DEVELOPMENT OF DYNAMIC MODEL FOR MR ELASTOMERS USING ARTIFICIAL NEURAL NETWORKS

FINAL YEAR PROJECT UG 2016

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This is to certify that the Final Year Project Titled

"DEVELOPMENT OF BIO INSPIRED INTERLOCKING COMPRESSED EARTH BRICKS"

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in

CIVIL ENGINEERING

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Dedication

To our beloved parents, teachers, mentors and colleagues who have stood by our side in rough and tough times, who have taught us to show perseverance in the face of adversity.

ACKNOWLEDGEMENTS

In the name of Allah, the most Beneficent, the most Merciful as well as peace and blessings upon Prophet Muhammad, His servant and final messenger.

We are first and foremost, extremely grateful to Allah Almighty for enabling us to complete our research project and without whose willingness we could not have imagined to accomplish such an enormous task.

The efforts and sacrifices that our parents and teachers have made over the course of our lives to reach where we stand today are highly acknowledged.

We respect and appreciate the efforts put up by our supervisor Dr. Muhammad Usman, Assistant Professor NICE. His valuable advice and research commitments were a source of motivation for us. Throughout the research project his constant support and taking time out of his busy schedule for mentorship kept us proceeding forward. Moreover, his professional grooming of the group in thesis writing and presentation is valuable and something that will help us in our practical life. Without him, it would not be possible for us to complete this project.

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Abstract

The fundamental step is to design MRE based devices for the adaptation of vibration over range of frequency, which is also known as the characterization of magnetorheological elastomers. The properties of shear mode for MREs are characterized over a wide range. Whereas in the squeeze mode, these properties are addressed less often in several studies. The reason behind this being complexities in design of the experiment. The properties of MREs are such that they can be very beneficial for changing stiffness property. These materials can be used for the sake of base isolation in buildings as well as in bridges. They can be used to resist unpredictable loading due to earthquakes and vibrations. The purpose of this research is to study the effect of nano particles of iron in the matrix of silicon rubber. The material was utilized to make samples of MRE elastomers and samples were prepared. The dynamic shear testing is done over these samples using different particle percentages and data is obtained. This data is then utilized in MATLAB to train a neural network. The artificial network model is created, and the data obtained from the neural network (this as results) can be compared with the actual results. The difference in the actual results and results obtained from training of neural network can be compared, which upon conclusion came out to be close.

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CHAPTER 1

INTRODUCTION

1.1 General:

"Base isolation" is an ultra-modern method through which the main structure or the superstructure is detached from its foundation or the base of the structure, that is, the substructure. It is done by inducing a suspension system between the main structure and the base. [1] With seismic design of structures in consideration, base isolation can also be substituted with seismic isolation. Seismic isolation can be done in a way that the structure present above the earth's surface, which is most affected by earthquake, is separated from the effects of earthquake by initiating a mechanism that will help the structure to be suspended. [2] The technique used to lessen the vibrations in a system is termed as base isolation. The mechanism is lodged at the foundation of the structure to separate it from the disastrous forces produced by the earthquake. Its working principle is the modification of natural frequency of the main system by decoupling the vibrations from the system.

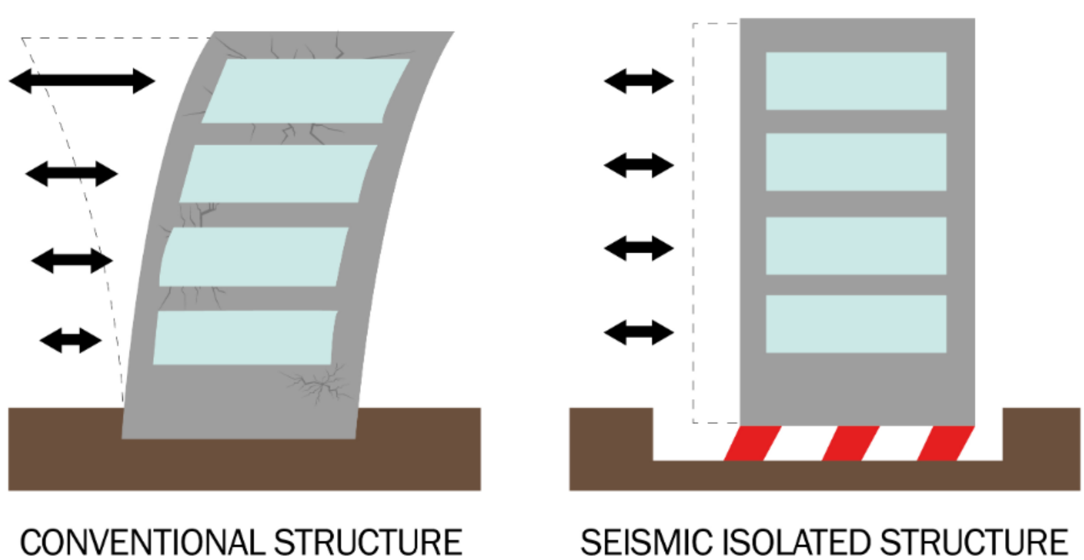


Figure 1 Behavior of conventional structure and seismically isolated structure

The idea of base isolation is easy to understand. It can be exemplified as a bird flying during an earthquake unaffected. Simplifying further, we can say that if the structure is not attached to the base and is floating, it will not be affected by the earthquake. The wind and earthquake are two phenomena that need a lateral structure for sustenance. [3] However, the earthquake cannot be controlled and it is impractical to design an indefinite seismic demand structure. The only practical solution is to accept the demand and build a structure that has more capacity than the demand. The inertial force produced by the earthquake is proportional to the mass of structure and acceleration of the ground. Increasing the ductile property of the structure or the elastic strength is the traditional method of dealing with seismic demand.

The base isolation works on the principle that the structure is made in such a way that the ground below the structure is able to move without transmitting any motion to the main structure above. Since complete isolation is possible in an ideal system, so in reality, it is important to have vertical support to transmit the load to base.

The relative displacement of the ground and the structure standing above it, is zero for a completely rigid structure. [4] This is due to the fact that acceleration produced in the structure is same as the motion of the ground. As no acceleration is produced in an ideally flexible system, the relative displacement in the structure will be equal to the ground movement.

The relative displacement of ground and the structure is zero for a perfectly rigid, zero period structure, since the acceleration induced in the structure is same as the ground movement.

The following figure shows the behavior of a building that has a fixed base versus a building that has base isolation.

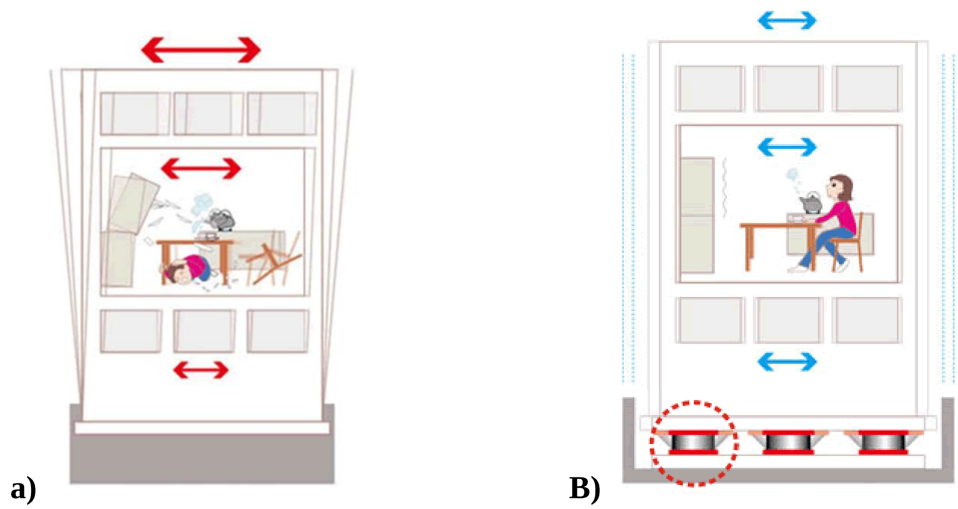


Figure 2: a) Building without a base isolation a) With Base Isolation

Since no structure is completely flexible or rigid, the response of the structure will be somewhere between two scenarios provided beforehand. Maximum displacements and accelerations are produced by earthquakes for different periods between zero to infinity. During earthquakes, there will be points at which the acceleration will be intensified beyond the displacements of the ground, but the relative displacements will not go beyond the ground displacements. To suppress this, base isolation is the best method. It reduces the transmission of motion as well as controls the building's displacement. In order to achieve an isolation, system damping, flexibility and resistance to vertical loads are necessary elements.

The question arises that what type of mechanism will help to acquire this while resisting the earth's gravitational pull. Will it be a lubricated sliding surface or a magnetic levitation? These solutions might seem right, but are not of engineering nature. The system should be one that can withstand the shear wind and the pull of the earth. As an ideal solution has not been yet found, therefore certain practical mechanisms are being used in earthquake engineering. [5] those of which include elastomeric rubber bearings, ball bearings, roller bearings, sliding bearing s and springs.

Magnetorheological fluids (MRF) base isolators were used to initially to overcome the problems of traditional base isolators. But, it still had some flaws like contamination of the environment, particle deposition on long-term basis etc. These isolators were then substituted by Magnetorheological Elastomer (MRE) base isolators. MRE and its functioning was studied in the middle of the 20th century. The phenomenon of MRE is its capability to adjust the rigidness or modulus within a magnetic field, making it adjustable to a variety of frequencies. Smart materials are a collection of materials having changeable properties with the change of magnetic fields. [6] MREs are controllable composites that consist of ferromagnetic fillers as magnetically polarizable particles, and elastomers as non-polarizable matrix. The composite material is created by adding filler material and elastomer in certain ratios and then mixing them together.

1.2 Problem Statement:

This research will develop mechanisms and alternatives for existing materials and practices in order to bring an improvement to the structural integrity of structures. Many studies have been done on MRE, however a research gap can be found regarding a network model; incorporating displacement, frequency, amplitude, magnetic field and filler particles percentage as inputs to increase the controllability of smart base-isolation.

1.3 Scope of Work:

This research aims to develop an artificial neural network model to represent dynamic behavior of MR elastomers. We aim to compare the developed artificial network model with experimental results and evaluate its effectiveness. We aim to come about a solution which is economical, environmentally friendly and convenient for transitioning into for the stakeholders already working in the sector, directly and indirectly.

1.4 Project Overview:

Initially the scope of our object was related to material optimization of filler material in magnetorheological elastomer. We aimed at observing any changes in characteristics of MRE by replacing the normally used iron fillers with the varying percentages of other filler materials including nickel, cobalt and iron oxide. The filler material, which was not available at local level, was imported from China. The required samples were prepared.

They were ready for testing, but unfortunately, due to the pandemic we had to initially postpone and then to change our scope. The new scope of the project focused on developing a network model for the MR elastomer for its various properties, using neural network modelling. The inputs of amplitude, frequency, and applied force were assessed across the output of displacement.

CHAPTER 2

LITERATURE REVIEW

2.1 General

The idea of using a material whose mechanical properties such as elasticity, Young's modulus shear modulus can be controlled had been under consideration for many years. The advancements had been brought into the idea and further working is being done for continuous improvement. For the base isolation, there should be some material which can be variably used with alteration in its magnetic properties during an event of an earthquake. For this purpose, the materials known as magnetorheological elastomers (MREs) are introduced, which can be utilized as a base isolator in buildings prone to earthquake regions. The aim of this research is to analyze the effects of using iron particles as a filler material to form elastomers whose magnetic properties can be altered.

2.2 History

Burnt bricks are often known as Fired Bricks as well. These bricks are baked in furnace kilns which alter their properties altogether.

The technique in which vibrations are used within a dynamic system is known as base isolation. [7] With the advancement in civil engineering and as early as when engineers were able to construct skyscrapers, there was in need of a material which could be installed within the structure to fight against seismic forces. Therefore research started on base isolators. Initially the base isolators that were introduced could only resist the earthquake of a specific magnitude. Conventional base isolators were not very effective and were highly vulnerable to earthquakes. [8] The phenomenon of residence was also not covered in these conventional base isolators. And as a result of destructive response of the earthquake is maximized due to residence and at a place where the frequency of the earthquake is low. Thus, for near fault earthquakes, conventional base isolators would not be preferable. The biggest side effect of using conventional base isolators is that their properties cannot be altered as soon as they are installed, and as a result, these isolators cannot respond to earthquakes of different frequencies. Therefore, these devices are completely incapable of resisting earthquakes that are unexpected.

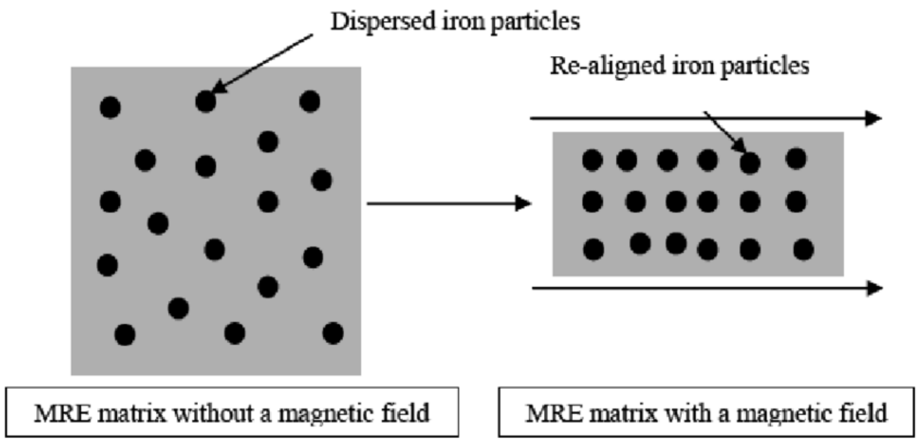


Figure 3 Particles alignment in magnetic field

2.3 Advancements in Work

The first modification to conventional base isolators were made in early 19th century, where magnetorheological fluids (MRFS) were introduced in base isolation technology. But utilization of these fuels had many disadvantages, some of them included deposition environment contamination and reduction in quality. Further advancement in technology made the researcher understand that the stiffness, the modulus of elasticity as well as the magnetic properties of MRFs can be altered by introducing some material which has magnetic properties. [9] By the introduction of these materials, it was observed that these materials have a quality such that they can change their magnetic properties in changing magnetic field, deeming them the term of "smart materials". MREs have a quality that they are controllable and have ferromagnetic filler which can be polarized, the other part being elastomers which are non-polarizable. In order to prepare the composite material, mixing of filler material and elastomers is done in designed ratios. Once the covering of the material has been done, the position of the elastomeric metrics does not change and becomes fixed. [10] Once these material are introduced in the magnetic field, they can be realigned using changing magnetic flux. As a result, a chain like structures is formed and the mechanical properties, e.g. Young's modulus and shear modulus of the material can be changed. This phenomenon was first observed by Joe Bob Rubino in 1948. Further research also included how the material properties can be changed by vitiating the composition and proportion of the metric mix. This phenomena is illustrated in the following figure.

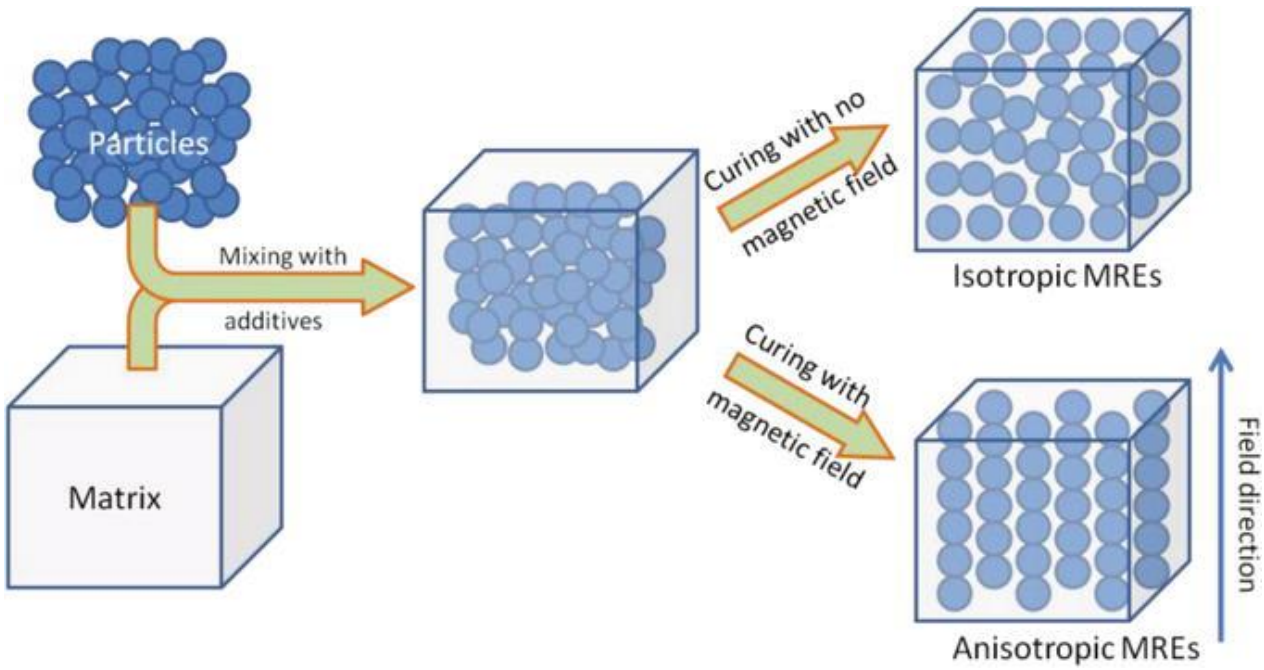


Figure 4 the working of MR elastomers under magnetic field

The viscous gel is a matrix and it has non-magnetized properties. These gels have an ability to hold ferromagnetic particles. [11] In early stages rubber was initially utilized as a mixed material because of the presence of hydrocarbons, either natural or synthesized. The disadvantage of using natural rubber is that it is not a softer material, and therefore there is a possibility that it may show resistance against the movement of the particles. In order to avoid these problems, a material which is softer such as silicon rubber is utilized. It not only behaves properly against resistance, but also performs well in extreme temperature conditions. [12]

For the filler material, iron particles are used because they have low remnant magnetization. [13] It is the ability of a material to remain magnetized even in the absence of magnetic field. The MRI effects are maximized because of high permeability and high saturation magnetization.

According to our research, using the filler particles in increased quantity enhances the reinforcing affect and conversely but during the filler content the magnetic effects are reduced.

According to Von Lockette, taking 40% by volume in particular has a tendency to maximize the stiffness is up to 50%.[14] A term known as critical particle volume concentration is introduced, which is defined as the ratio of apparent density to real density of iron particles. It has been observed that the current density of the powder is looser than the original density of iron powder. In order to generate a softer mattress, along with the filler particles Silicone Oil is also been introduced in MRE material to form a homogeneous soft matrix. [15] The silicone oil also enhances the lubricating affect and will definitely behave better up to 20% silicone oil.

In order to study the effect of the elastomer, dynamic testing is carried out. There are two different modes of this testing which are separated in accordance to the direction of the magnetic field applied. The magnetic field is applied either parallel or perpendicular. When a perpendicular magnetic field is applied, it is said to be in the shear mode. Whereas, when the magnetic field is applied in parallel, this mode is known as squeeze mode.

During an earthquake, the dominant affect is that over shear. Therefore, most of the time shear mode is applied during testing of MREs. The elastic modulus increases with the increase in strain rate and flux density 0.5 T to 5 T.

There is another research by dumchunk and Kuz'min that the smaller particles exhibit larger models than that of a larger particles in the absence of magnetic field. It has also been observed that because of the influence of magnetic field, the elastic modulus for the material having larger particles is larger than the material in which the particle size is smaller. Thus, the most preferable particle size that should be utilized in these isolations should be greater than 3µm. The shared storage modulus of material having Nano particles can be increased by utilizing iron particles sized above 20µm. Later on, the research on hybrid MREs were carried out and it focused on adding materials as smaller as 0.5µm.

A research by Palacios et.al focused on using nano and micro-sized carbonyl iron particles in the last experiment which concluded that variation of size of material can influence the magnetic properties of the base isolators. With further advancement and more modern techniques, the micro-sized particles can be achieved and can be reduced further to ensure more uniformity and homogeneity of a mixture. [16] It has also been observed that the nano sized particles enhances the reinforcement effect of MRE.

This research has been conducted to study hybrid MREs in which the utilization of nano-sized iron particles is done. In place of a rubber material, silicone oil up to 10% is used along with the silicone. Experimentation is carried out under which the samples will be tested under dynamic shear test and the results are compared with the changing magnetic flux, frequencies as well as the amplitude of the vibration.

2.4 Neural Networks and Artificial Intelligence

A set of algorithms that are designed to recognize patterns which are modeled closely after the human brain is called neutral networking. By clustering or labeling input which is raw, the sensory data is decoded. Contained in form of vectors, the data is recognized as numerical, in which all data of real world must be translated like sound, images, time series or text.

Neural networks help us to classify the cluster. In neural networks, classification and clustering of layer on top of the data is carried out. By picking the similarities in the input they gather the unlabeled data, and on basis of labeled datasheet they proceed on to classify the data

It is known as a "universal approximator" because it can give an approximate value of an unknown factor and find a connection between the input and the output.

For example, for f(x) =y where x is any input and y is the output. If we assume that these both have a correlation between them, then the neural network finds the right way to transform x into y.

2.4.1 Classification

Labeled datasheets is the backbone for classification of data; i.e. in order for correlation between data and labels, neutral networking must learn this technique of correlating and thus, humans must transfer their knowledge to the dataset. Otherwise known as supervised learning. The classification depends on the labeled datasets. That means that the humans must tell the network what is the correlation between the labels and data. This is called "Supervised Learning". The practical applications of using neural networks are as follows:

- identify people in images, recognize facial expressions, Detect faces
- objects identification in images (pedestrians, stop signs, lane markers…)
- in video gestures are recognized
- recognize sentiment in voices, transcribe speech to text, identify speakers, Detect voices
- recognize sentiment in text (customer feedback) i-e Classify text as spam (in emails)

Neutral networking can be trained by humans and get the outcomes to their own desire.

2.4.2 Clustering

Clustering is the detection of similarities. For detecting similarities deep learning is not required. And thus is called unsupervised learning i-e labels are not required to learn. World's data is unlabeled most of the times. The accuracy can be increased by giving the algorithm more data to train on, this is one of the law in which machines learns. Therefore, Models of high accuracy can be produced using unsupervised learning.

- Search: sounds or images to get similar items, Comparing documents
- Anomaly detection: The flipside of detecting similarities is detecting anomalies, or unusual behavior. In many cases, unusual behavior correlates highly with things you want to detect and prevent, such as fraud.

Clustering is the recognition of likenesses in the data. Deep learning doesn't expect marks to distinguish similarities. Learning without labels is called unsupervised learning. Unlabeled information is most of information in the world. One law of AI is: the more information a calculation can prepare on, the more exact it will be. In this way, unsupervised learning can possibly create exceptionally precise models.

2.4.2.1 Predictive Analytics: Regressions

Correlations between, say, the name of a person and pixel in image is established using classification or more precisely supervised learning. Static prediction can be the name given to it. By the same token, exposed to enough of the right data, between future events and present events correlation is established using deep learning. Between the future and the past regression can be ran. In a sense future event is no more than a label. Time is not a factor for deep learning, or the fact that something hasn't happened yet. Deep learning may predict the number most likely to occur next by reading strings of numbers in a given time series. With arrangement, deep learning can set up connections between, states, pixels in a picture and the name of an individual. You may call this a static prediction. By a similar token, presented to enough of the correct information, deep learning can set up connections between current occasions and future occasions. It can run relapse between the past and what's to come. The future occasion resembles the name one might say. Deep learning doesn't really think about time, or the way that something hasn't occurred at this point. Given a period arrangement, deep learning may peruse a string of number and foresee the number well on the way to happen straightaway.

2.4.3 Neural Network Elements

It is networks composed of several layers. "Stacked neural networks" is the name we use for Deep learning.

Nodes are used to make layers. Place in the human brain, loosely patterned on a neuron where computation happens is called a node, after encountering sufficient stimuli it fires. Set of coefficients and input from the data is combined at node, input is either dampen or amplify, thereby the algorithm we are trying to learn the significance of input is greatly increased; e.g. without error which input is most helpful in classifying data? The activation function is then utilized which sums the input and is passed through the node, to determine whether and to what extent that signal should progress further through the network to affect the ultimate outcome, say, an act of classification. If the signals passes through, the neuron has been "activated." Networks consisting of several layers is called as "stack neural networks" that is the name we use for deep learning .The layers in stack neural networks are made of "nodes" which are designed on the basis of neurons in a human brain which go off when it is hit by a stimuli. There is a a set of values or coefficients or we can say weights that bring about changes in a data or restructures the data, so what a node does is combine the input data with these coefficients therefore giving importance to the data with respect to the problem the algorithm it is trying to learn.

In many business issues such as risk management, data validation, customer research, and sales forecasting, now a days neural networks are used. For instance for anomaly detection in data, natural language understanding, time-series predictions neutral networking is applied in statsbot.

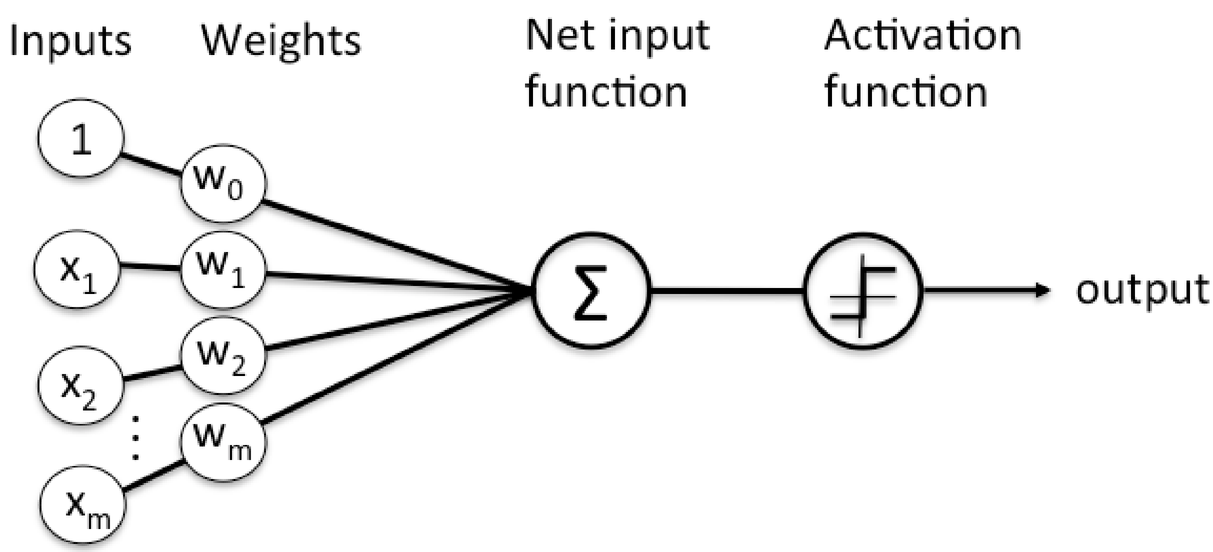


Figure 5 Systematic Figure of a Node

Therefore from the above figure it is concluded that each node is a row of these neurons switched that turn on and off as the information is given. Each layer's output is the input of the subsequent layer

CHAPTER 3

RESEARCH METHODOLOGY

3.1 General

It is need of the hour to research on the application of MREs, it is one of the main areas of search for structural materials having improved results. There are a lot of materials, a lot of compounds having ferromagnetic properties induced in them. So a lot of work, a lot of research and a lot of tests are waiting for us. A small effort by us presents the results of studies of behavior of MRE's under compression and the effect of static magnetic field.

3.2 Methods and Procedures

There are different methods and their procedures to study behavior of different materials in MR Elastomers. One is experimental method and other is Neural Network Method. In experimental method, first we check size of particles and made samples and then go through different tests and compile the results. And we have to repeat the procedure for each type of material. But in case of Neural Network, it is quite easy. Artificial Intelligence have make live easy and it is giving so accurate results that many industrial sectors are now relying on it. We make research on one material and then compile the complete data in excel sheets. Then properties and percentages of material under study is placed in input. And in this way, after processing the input data, we obtain the results.

3.3 Material Acquisition and Testing

3.3.1 Material selection

Iron particles were used in previous studies regarding MR Elastomers. So we were dire ted to choose materials having ferromagnetic properties. We have to keep in mind the cost of materials along with their properties. So we chose nickel, cobalt and iron oxide to conduct our study as these materials are easily available in the market and their cost is not so much high. First of all, we tried to procure the material from Pakistan. We tried from different parts of Islamabad and Rawalpindi, but unfortunately cannot found the required size. We had option to use milling machine to make sample according to our choice. But there was possibility of delay and possibility of human error, so we opted to procure from an online store located in China. But we faced difficulty after procurement of materials and after making samples, so scope of work was changed. After change in scope, if we talk about the cases and samples, samples with Iron particles up to 20, 30 and 40 percent are used. For each percentage, there were 60 cases and total number of cases were 180. These different cases focused on amplitude, frequency and magnetic flux.

3.3.2 Testing

In order to conduct the studies, we had to perform different types of tests. But as we were in middle of our project, we faced issues like COVID-19 outbreak, which stopped our work. Our samples for ready for testing in Textile University Faisalabad, but due to lack of facilities and orders of government to take safety measures first, we were not given permission. So we headed towards Artificial Intelligence. We used neural network in MATLAB.

3.4 Sample Shape and other properties

Nickel, Cobalt and Ferric oxide samples made for testing were all rectangular because the testing assembly required rectangular samples, so we opted for a rectangular mold according to the specifications of the testing machinery.

Iron Particles Percentage	20%, 30%, 40%
Magnetic Flux	0 to 0.4 Tesla
Frequency	0.5 Hz, 1Hz, 2Hz, 3Hz
Amplitude	4.2, 7, 9.8

3.5 Neural Network Elements

We can understand neural network elements by following layers.

Input layer: It is the layer in which the data is inserted.

Hidden layer: It is the layer in which algorithms are run which train the input player

Output layer: It is the layer in which the output layer, once the algorithm are done and the data is been trained the results are obtained.

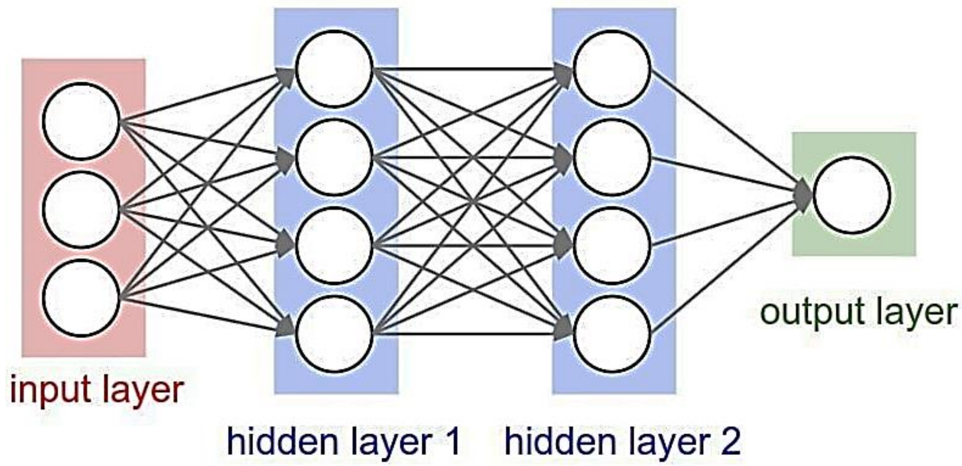


Figure 6 Layers Overview

3.6 Experimental Study

We used iron particles with multiple percentages and for each number of percentage sample, the properties such as magnetic flux, frequency and amplitude are studied. Here, the question arose that how were we going to use the data that we obtained from testing that had been done in previous researches. The answer to this lied in Artificial Intelligence. We used the Application of Neural Network to interpret the data and compare the results drawn from it, with the experimental results.

The following steps shows the basic hierarchy which points out working of neural networks. As we can see that there are multiple steps involved in Neural Network.

- First it clusters the data
- Then it classifies each cluster
- And then it approximates a function.
- After that function approximation is done. A function is generated that gives the same output for the given input as the model.
- After this optimization of the function take place.
- And last step is Determining value for input variable to achieve desired values for the output variables. These values should be near to the actual experimental values.

Now the following points will guide towards the steps that are utilized in modeling an artificial neural network.

- Collection of data.
- Selection of suitable network architecture in which number of layers, number of neurons etc. are decided.
- Training of the data.
- Testing of the network.
- Validity of the network is ensured by comparison with the experimental results.

3.7 Numerical Modelling in MATLAB

Starting with MATLAB, We used MATLAB in which NN also known as double N TOOL is used which is neural network Tool. Out of all the data we had, 50% data was selected for training and remaining 50% for validation. In this way, we could compare the result of neural network in which 50 % data is used for training, and the results obtained from this is compared with the remaining 50% data.

Once the Behavior is noted through neural network, the results are to be compared with the actual experimental result. Here is an overview of what we did during training the data and getting the outcomes. We have tried to summarize them in bullets points.

There are several kinds of network types in MATLAB, but we used feet forward.

Once the type of network is decided next step is to select the number of layers.

After that the number of neuron on each layer are to be decided.

In our case we used 10 number of neurons in each layer.

After that the performance and the regression were checked and compared once the plots were obtained.

CHAPTER 4

TEST RESULTS

4.1 Neural Network Modeling Results

Layer recurrent type neural network was used for modelling with ten layers and four neurons in each layer. After providing the input and target data, following training parameters were used to train the neural network as shown in the following figure:

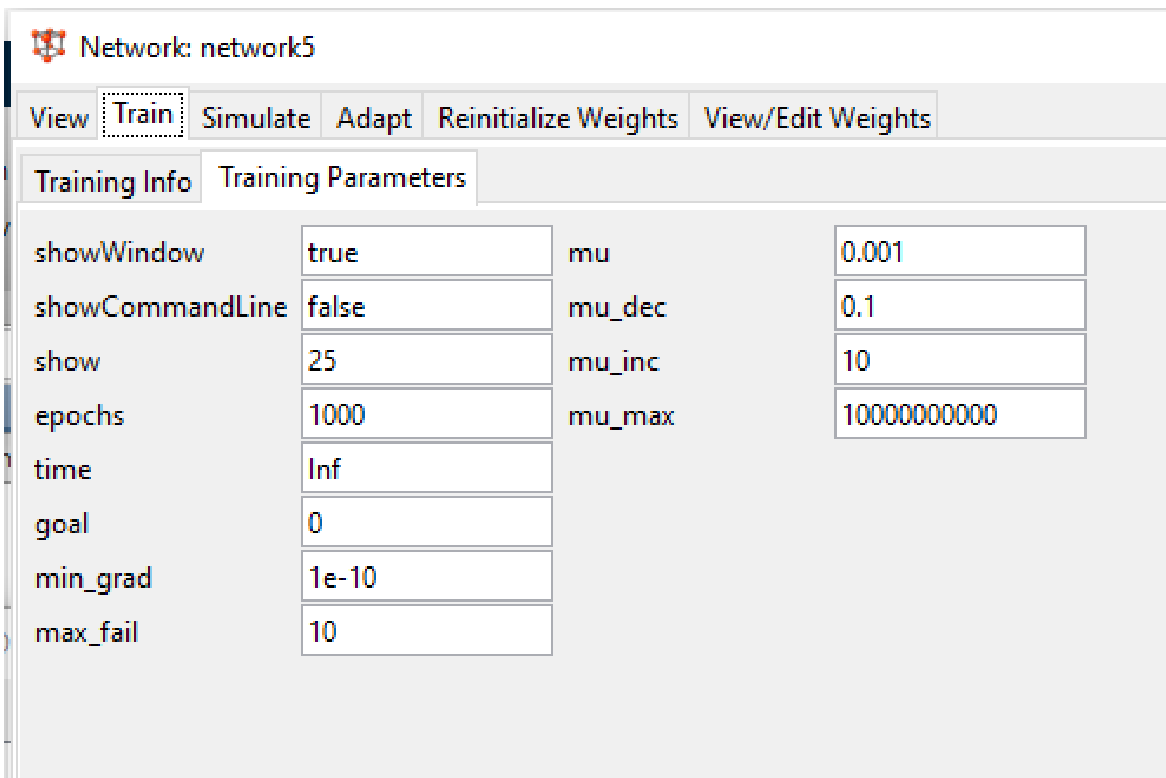


Figure 7 Training Parameters

The **performance** curve of the trained neural network is shown in the following figure:

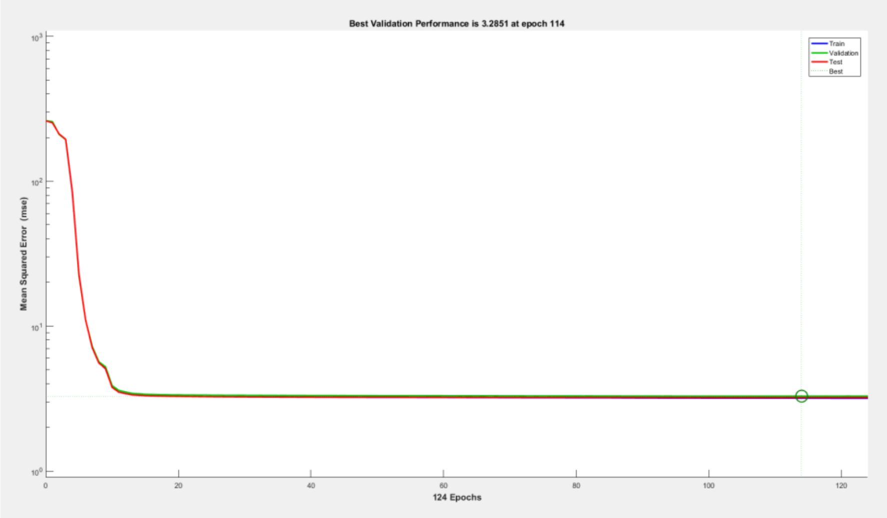
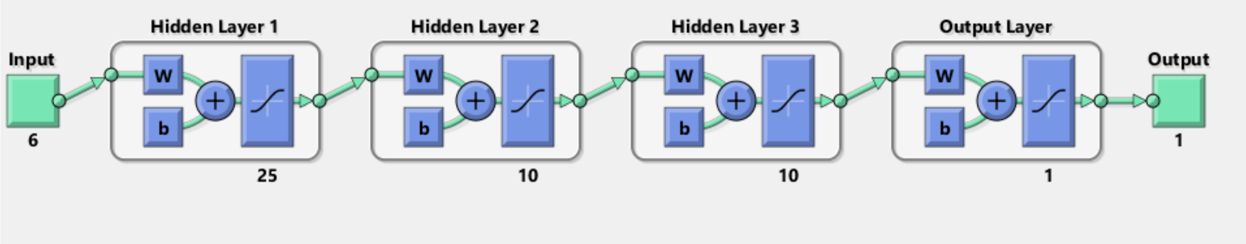


Figure 8 Performance Curve of trained neural network

Once the neural network is trained, it develops a neural network model as shown in the following figure with input, target and suitable number of hidden layers:



4.1.1 Regression Curves.

The regression curves obtained after the neural network has been trained show the extent of accuracy of neural network model. In the following figures, the value of R is very close to 1 and the regression curve makes an angle of approximately 45 degrees which shows that the neural network model obtained is quite accurate.

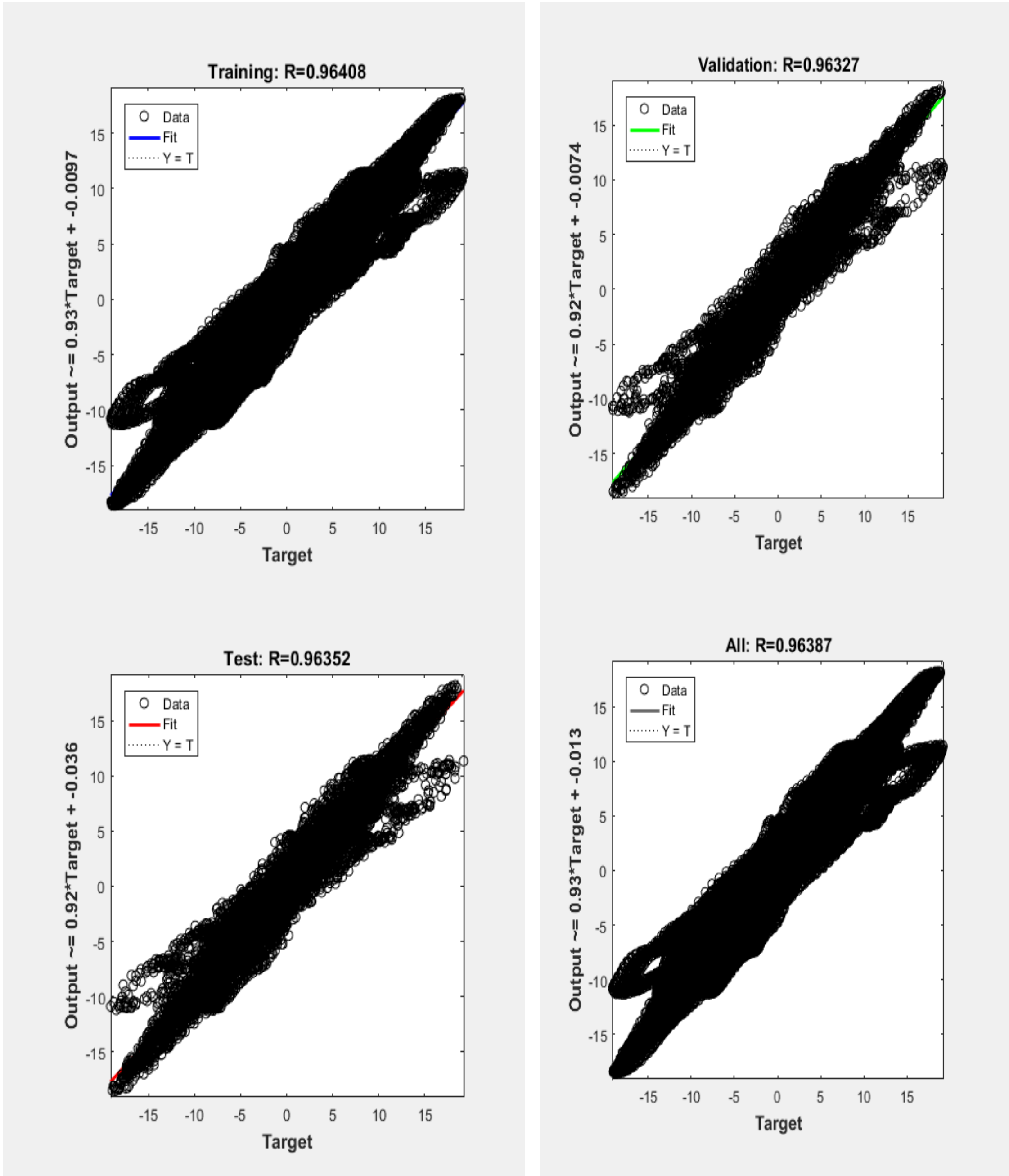


Figure 9 Regression Curves

4.1.2 Variation of displacement amplitude

The following three figures show the variation of displacement amplitude while keeping the values of filler percentage, magnetic field and frequency fixed as:

Filler=20%, magnetic field=0T, Frequency=0.5Hz

For displacement amplitude = 4.2mm

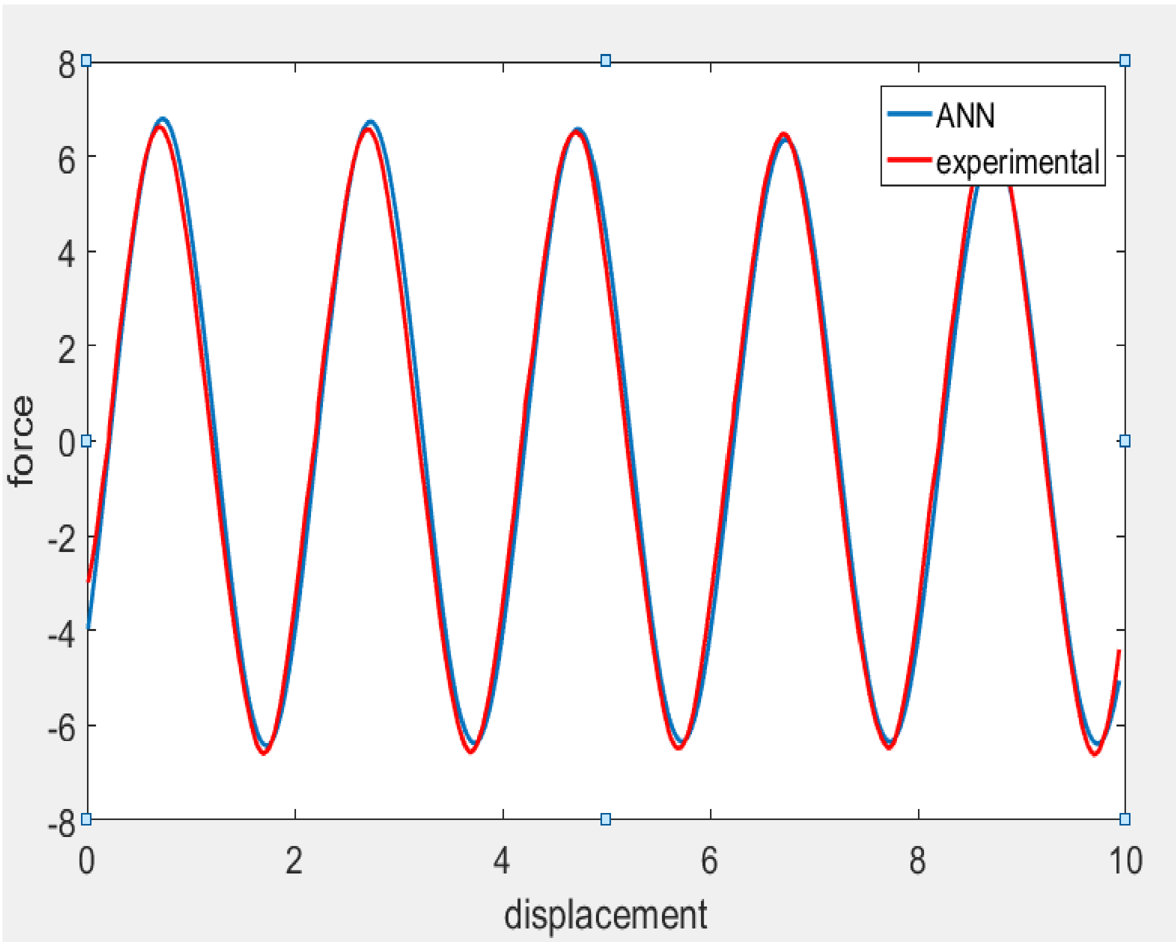
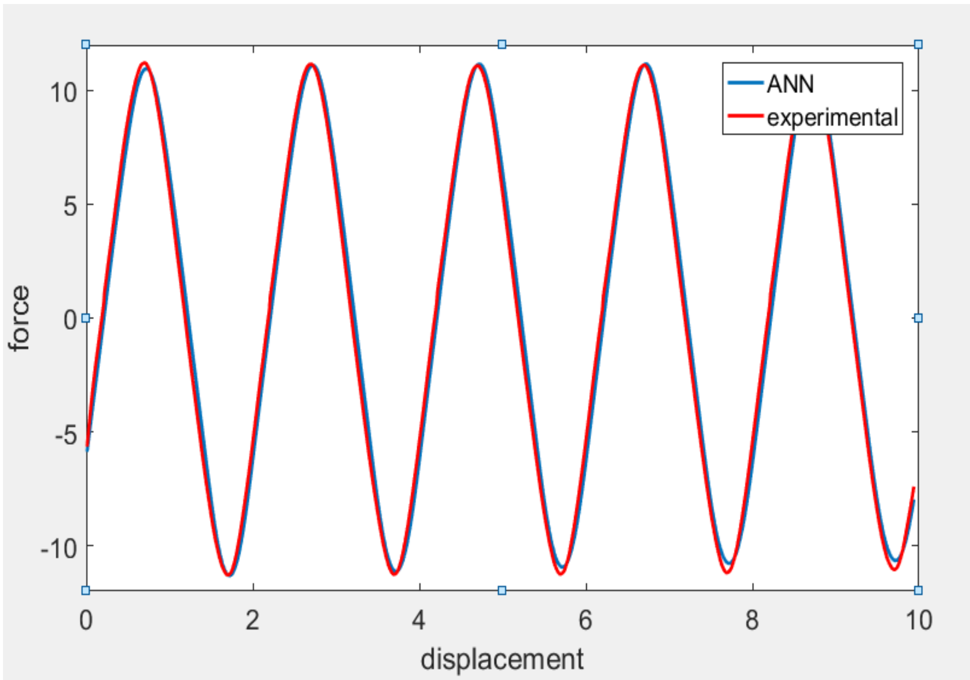
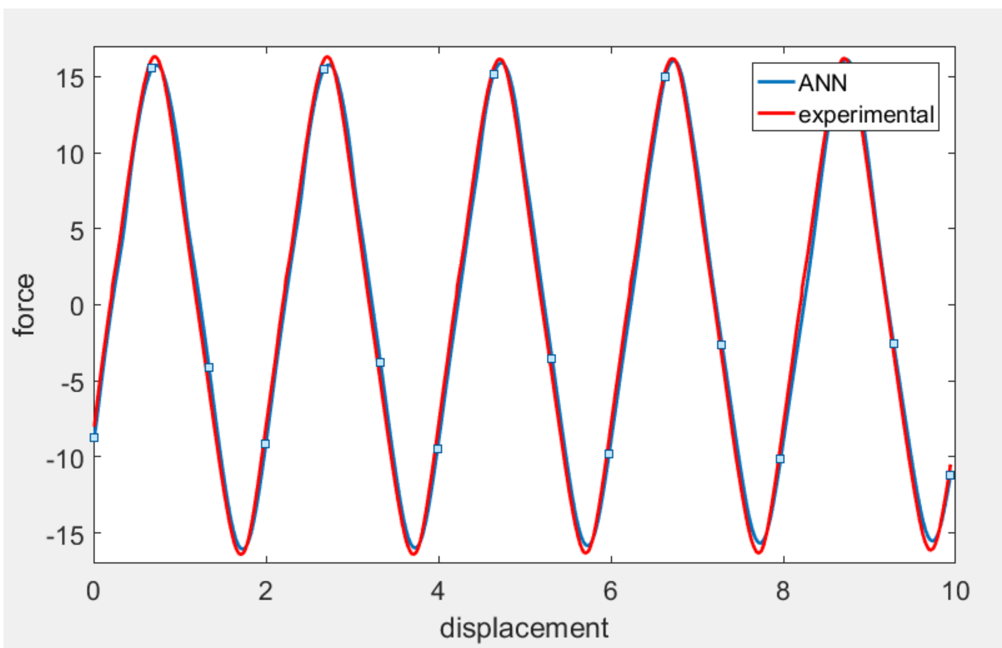


Figure 10 Comparison of ANN and Experimental

For displacement Amplitude = 7mm



For displacement amplitude = 9.8mm

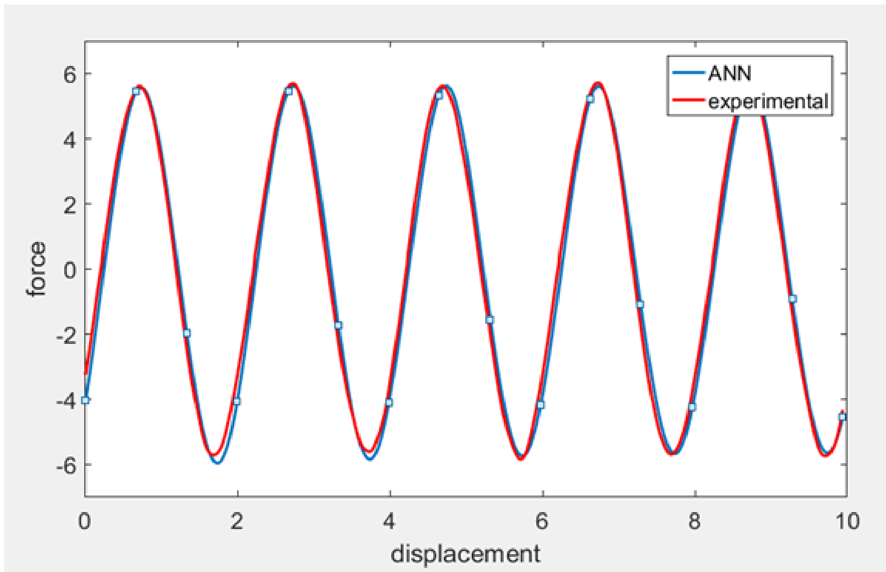


4.1.3 Variation of frequency

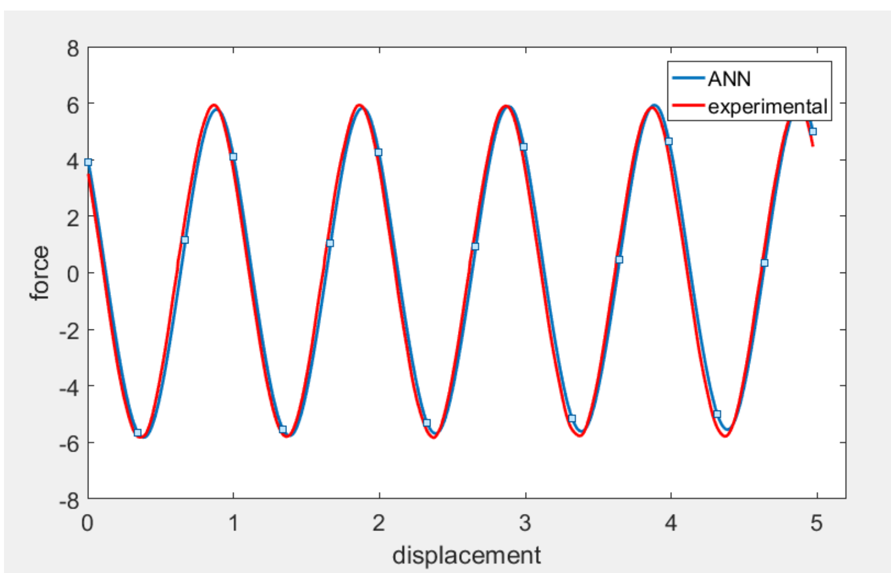
The following three figures show the variation of frequency while keeping the values of filler percentage, magnetic field and displacement amplitude fixed as:

Filler=20%, Field=0.1T, Amp=4.2mm

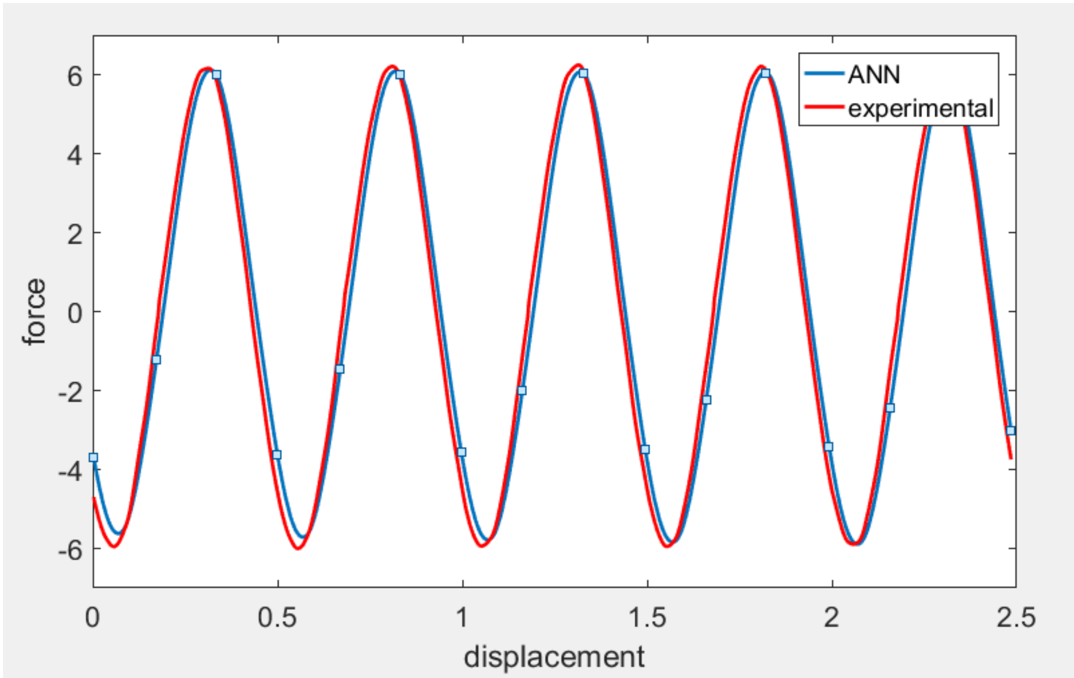
For frequency = 0.5Hz



For Frequency = 1Hz



For Frequency = 2Hz

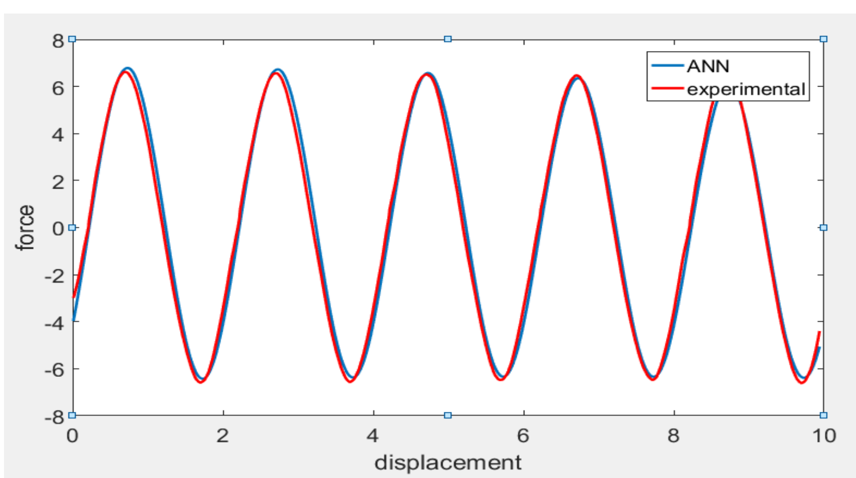


4.1.4 Variation of magnetic field

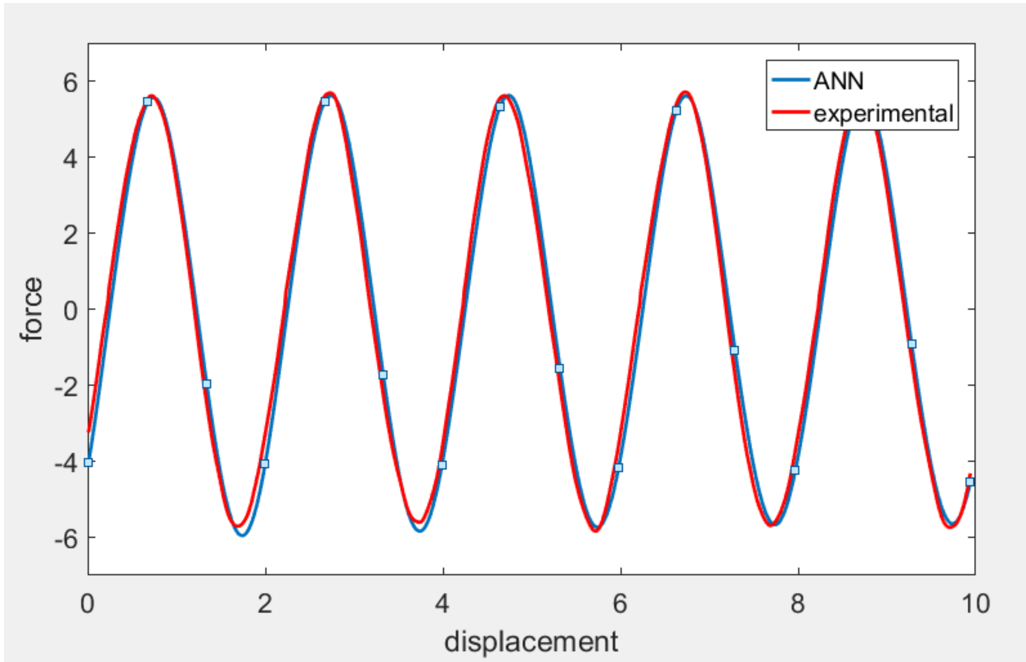
The following three figures show the variation of magnetic field while keeping the values of filler percentage, displacement amplitude and frequency fixed as:

Filler=20%, Frequency=0.5Hz, Amp=4.2mm

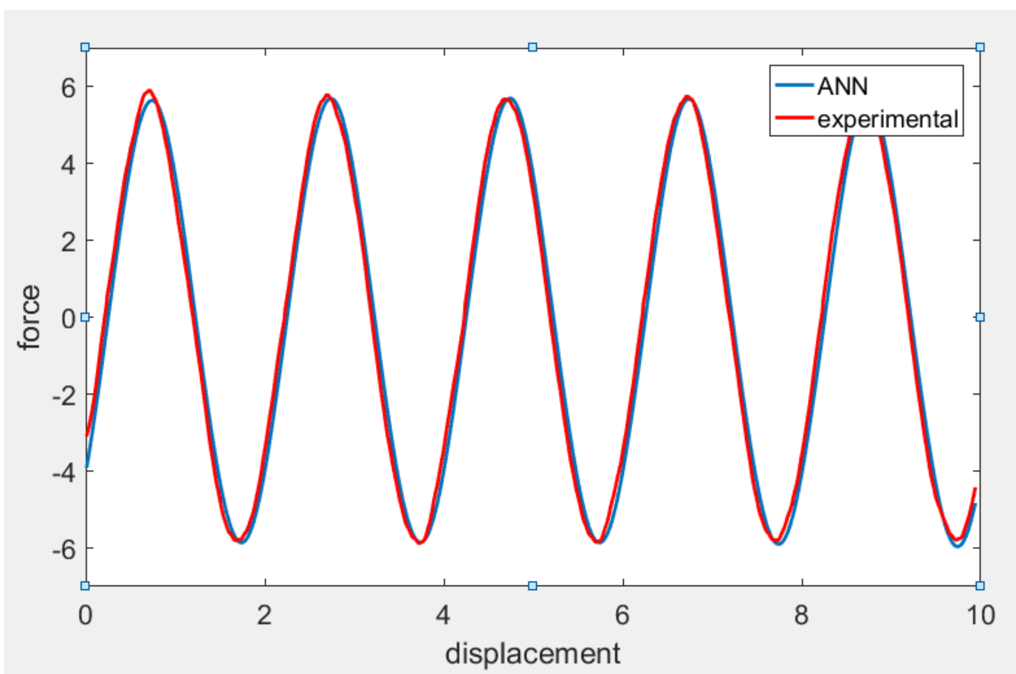
For magnetic field = 0T



For magnetic field = 0.1T



For magnetic field = 0.2T

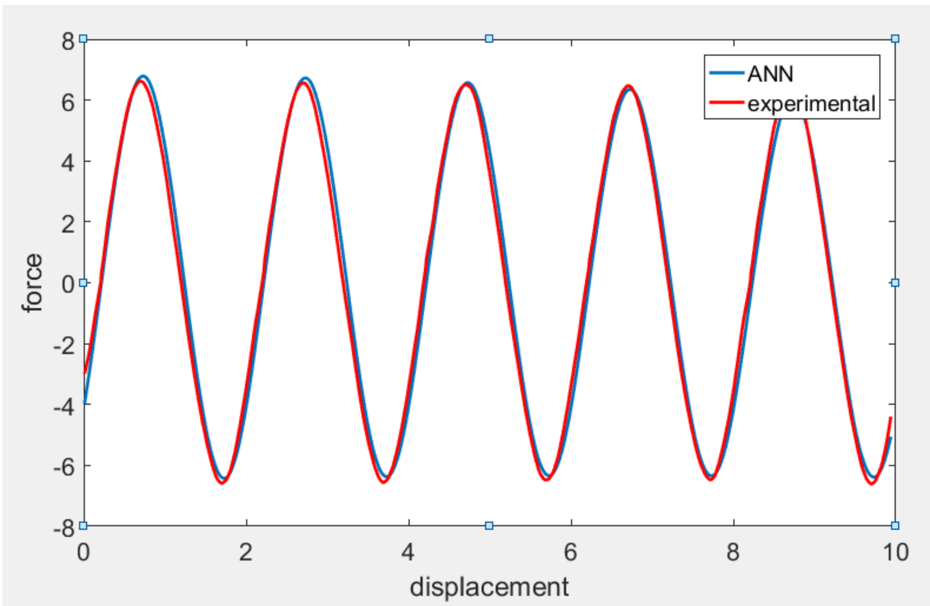


4.1.5 Variation of filler percentage

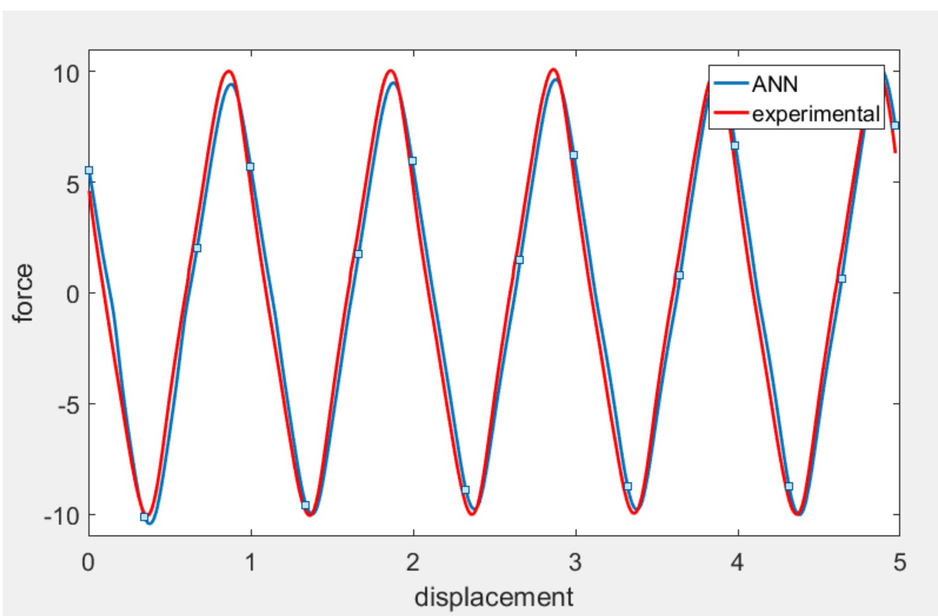
The following three figures show the variation of displacement amplitude while keeping the values of filler percentage, magnetic field and frequency fixed as:

Magnetic Field=0T, Frequency =0.5Hz, Amp=4.2mm

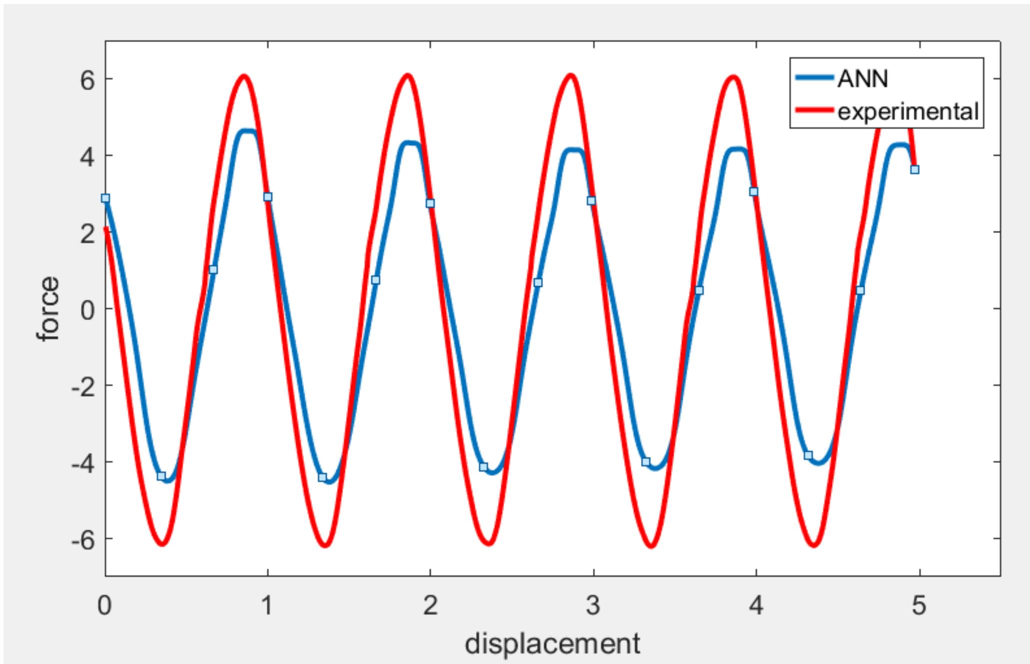
For filler percentage = 20%



For filler percentage = 30%



For filler percentage = 40%



CHAPTER 5

CONCLUSIONSAND RECOMMENDATIONS

5.1 Conclusions

- The data of percentage of iron particles in samples up to 20%, 30% and 40%, is used to train the neural network.
- The magnetic flux is varied from 0 to 0.4 Tesla. The results of each case is used to train the neural network.
- Frequency is varied through 0.5 Hz, 1 Hz, 2 Hz, and 3 Hz. And the results are utilized in training process.
- The amplitude is varied through 4.2, 7 and 9.2.
- Neural network using NN tool is trained in MATLAB.
- The results obtained from developed neural network is quite comparable and similar to the results of actual experiments.
- The similarities between the results obtained from two different domains shows that the neural network that has been developed is acceptable and all the plots obtained as results are having very minor difference

5.2 Challenges Faced

- Material Availability: In the beginning of the project we were unable to arrange the material such as Iron, nickel, cobalt nanoparticles in Pakistan. Therefore the material was imported from Ally express China.
- Sample preparation: Once the particles of nickel, cobalt and iron were obtained next hurdle was to prepare samples. To pace of the work after waiting for almost 2 months all of the group team members and the supervisor advert hard in preparation of the samples.
- When the sample preparation was in its last stages, Global pandemic i.e. Covid 19 just emerged out. As a result of which the university had to close down as per government orders.
- Change of Scope: During the lockdown due to COVID-19 pandemic, we could not perform testing of our samples which was planned to be done in Textile University, Faisalabad. Therefore, we did not have our own data but our supervisor Doctor

Muhammad Usman arranged data for our project and helped us in deciding the changed scope.

5.3. Recommendations

- User friendly moulds can be used to prepare the samples.
- Better results can be obtained if data from multiple sources is used for training the neural network.
- Neural network can be trained for sample such as cobalt, and nickel as well and the results can be compared with samples with iron particles.
- For the testing of samples university should arrange modern machinery which can be used for shear testing of samples.

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