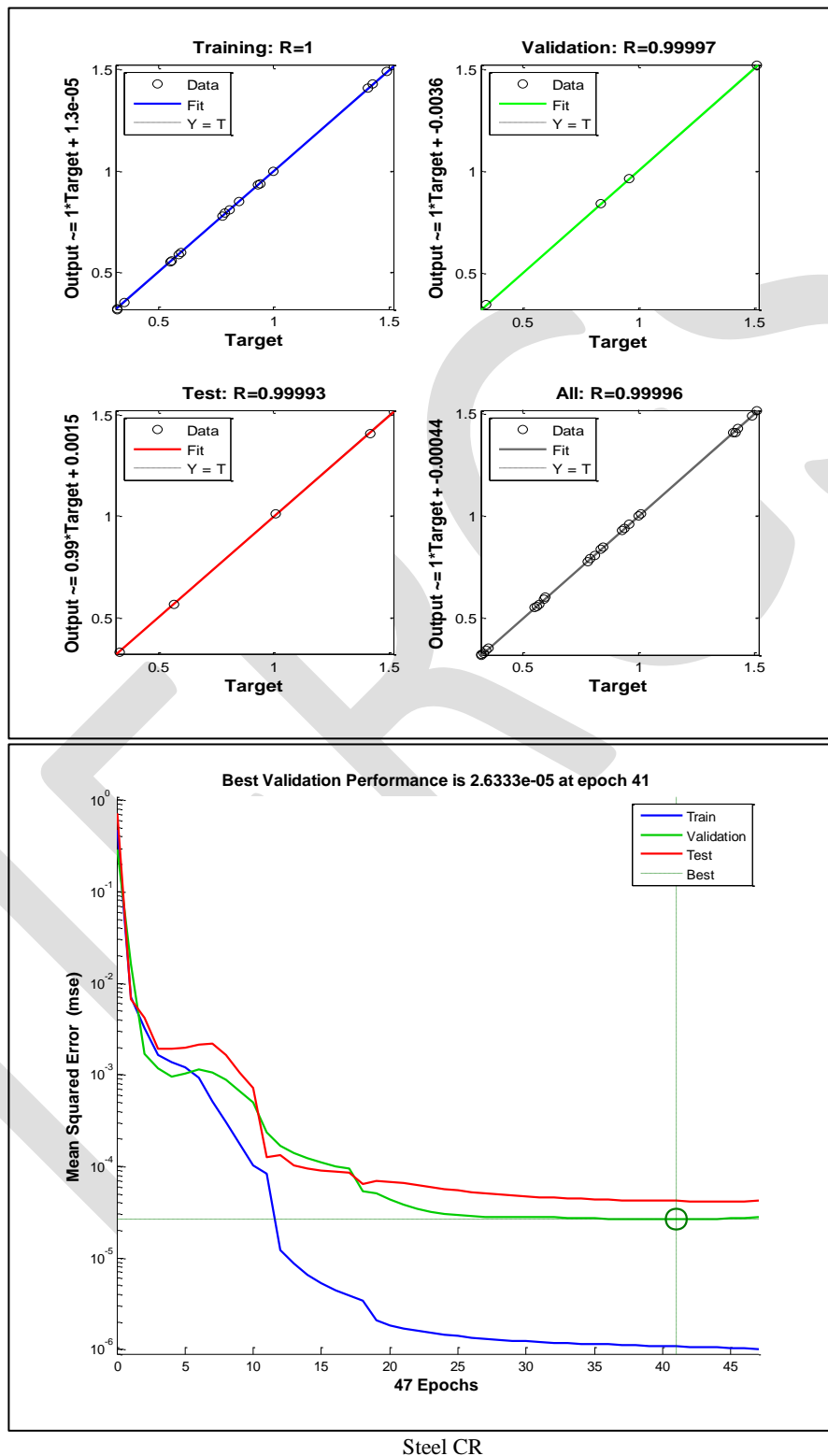


Figure 6. Regression analysis plot performance plot using scaled conjugate gradient training method

## 8. CONCLUSION

In this work, a trained set of back propagated scaled conjugate gradient algorithm is used to validate the punch entry of pierced parts. The major advantage of using scaled conjugate gradient algorithm is that, model can estimate the punch entry accurately at very faster rate. The corresponding coefficient of regression for 2-5-1 topology with scaled conjugate gradient algorithm shows best results in each selected materials. From results it is observed that, selected ANN algorithm suits well to process the experimental data. All the computed results are compared with experimental findings in order to examine their validity, which shows very close relationship with each other.

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