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Analysis of Natural Frequency of a Rectangular Beam Using Finite Element Analysis and Artificial Intelligence

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ABSTRACT

Natural vibrations are the unforced oscillations of an elastic body that occur at the natural frequency. A substantial increase in vibration amplitude occurs when an object vibrates at a frequency that is equal to its natural frequency, which could cause irreparable harm. Therefore, it is essential to comprehend the natural frequency. In order to predict the natural frequency or free vibration characteristics of a rectangular copper beam that is simply supported and cantilevered, machine learning techniques are used to examine the natural frequency of the beam. Here copper material properties is used to predict, where copper has minimal chemical reactivity, is malleable and ductile, and is an excellent conductor of heat and electricity. An artificial neural network and linear regression algorithm model has been developed to estimate relationship between material properties, angular frequency and natural frequencies obtained by Euler Bernoulli method and Ansys 14.5 software as an output layer. Without the need to solve any differential equations or undergo time-consuming experimental procedures, the proposed machine learning algorithms can predict the natural frequencies. The results show that artificial intelligence (AI) can be efficiently adapted to modal analysis problems of beams. The graph behaviour on the natural frequency from AI is also demonstrated.

Keywords : Natural frequency, Copper material, Artificial neural network, rectangular beam, Finite Element Analysis and Linear Regression.

I. INTRODUCTION

Recently, machine learning has been used in material science to aid in the discovery of novel materials. Sefa Yildirim used the ansys approach to determine the natural frequency of axially and transversely loaded beams for various materials and their characteristics. Investigating the impact of grading direction on the natural frequencies of heterogeneous isotropic beams and estimating the free vibration characteristics using an artificial neural network approach. The power-law form determines whether to grade the two-dimensional beam in an axial or transverse orientation. For the purpose of estimating the relationship between material properties and model, grading direction, and slenderness ratio as input layers and natural frequencies obtained using the Finite-Element method as output layers, an artificial neural network model has been developed. The frequencies of the various layers will be computed. Additionally, using artificial intelligence, ANN is used to forecast the frequency of the same material [1]. Ahmed B. Khoshaim et.al [2] Residual stresses (RS) produced in machined components have a substantial impact on the completed items' quality and longevity. Because a variety of cutting parameters and conditions have an effect on RS generation, it is crucial to understand the relationship between RS generation and those features in order to minimise the generated tensile RS. Experimental data on the effects of several parameters, including cutting feed, depth, and speed that generate RS on both circumferential and radial, is gathered. The residual stresses of iron are predicted using ANN. Pengcheng Jiao [3] Visible models with AI capabilities are a practical tool for designing, predicting, and optimising PENG and TENG structures and materials. In this model, the mechanical to electrical performance is predicted using AI-PENG and AI-TENG. Dingqiang Fan, Rui Yu et.al [4] here 80 mixture of concrete is used to predict the performance, Modified andreasen and Anderson and Genetic algorithm based ANN used to predict the ultra high performance of concrete. Dike Li, Lu Qiu [5] An turbine guide vane is modelled and meshed in a CFD Software to estimate the cooling efficiency of it. Fot the data collected for the turine vane using CFD will run through ANN to predict the Cooling Efficiency of a turbine vane. In order to pass through a body crack, V. Khalkar and S. Ramachandran[11] used a spring steel cantilever beam with slots that were both rectangular and V-shaped. The static deflection and natural frequency of the spring steel cantilever beam are calculated using the ansys programme for each depth and length of the crack for both v- and rectangular-shaped cracks. discovered how crack affected natural frequency. Copper tubing is currently the best product available for use in plumbing, fire sprinklers, and other applications in buildings. Copper tubing is a fantastic option for natural gas piping systems. Copper and other non-ferrous metals have a long history of being closely linked to humanity. Copper is a fascinating substance that also possesses a wealth of resources. As a result, it is widely utilised in high-tech domains, emerging industries, and the creation of petrochemicals, machinery, lighting, electronics, and electrical power. In addition to being malleable and ductile, copper has a low chemical reactivity and excels as a heat and electricity conductor. Therefore, machine learning approaches are suggested in this study to estimate the Natural Frequency using the attributes of the copper material.

II. METHODS AND MATERIAL

Ansys 14.5 software and Euler Bernoulli analytical method is used in this methodology for calculating the natural frequency. Linear Regression and Artificial Neural Network methodology in

Artificial Intelligence is used to predict the natural frequency from the data obtained.

Before analyzing the data for the built model, Data should be collected from the Ansys 14.5 software and Analytical method (Euler Bernoulli) for Rectangular simply supported Beam and Cantilever Beam.

A Rectangular beam of width 20mm (0.02m) and height 20mm (0.02m) is considered for the varying length of 1000mm(1m), 2000mm(2m) and 3000mm(3m) for copper material.

The Table 1 consist of copper material property which is taken from [6] as shown below:

Table 1. Copper material Property

Young's Modulus(pa)	Poisson's Ratio	Density (kg/m3)
117 x 109	0.33	8940

ANSYS

Ansys 14.5 software is used for both the cantilever and simply supported beam. Before building the model, structural and material properties are provided here.

The modelling for the aforementioned dimension is completed with the addition of 2 Node 188-element type, and meshing will follow. Boundary conditions are given for cantilever one side is Constrained, For the simply supported beam boundary conditions are given on the both the sides except ROTZ everything will be constrained. Finally modal analysis and 10 modes will be given and solution will be taken out from results summary.

Table 2 lists the results from the Ansys 14.5 programme for both cantilever beam and simply supported beam. When five modes are taken into account, the simply supported and cantilever are represented by numbers 1 and 2 in the support column.

Table 2. ANSYS values

SL.NO	LENGTH	MODE	SUPPORT	ANGULAR FREQUENCY	FREQUENCY
1	1	1	1	208.39	33.167
2	1	2	1	861.42	137.1
3	1	3	1	2048.88	326.09
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
28	3	3	2	152.57	24.283
29	3	4	2	319.59	50.865
30	3	5	2	578.99	92.15

1.1. EULER BERNOULLI

The Euler Bernoulli beam theory, which provides a method for determining the load-carrying and deflection properties of beams, simplifies the linear theory of elasticity. It solely handles the scenario associated with small beam deflections brought on by lateral load.

The equations for free vibration simply supported beam are:

$$\omega_n = \frac{n^2\pi^2}{l^2}\sqrt{\frac{EI}{\rho A}} \text{ (Rad/sec)} \quad \textbf{(1)} \qquad f_n = \frac{\omega_n}{2\pi} \text{ (Hz)} \quad \textbf{(2)}$$

The equations for free vibration simply supported beam are:

$$\omega_n = \left(\frac{(2n-1)\pi}{2} + e^n\right)^2 \frac{1}{l^2}\sqrt{\frac{EI}{\rho A}} \text{ (Rad/sec)} \quad \textbf{(3)} \qquad f_n = \frac{\omega_n}{2\pi} \text{ (Hz)} \quad \textbf{(4)}$$

Where f_n = Frequency ω_n= angular frequency, n= no of modes, e^n= error, l = length, E = Modulus of Elasticity, I = Moment of Inertia, ρ = Density of material, A= Area of the material.

Table 3 lists the results from the Euler Bernoulli's analytical approach for both cantilever beams and simply supported beams. When five modes are taken into account, the simply supported and cantilever are represented by numbers 1 and 2 in the support column. Equations (1) and (2) are used to determine the angular frequency and frequency of a simply supported beam, while equations (3) and (4) are applied to cantilever beams.

Table 3. Euler Bernoulli values

SL.NO	LENGTH	MODE	SUPPORT	ANGULAR FREQUENCY	FREQUENCY
1	1	1	1	206.12	32.806
2	1	2	1	824.54	131.23
3	1	3	1	1855.23	295.27
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
28	3	3	2	143.18	22.789
29	3	4	2	280.57	44.655
30	3	5	2	463.8	73.817

1.2. ARTIFICIAL NEURAL NETWORK

Computer architectures known as artificial neural networks (ANN) are based on the biological neural networks seen in animal brains. The core of an ANN is made up of artificial neurons, which are a collection of connected units or nodes that resemble the neurons in a biological brain.

A weighted directed graph, in which the nodes stand in for the artificial neurons, is the best way to depict a synthetic neural network. A directed edge with weight represents the relationship between the inputs and outputs of neurons.

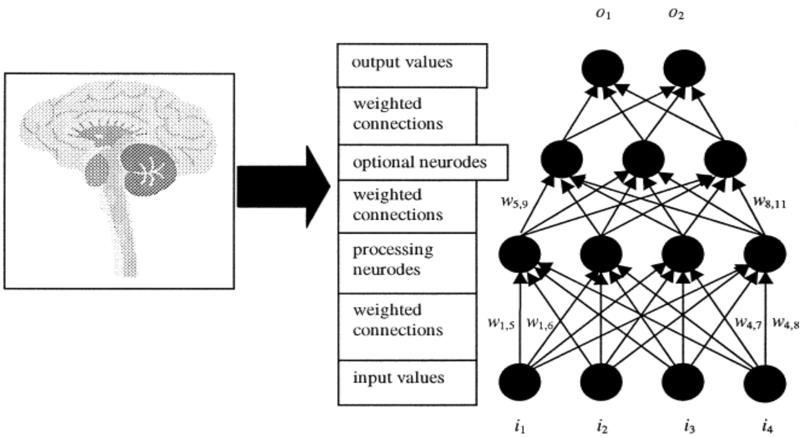


Fig. 1. Artificial Neural Network

1.3. LINEAR REGRESSION

By applying linear regression analysis, one variable's value can be used to predict the value of another variable. The dependent variable is the one you must be able to foresee. You must first decide which variable will be the independent one before you can estimate the value of the other variable.

- Validation of model

A model's validation enables evaluation of the trained model's efficacy and correctness. For each machine learning method, real data will be used to build a training set and a test set. The model is validated using the test set after having been trained using the training set of data. For the test data to be predicted in this model, 30% values are used.

III. RESULTS AND DISCUSSIONS

In this work, the length, support, modes, constant and angular frequency of copper material is considered as the input and the output is Natural Frequency. The network is trained using the methods LR and ANN.
Spyder is used for the aforementioned work.
The model accuracy is predicted using the R-Square value.
R-squared = Explanted Variation / Overall Variation
It has a value between 0 and 1. Zero means the model made a poor prediction, whereas one means it made a flawless prediction.
A. Prediction of Natural Frequency for ANSYS
The R-Squared value achieved using the Python software for ANN and LR Machine learning Techniques is displayed in Table 4. It demonstrates that LR and ANN produce superior outcomes with an R-Squared value of 1. It suggests that both methods are effectively employed.

Table 4. R-Squared value for ANSYS Natural Frequency

Technique	LR	ANN
R-Squared	1	1

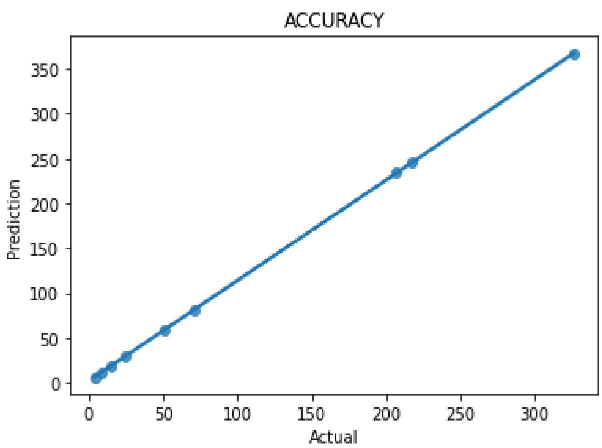


Fig. 2. Actual vs prediction Frequency using ANN

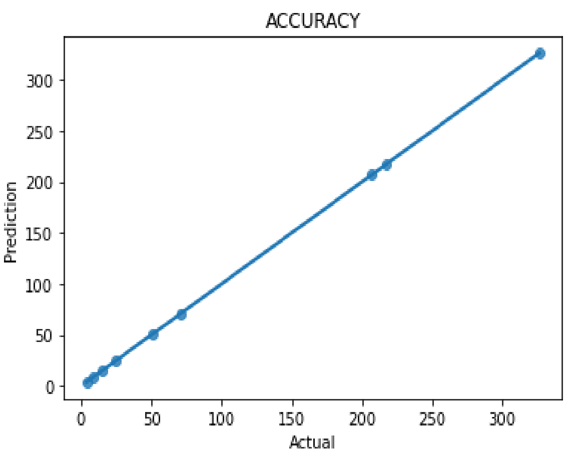


Fig. 3. Actual vs prediction Frequency using LR

For the Natural Frequencies for both techniques, Figure 2-3 shows the Actual versus Prediction Values graphs (LR and ANN). The fitting region, which was identified using linear regression and an artificial neural network, covers almost all of the data points in Figures 2 and 3, and it is equal to 1. The ANN & LR plot has a better match, as shown by the graph above. In terms of fitting points to regression lines for the ANSYS Natural Frequency, the ANN & LNN approach definitely performs better. Because of this, Ansys Natural Frequency of Copper predictions made using the ANN & LR approach are better and more accurate. R-Squared has showing 1 for both the algorithms which means 100% accuracy in the actual versus prediction plot obtained.

B. Prediction of Natural Frequency for Euler Bernoulli

The R-Squared value achieved using the Python software for ANN and LR Machine learning Techniques is displayed in Table 5. It demonstrates that LR and ANN produce superior outcomes with an R-Squared value of 1. It suggests that both methods are effectively employed.

Table 5. R-Squared value for Euler Bernoulli Natural Frequency

Technique	LR	ANN
R-Squared	1	1

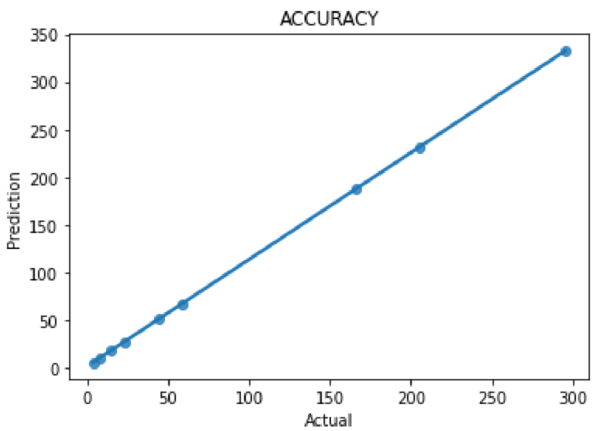


Fig. 4. Actual vs prediction Frequency using ANN

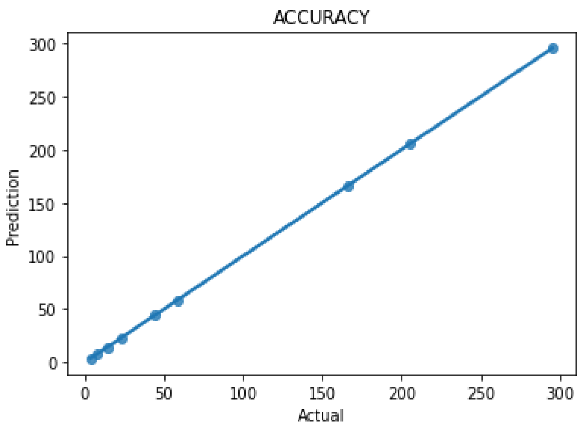


Fig. 5. Actual vs prediction Frequency using LR

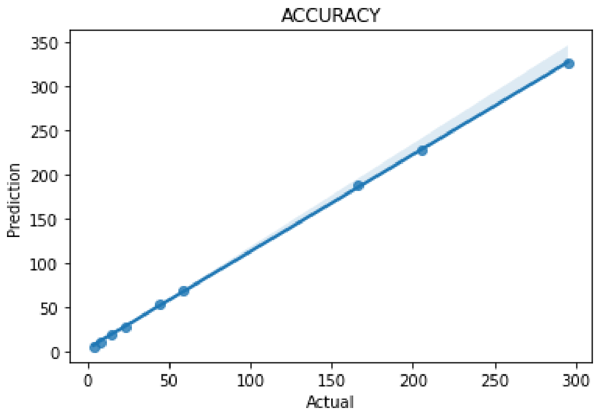
For the Natural Frequencies for both techniques, Figure 4-5 shows the Actual versus Prediction Values graphs (LR and ANN). The fitting region, which was identified using linear regression and an artificial neural network, covers almost all of the data points in Figures 2 and 3, and it is equal to 1. The ANN & LR plot has a better match, as shown by the graph above. In terms of fitting points to regression lines for the ANSYS Natural Frequency, the ANN & LNN approach definitely performs better. Because of this, Ansys Natural Frequency of Copper predictions made using the ANN & LR approach are better and more accurate. R-Squared has showing 1 for both the algorithms which means 100% accuracy in the actual versus prediction plot obtained.

C. Prediction of Natural Frequency for Euler Lagrange

The R-Squared value achieved using the Python software for ANN and LR Machine learning Techniques is displayed in Table 6. It demonstrates that LR and ANN produce superior outcomes with an R-Squared value of 1. It suggests that both methods are effectively employed.

Table 6. R-Squared value for Euler Lagrange Natural Frequency

Technique	LR	ANN
R-Squared	1	1



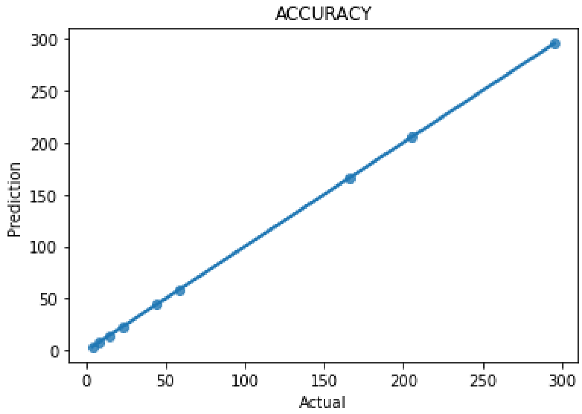


Fig. 6. Actual vs prediction Frequency using ANN Fig. 7. Actual vs prediction Frequency using LR

For the Natural Frequencies for both techniques, Figure 6-7 shows the Actual versus Prediction Values graphs (LR and ANN). The fitting region, which was identified using linear regression and an artificial neural network, covers almost all of the data points in Figures 2 and 3, and it is equal to 1. The ANN & LR plot has a better match, as shown by the graph above. In terms of fitting points to regression lines for the ANSYS Natural Frequency, the ANN & LNN approach definitely performs better. Because of this, Ansys Natural Frequency of Copper predictions made using the ANN & LR approach are better and more accurate. R-Squared has showing 1 for both the algorithms which means 100% accuracy in the actual versus prediction plot obtained.

Table 7. Performance Comparison Table

PERFORMACE	ANSYS		EULER BERNOULLI	
	ANN	LR	ANN	LR
R-SQUARED	100	100	100	100

Table 7 displays performance comparisons for all the factors.

IV.CONCLUSION

The Natural Frequency is estimated in this study using two machine learning methods: LR and ANN. For cantilever and simply supported beams, copper material properties are utilized to calculate frequencies using boundary conditions. The data was gathered using the Euler-Bernoulli analytical method and Ansys 14.5 software for both the beams. The analytical approach and the ansys software are used to produce the training and testing data sets for the machine learning algorithms. Using the ANN and LR algorithms, Natural Frequency values can be predicted with greater accuracy. In addition to being outlier-sensitive, linear regression only works well with linear connections. Based on data from the Ansys software and analytical techniques (Euler Bernoulli), it can be seen that LR and ANN produce better and more accurate values when compared to plots of actual vs. predicted values. Similar techniques can be used in future study to identify distinctive materials in other composites by utilizing various machine learning techniques. Machine learning is useful in other fields of material science as well.

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