International Journal of Recent Advances in Multidisciplinary Topics
Volume 2, Issue 7, July 2021
https://www.ijramt.com | ISSN (Online): 2582-7839

The Applications of Neural Networks to Non-Destructive Testing Techniques

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***Abstract*: This study aims to investigate the prediction of eccentric loading and strength of bolts made up of Brass using Artificial Neural Networks (ANN). A simple experimental model has been developed that contains a C-Channel, a base plate and a load plate where Base plate is directly fixed to supporting members that is the C-Channel with the help of studs & the load plate is fixed to this with the help of four Bolts along with the simply supported boundary condition. Use of Artificial Neural Networks to model the eccentric loading and other strength parameters have been explored in this paper. Multi-Layered Neural Networks (MLNN), Back-Propagation Neural Networks are used to associate the Load carrying capacity with the keen consideration of its point of failure or breaking point. Result of experimental study on eccentrically loaded threaded bolt members was used to train and validate the proposed ANN model. And on comparing experimental results with the predicted data obtained from the neural networks we get to know that these networks have achieved good agreement with the training data and have yielded satisfactory generalization. A neural network could be effectively implemented for estimating the eccentric load and other strength parameters. ANN and its methodology can be applied for numerous other science and engineering solutions saving time and effort to predict unknown data accurately.**

***Keywords*: Artificial Neural Networks, MATLAB, Eccentric Loading.**

1. Introduction

When engineers design equipment and structures, they specify the required physical properties of the construction materials. Destructive testing of materials is part of a material verification process to check the properties meet the specifications of the engineer's design of equipment and structures, with material compliance with regulatory body standards. Materials testing may be carried out when materials are initially manufactured, for example, impact testing machine used to examine the load carrying capacity and also analysis the service life of a part or material which counts to be a destructive testing. Destructive testing and material verification can also be included in structural welding tests to look at the properties of welds following fabrication. (watson, 2001). In this paper we will have a brief overview on Eccentricity, ANN, hardware and Software application comparing the old decades equipment's with new generation change, their defects, signal processing, analysis through experimental setup etc.

At the end, we have performed an experiment that is based on analysis of eccentric loading using ANN tool in MATLAB. In this, we have taken brass bolts of 4mm and 3mm as testing components whose failures point had been investigated by applying different weights on load plate that is fixed with the base plate and c channel through bolts. A related graph has also been plotted between actual load and eccentricity using ANN tool in MATLAB.

1) Eccentricity

Distance between the actual line of action of compressive or tensile load and the line of action that would produce a uniform stress over the cross section of the specimen is known as Eccentricity. It is denoted by e. Increase in the eccentric load increases the axial load and the moment acting on the material, this makes the material to bend. But while destructing we came across many problems like we need to destruct the material which is costly, performing destructive testing consumes time, it can only detect defect of open surface etc. On the other hand, non-destructive testing does not require sampling and they are simple, fast to perform, and efficient. However, these methods result in large dispersion of the values they estimate, with significant deviation from the actual values of compressive strength. In today's world the non-destructive testing is more convenient and can be achieved with much higher accuracy through ANN using various software. (Kadi, 2008)

2) Artificial Neural Network (ANN)

An artificial neural network (ANN) is the piece of a computing system designed to simulate the way the human brain analyzes and processes information. It is the foundation of artificial intelligence (AI) and solves problems that would prove impossible or difficult by human or statistical standards. (Dwivedi, 2018)

2. Literature Review

1) Old Era of NDT Testing

In deciding the best route to take the research and development of a system such as this a compromise must be made between simplicity and flexibility. Many decades before we used large setup instruments (as shown in fig.1) for the non-destructive testing as shown in fig. But now we used highly advanced software like MATLAB which provides a technical

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computing environment for users with graphical interface, memory management and high-level programming language. (D.S. Nagesh, 2002).

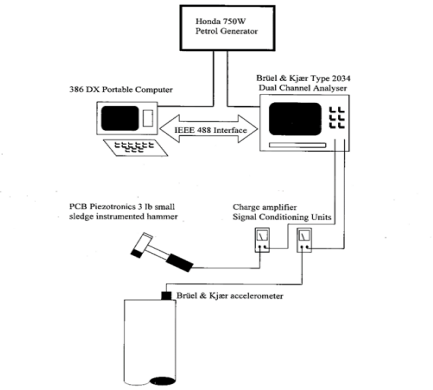

Fig. 1. Old setup for NDT testing

2) Important parts of setup

1. *PCB Piezometric Hammer*: - It is used to impact force on particular instrument of which we have to perform testing. It works as a sensor, the head sledge is 1.3 kg and sledge is 5.44kg. Its tip can be made up of rubber, soft plastic, hard plastic and aluminium.
2. *Generator:* - It is the power source for the portable computer and the dual Channel Analyzer. It carries around 750w power.
3. *Portable Computer and Dual channel Analyzer*: - portable computer displays the output results of the test which the dual CHANNEL analyser analysis the data. They are connected with each other through an IEEE 488 interface. All the processing carried out in hardware are now carried out using functions contained in the MATLAB signal processing toolbox.
4. *Signal Computing Units*: - Both the hammer and the accelerometer are supplied with same signal conditioning units (PCB480E09). This is a battery powered charge amplifier that provides a linear gain of 1,10 or 100 to a maximum value of +/- 4.5 volts. (Paulraj M P, 2012).

3) Reasons why we shift from old era to new

a) It was bulky and was not very mobile.
b) The generators and CHANNEL analyser were very big thus requires a Van for transportation.
c) It uses Analog monitoring rather than digital monitoring.
d) MATLAB is used for mathematical programming and optimized for matrix manipulation and linear algebra.

4) New Era Of NDT Testing: Artificial Neural Network & MATLAB

ANN is an interconnected group of Artificial neurons that uses a mathematical or computational model for information processing based on a connectionist approach to computation. The system can be broadly categorized into three classes on the bases of their application and its processing: (Schmidhuber, 2015).

5) Unsupervised Learning

These ANN's have no defined output associated with their training. The generic applications of unsupervised learning are:

a) *Prototyping:* - Networks may group the input patterns into statistically similar categories.
b) *Coding:* - If the outer space is smaller than the input space, such a network could be utilized as a method for data encoding.
c) *Feature Mapping*: - Statistically similar inputs would excite geometrically close outputs.

6) Supervised Learning

When the target output for a given input is known then the network is trained to model the association between the given input and output pattern. In auto associate network the system is required to reproduce the input pattern as its output.

7) Multi Layered Neural Networks (MLNN)

For multi-layer system the output from the first layer can be fed into a second layer, whose output can in turn to fed to a third and so on.

8) Types of MLNN

a) *Multilayer Perceptron*: - Perceptron used to describe units with linear activation functions. It is class of feedforward artificial neural network. It referees to networks compose of multiple layers of perceptron's. Each network is made up of unlimited no. of layers. Each layer is made up of unlimited units. Each layer is made up of either sigmoid, hyperbolic tangent or linear activation function.
b) *Radial Basis Neural Networks*: - It transforms the input signal into another form, which can be then feed into the network to get linear separability. RBNN is composed of input, hidden and output layer. It strictly limited to have exactly one hidden layer; we call the hidden layer as feature vector.
c) *Wavelet Basis Neural Network*: - In this both scaling function and the wavelet function of a multi resolution approximation (MRA) are adopted as the basis for approximating functions. A sequential learning algorithm for WBFNNs is presented and compared to the sequential learning algorithm for RBFNNs. WBFNNs has better generalization property and require shorter training time than RBFNNs.

9) MATLAB

MATLAB is an engineering software that allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interface written in other languages. MATLAB can call functions and sub routines written in the programming language c, Fortran.

10) Features of MATLAB

- Implement and test your algorithms easily
- Develop the computational codes easily
- Debug easily
- Use a large database of built-in algorithms
- Process still images and create simulation videos easily
- Symbolic computation can be easily done
- Call external libraries

- Perform extensive data analysis and visualization
- Develop application with graphics user interface

3. Experiment

1) Experimental Setup

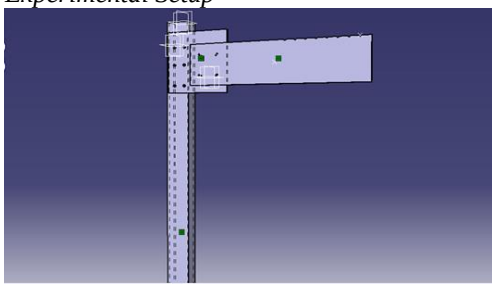

Fig. 2. Experimental Setup

B. Parts of Setup

1) C-channel

The C-CHANNEL, having cross-section shown in figure 4 is used to mount the complete system of load and displayed. More than one third of its height is inside ground to provide stability and rigidity against fluctuation and deflection due to loading on base plate.

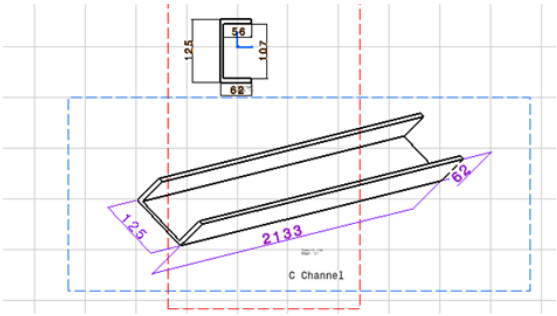

Fig. 3. C-channel

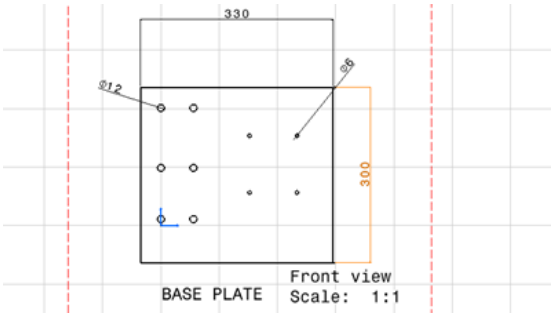

Fig. 4. Base plate

2) Base plate

Base plate, as shown in figure 5 is the part of set up which is directly fixed to supporting members (C-CHANNEL) with the help of studs. The load plate is fixed to this via 4 bolts.

3) Load plate

Load plate is the most important member of the set up because it is acted upon by repetitive loading to break the threaded system. It has seven notches which are equally spaced (50 mm apart) on which load is applied with a hanger arrangement. Figure 6 shows the dimensions of the load plate used.

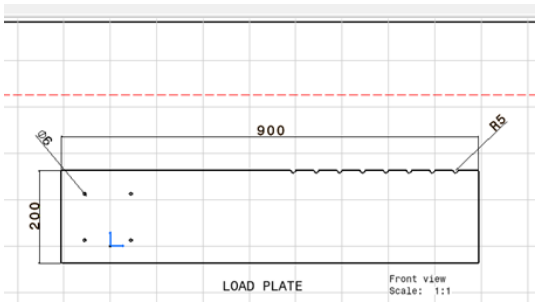

Fig. 5. Load plate

This is movable type rope and plate arrangements to apply load on system. It can easily move on load plate so as to change it eccentricity.

4) Studs

Studs, are fastening elements which are simply threaded cylindrical rods which use nuts on both sites to fasten 12 mm diameter, six studs are used to fix the base plate with channel.

5) Experimental data

Experiment result for Brass bolts of different diameter is shown in the Table below:

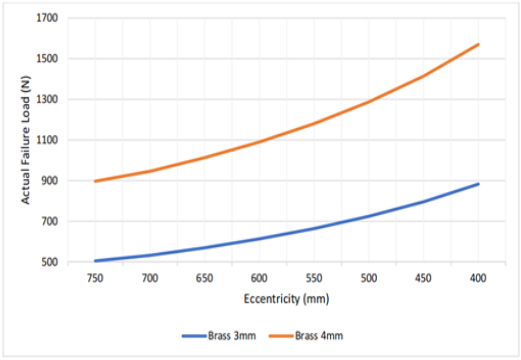

Fig. 6. Table of Readings (Material = Brass)

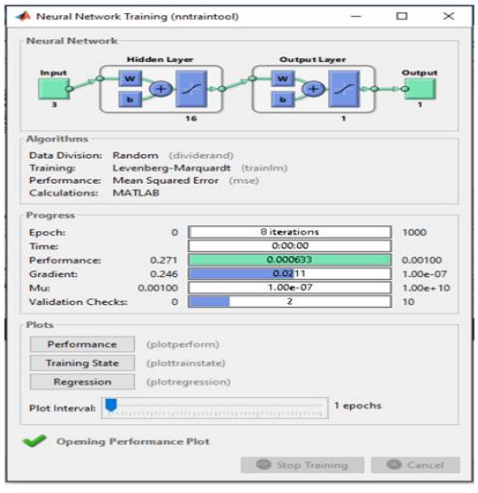

Fig. 7. Actual Failure Load variation with eccentricity for Brass bolts

Table 1
Brass bolts of different diameter

S. No.	Material	Failure Stress (MPa)	Diameter (mm)	Eccentricity (mm)	Actual Failure Load (N)	Theoretical Failure Load (N)
1.	Brass	220	4	750	197.14	975.30
2.	Brass	220	4	700	945.78	1040.28
3.	Brass	220	4	650	1012.90	1114.22
4.	Brass	220	4	600	1090.27	1199.45
5.	Brass	220	4	550	1180.45	1298.74
6.	Brass	220	4	500	1287.54	1415.88
7.	Brass	220	4	450	1414.41	1556.13
8.	Brass	220	4	400	1570.00	1727.03
9.	Brass	220	3	750	504.64	548.73
10.	Brass	220	3	700	532.00	558.16
11.	Brass	220	3	650	569.75	629.75
12.	Brass	220	3	600	613.28	674.69
13.	Brass	220	3	550	664.00	730.34
14.	Brass	220	3	500	724.24	796.43
15.	Brass	220	3	450	795.60	875.32
16.	Brass	220	3	400	883.12	971.45

4. Conclusion

By thoroughly reviewing the literature, we came to know that Decades ago, we used to analysis the neural networking proceedings with the arrangement of setup that was too bulky and was challenging for a user to transport it. Since it consists of a generator, monitor, analyzer, hammer and signal controlling unit, it provides us with analogous data that found to be less accurate with inefficiencies. But nowadays, we are putting a step ahead with the development of numerous software's like MATL, Neuroph, neuralN etc. these software's provides us digitalized data interpretation with higher accuracy and efficiency and are easy to carry and transmit data quickly over those bulky setups that were used previously. In this study, the ANN model was developed to predict the eccentric load capacity of Bolts under the application of load. A Multi-layered Neural Network & back-propagation artificial neural network (BPANN) was used. The measured experimental results are compared with the output calculated from ANN model. A parametric study was carried out to explain the effects of various parameters on the behavior of Bolts when load is applied on it.

From this study it can be concluded that:

- The ANN model is active and valid to simulate the behaviour of Bolts under the application of load. The ANN predictions are accurate provided that the input data are within the ranges used for training the Neural Networks.
- ANN algorithm is a powerful and economical apparatus for completing parametric study among a few parameters that influence physical marvel in engineering as showed for the instance of Brass bolts.

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