5.0 ARTIFICIAL NEURAL NETWORK (ANN)

Either from known or unknown source, a neural network may be trained with measured data. There are software tools designed to estimate the relationships in data where they can be trained to perform classification, estimation, simulation and prediction of the underlying process generating the data. The Neural Networks package supports several function estimation techniques that may be described in terms of the different types of neural networks and associated learning algorithms. Artificial neural networks are nonlinear information (signal) processing devices, which are built from interconnected elementary processing devices called neurons. ANN is a very important tool for studying the structure-function relationship of the human brain. Each computing unit, i.e., the artificial neuron in the neural network is based on the concept of an ideal neuron. An Artificial Neural Network (ANN) is an information-processing paradigm that is inspired by the way of biological nervous systems, such as brain and process information. It is composed of a large number of highly interconnected processing elements (neurons) working in union to solve specific problems. Since most manufacturing processes are complex in nature, highly non-linear,
and there are a large number of input variables, there is no accurate mathematical model which can describe the behavior of these processes.

A neural network is a massively parallel-distributed processor that has a natural propensity for storing experimental knowledge and making it available for use. Knowledge is acquired by the network through a learning process, and inter-neuron connection strengths known as synaptic weights are used to store the knowledge.

Much research is related to applications of Artificial Intelligence (AI), especially Artificial Neural Networks (ANN), for engineering fields such as manufacturing processes prediction, monitoring and controlling. Thus, the new approach which ensures efficient and fast selection of the optimum conditions and processing of available technological data are the ANNs and they are mostly used in the fields of biology, electronics, computer science, mathematics and engineering. The method has proved to be excellent for solving the optimization problems, for pattern recognition and for the adaptive control of machines.

5.1 BUILDING BLOCKS OF ARTIFICIAL NEURAL NETWORK

The basic building blocks of the artificial neural network are

1. Network architecture
2. Setting the weights
3. Activation function
5.1.1 Network Architecture

The arrangement of neurons into layers and the pattern of connection within and in between the layers is generally called as the architecture of the network. Feed forward, feedback, fully interconnected network, competitive network, etc. are the various types of network architectures.

**Single Layer Network:** It is one of the feed forward networks. It has only one layer of weighted interconnections. The inputs may be connected fully to the output units. In some cases, none of the input and output units are connected with other input and output units respectively. In a single layer network, the weights from one output unit do not influence the weights of other output units.

![Single Layer Network Diagram](image)

**Fig. 5.1 single layered feed forward network**

**Multilayer Network:** It is also feed forward net i.e., the network where the signals flow from the input units to the output units in a forward direction. The multi-layer network pose one or more layers of nodes between the input and output units.
Recurrent Network: One of the simplest is fully recurrent network. All units are connected to all other units and every unit has both an input and output network. Recurrent networks allow processing sequential information, where the processing depends on the state of the network at the recent step and the response to the current input depends upon previous inputs.

5.1.2 Weights Settings

The process of learning or training depends on setting the value for the weights. The process of modifying the weights in connection between network layers with the objective of achieving the expected outputs is called training a network. Learning is the internal process that takes place when a network is trained. Supervised training and Unsupervised training are the important types of training.
**Supervised Training:** Supervised training is the process of providing the network with a series of sample inputs and comparing the outputs with the expected responses. The training continues until the network is able to provide the expected response. In a neural network, for a sequence of training inputs there exist target output vectors. The weights may then be adjusted according to a learning algorithm. This process is called supervised training.

**Unsupervised Training:** If the output is unknown, for the training input vectors the method of unsupervised training is used. The network may modify the weight so that the most similar input vector is assigned to a same output unit. It is expected to form an example or code book vector for each cluster formed.

### 5.1.3 Activation Function

The activation function is used to calculate the output response of neuron. The sum of the weighted input signal is applied with an activation to obtain the response. Same activation functions are used for neurons in the same layer. The non-linear activation functions are used in a multilayer network. The output of a neuron in a neural network is between certain values (usually 0 and 1, or -1 and 1). In general, there are three types of activation functions they are the threshold function or step function, the pure linear function and sigmoid function.
The Threshold Function or Step Function:

\[
\phi(v) = \begin{cases} 
1 & \text{if } v \geq 0 \\ 
0 & \text{if } v < 0 
\end{cases}
\]

Fig: 5.3 Step Function

The Pure Linear Function: This function can take on the values of 0 or 1, but can also take on values in between depending on the amplification factor in a certain region of linear operation.

\[
\phi(v) = \begin{cases} 
1 & v \geq \frac{1}{2} \\ 
-\frac{1}{2} < v < \frac{1}{2} & \text{if } -\frac{1}{2} < v < \frac{1}{2} \\ 
0 & v \leq -\frac{1}{2} 
\end{cases}
\]

Fig 5.4 Pure Linear function
The Sigmoid Function: This function can range between 0 and 1. This function is generally used in multi-layered networks that are trained using back propagation algorithm.

\[
\varphi(v) = \tanh\left(\frac{v}{2}\right) = \frac{1 - \exp(-v)}{1 + \exp(-v)} \tag{4} 
\]

\[a = \text{logsig}(n)\]

5.2 LEARNING RULES

The process by which the free parameters of a neural network get adapted through a process of stimulating by the environment in which the network is embedded is learning.

5.2.1 HEBBIAN LEARNING RULE

Hebb’s learning says that, if two neurons on either side of a synapse are activated simultaneously, then the strength of the synapse is selectively increased and activated asynchronously, then that synapse is selectively weakened or eliminated. If the cross product of output and
input is positive, this result in increase of weight, otherwise the weight decreases.

**5.2.2 PERCEPTRON LEARNING RULE**

The difference between the actual response and the desired value is the perceptron learning rule which is supervised. In the network each neuron receives total input from all of the neurons in the preceding layer as follows:

\[
\text{Net}_j = \sum_{i=0}^{n} W_{ij} X_j \quad \ldots \ldots \ldots 5
\]

Where \( \text{Net}_j \) = Total or net input

\( n \) = No. of inputs to the \( j^{\text{th}} \) neuron in the hidden layer

\( W_{ij} \) = Weight of the connection from the \( i^{\text{th}} \) neuron in the forward layer to the \( j^{\text{th}} \) neuron in the hidden layer

A neuron in the network produces its output (Out\(_j\)) by processing the net input through an activation (Transfer) function \( f \), such as the tangent parabolic function and is given as:

\[
\text{Out}_j = f(\text{net}_j) = \frac{1-e^{-2\text{net}_j}}{1+e^{-2\text{net}_j}} \quad \ldots \ldots 6
\]
5.2.3 DELTA LEARNING RULE or LEAST MEAN SQUARE RULE (LMS)

The delta learning rule, a supervised learning rule is valid only for continuous activation functions. The learning signal for this rule is called delta. The aim of the delta rule is to minimize the error in the overall training patterns.

5.2.4 COMPETITIVE LEARNING RULE

The idea behind this rule is that there are a set of neurons that are similar in all aspects except for some randomly distributed synaptic weights, and hence are expected to respond differently to a given set of input patterns. This rule has a mechanism such that only one output neuron or only one neuron per group is active at a time. The rule is suited for unsupervised network training.

\[ N=1 \quad \text{if } V_p > V_q \text{ for all } q, \quad p=q \]

\[ =0 \quad \text{otherwise} \quad \ldots \ldots \ldots \ldots \ldots \]

5.2.5 BOLTZMAN LEARNING

This is a stochastic learning. A neural net designed based on this learning is called Boltzmann learning. This learning is characterized by an energy function, \( E \), the value of which is determined by the particular states occupied by the individual neurons of the machine, given by
\[ E = -\frac{1}{2} \sum_{i,j} W_{ij} x_i x_j, \quad i \neq j \quad \ldots \ldots \ldots \] 

Where \( X_i \) is the state of neuron \( i \), and \( W_{ij} \) is the weight from neuron \( i \) to neuron \( j \). The operation of machine is performed by choosing a neuron at random.

5.3 MATLAB SOFTWARE

MATLAB (matrix laboratory) is a high-level language with interactive environment that enables to perform computationally intensive tasks faster than with traditional programming languages such as C, C++ and FORTRAN. In teaching linear algebra and numerical analysis, MATLAB is used and has become a useful tool for problem solving in many areas. The problems and solutions are expressed in mathematical notation.

Areas of application of MATLAB include

1) Maths and computation

2) Algorithm development

3) Modeling, simulation and prototyping

4) Data analysis, exploration and visualization

5) Scientific and engineering graphics

6) Application development, including graphical user interface building.
5.3.1 Toolboxes

The various toolboxes available in MATLAB are Control system, Communications, Signal processing, System Identification, Robust Control, Simulink, Neural Network, Fuzzy Logic, Image Processing, Analysis, Optimization, Spline and Symbolic.

5.4 DEVELOPING NEURAL NETWORK

MATLAB platform is used for developing a Neural Network Model. ANNs are computational models, which replicate the function of a biological network, composed of neurons and are used to solve complex functions in various applications. Neural networks are a non-linear mapping system that consists of simple processors, which are called neurons linked by weighted connections. An output is generated with each input neuron which is seen as the reflection that is stored in connections [53, 55]. The output signal of a neuron is fed to the other neurons through interconnections as input signals. If the function is complex in nature, as the capability of single neuron is limited, many processing elements are connected. The performance of the network depends on the activation function, network structure, data representation and normalization of inputs and outputs.

The measured tensile strength results are used to train, and two networks are trained. Network1 and Network2 are created based on the
tool profiles. Network1 is for square pin profile tool and Network2 is for modified square pin profile tool.

The network created is a two layered feed forward network by considering TRS, WS and F as inputs and number of hidden layer is one. Network1 and Network2 consists of two layers. Tangent sigmoid function is the network transfer function, and the neural network model is trained using Levenberg-Marquardt Algorithm.

The following are the steps for developing the network:

1. Database collection.

2. Analysis and pre-processing of the data.

3. Training of the neural network.

4. Test of the trained network.

5. Post processing of data.

6. Use of the trained NN for simulation and prediction.

5.5 ANN MODEL FOR SQUARE PROFILED TOOL

The experimental work is carried by varying the parameters, and from the results obtained by conducting DOE and ANOVA, it can be drawn that the mechanical properties obtained using square profiled tool are better when compared to other tools. An ANN model is developed for
square profiled tool represented as Network1, and using the modified tool of square profiled tool represented as Network2. The networks are trained using the experimental data with TRS, WS and F as inputs (Fig. 5.7) and tensile strength as output.

Fig. 5.6 Network 1

Fig. 5.7 ANN architecture used
Fig. 5.8 Training Parameters of Network1

In this work, the neural network is trained by using Levenberg-Marquardt algorithm. The training parameters are shown below.

Fig. 5.9 Training Algorithm of Network1
Fig 5.9.1: Training and Validation of Network1

Fig 5.9.2 Testing and Regression Graph of Network1
Fig. 5.10 Training Parameters of Network2

Fig. 5.11 Training Algorithm of Network2
Fig. 5.11.1 Training and Validation of Network2

Fig. 5.11.2: Testing and Regression of Network2