VIBRATION ANALYSIS OF MONO SUSPENSION USED IN A TWO WHEELER BY NUMERICAL RELATION AND MATLAB SOFTWARE

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ABSTRACT

The present work deals with the behaviour of mono suspension helical spring of a two wheeler suspension system under different road conditions and to find the different governing parameters using the numerical relations which are traditionally accepted and to compare the parameters such as speed, transmissibility, stress, and force (i.e. the jerk obtained at different speeds of a running vehicle due to uneven road conditions) to perform a forecasting of that analysis using MATLAB ANN tool using different inputs which are responsible for certain outputs. Finally we will perform a comparative study on numerically obtained results and the results obtained from MATLAB ANN tool to validate our research. The present work also involves the study of behaviour of different spring materials which can be used for manufacturing of a mono suspension spring.

Keywords: *Mono suspension Spring, MATLAB, Speed, Force, Stress, Transmissibility, Artificial Neural Network (ANN)*

INTRODUCTION

A mono suspension spring is that type of spring which is generally used in the front wheel of a two wheeler automobile as it connects the frame and swing arm which is finally pivoted to the axle to act as a cushion. Sometimes it is also placed in the rear suspension to act the same function of absorbing shock. The mono suspension spring are used now days as they are compatible with the present Indian roads which are much better then the severe road conditions if we talk around 20 years back. Although the dual shock absorbers are strong enough to withstand the load coming from a extremely bad road surface but due to weight and cost associated, it is now can be replaced by mono suspension spring which is comparatively very light and can handle the variable loads with grater handling and stability. They can be designed in such a way that they show nonlinear behavior. This means that the spring stiffness is not constant but depends on the compression. This nonlinear behavior occurs when the number of active coils decreases or increases with varying compression. The nonlinear behavior of a spring can be achieved

Figure 2 Mono suspension Spring

Materials used for Manufacturing of spring: A verity of materials are used for the manufacturing of spring and for its applications like in machine automobiles, Electrical appliances, Toys, compression springs are generally used for shock absorbers, special purpose pencils, and pens etc., Extension springs are those which are used in tensile load applications such as in braking mechanism, automatic door mechanisms, in musical instruments etc. Some kind of torsion springs are also used where twisting application is required like in mouse trap mechanism.

Figure 3 Types of springs

Some of the spring materials are described as follows:

1. **Inconel Springs**: These are having the main ingredient as nickel, it is having oxide coating which makes it corrosion resistant, can work at elevated temperatures, supportive at reversible range of temperature and having good tensile strength. Applications: gas turbines, aerospace, chemical processing, industrial heating, nuclear, and heat treating
2. **Chrome Silicon**: Before actual manufacturing they are cold drawn and heat treated. The main ingredients are chromium, silicon, carbon, manganese, sulphur and phosphorous. This type of material is used for absorbing sudden loads and is used under moderate temperature conditions. It is having good strength and durable. Applications: Gun recoils and performance vehicles.
3. **Chromium Vanadium**: These are made up of chromium, carbon, vanadium, and other metals. These are load tolerant, having good hardness, corrosion resistant, and can perform under extreme temperatures. Applications: IC engines and punching press working

4. **Phosphor Bronze Springs**: The main ingredients are tin, zinc, iron, lead and phosphorous. They came in conical as well as rectangular shapes and are having good physical properties, strong structure, and having good strength, wear resistant, fatigue resistant, formability, machine-ability and excellent electrical conductivity.

   Applications: Switches, vacuum cleaners, fuel pumps, oil rigs, pipeline valves.

5. **Beryllium Copper**: The main ingredients are copper, beryllium, nickel and cobalt. They posses high strength, machine-able, formable, ductile, weld-able, corrosion resistant and reliable. Due to their non ferrous characteristics they are weak and wear out faster than steel springs.

   Applications: Valves, copper wires, weapons, cryogenic equipments, musical instruments etc.

6. **Stainless Steel Springs:** The main ingredients are chromium, nickel, Molybdenum and Aluminum. They are corrosion resistant, temperature resistant, and posses good mechanical properties. Generally these materials are categorized in four types namely martensitic, ferritic, austenitic, and precipitation hardening out of which austenitic and precipitation hardening materials are widely used in spring applications. Applications: Air-Crafts, mobile devices, medical equipments, Shock absorbers, IC engine valve, home fitness equipment etc.

7. **Music Wire Springs:** The main ingredients are carbon, manganese, silicon, phosphorous and sulphur. They are cold drawn material drawn into wires. Generally used for manufacturing small spring's and posses high strength, fatigue and impact resistant, electrically conductive. Applications: Musical instruments

OBJECTIVE OF THE STUDY

1. To study empirically the relation for shock transmitted from the road surface to the passenger travelling on a two wheeler.
2. To study about the materials most suitable for manufacturing of mono suspension spring and to obtain the best possible material among all.
3. To obtain the results for a range of vehicle speeds i.e., from 03 Km/hr to 60 Km/hr
4. To carry out the same analysis using MATLAB simulation software.
5. To validate the results obtained from MATLAB by performing a comparative analysis between the analytical and simulation data.

LITERATURE REVIEW

Lade AV, Paropate RV, Choube AM and Wakulkar RE [1] analyzes spring, shock absorbers and linkages which connects vehicle to its wheel and allows relative motion between them are termed as suspension. Springs are helical metal coil which can be pressed or pulled but they have tendency to return to its original shape and size when released generally springs are used to absorb the shock or movement by its elastic action. Helical springs are being used in many vehicles as shock absorbers to have smooth ride, better control over vehicle, maintain correct ground clearance, and keep tires in contact with road.

Kumhar Vikky, [2] analyzed the effectiveness of the shock absorber in spring frequency under load condition. The shock absorber is commonly used at all vehicles today. The purpose of this research paper is to investigate and identified the problem in shock absorber spring during ride a motor cycle on bump. After identified problem we can decreases stress, deformation and increases its frequency capability by changing its coil diameter of spring. There are some problem happen at the vehicle when ride at the bumping road condition. One of the problems is that the vehicle bounce continuously more than one times and it is called as bouncing problems. The scope of study for this paper includes, experimental of suspension systems and bouncing problem in vehicle, apply structural analysis and model analysis on the shock absorber spring and application of Finite Element Analysis (FEA). To study the stress pattern of shock absorber spring in its loaded condition, a solid model of Shock absorber is prepared with the help of

Creo Parametric 2.0 software. Pattern of stress distribution in 3D model of shock absorber spring is obtained using ANSYS 15.0 software. In this present work, the obtained stresses by using finite element analysis with different coil spring as same material and validate to other research work reduce stress & Deformation by changing material property.

Choube AM, [3] deals with analysis of mono suspension by using FE approach and validated with analytical with varying speed. Helical spring is the most common element that has been used in suspension system. In this research, helical spring related to light vehicle suspension system under the effect of a uniform loading has been studied and finite element analysis has been compared with analytical solution. Maximum stress and deflection have been compared at various speeds for carbon steel material.
This study presents the stress analysis of mono suspension spring. Here, stresses and deflections are calculated with changing speed and validated with FEA. From the finite element analyses, the following findings are reported. Though, the results are elaborated in earlier chapter, the brief discussion and conclusion is presented as follows. For Mono suspension spring, it is observed that deflection get increases with increasing speed upto 10 km/hr on other hand shear stresses are also increases. But after 10km/hr, both deflection and shear stresses are going to decreases with increasing in speed. It means at higher speed, it gives low deflection and low shear stresses which are beneficial for life of spring.

Lavanya N and Rao P Sampath and Reddy Pramod M, [4] in 2014 Observe the vibrations from shock loads due to irregularities of the road surface. It is perform its function without impairing the stability, steering (or) general handling of the vehicle. Generally for light vehicles, coil springs are used as suspension system. A spring is an elastic object used to store mechanical energy and it can be twist, pulled (or) stretched by some force and can return to their original shape when the force is released. The present work attempts to analyze the safe load of the light vehicle suspension spring with different materials. This investigation includes comparison of modeling and analyses of primary suspension spring made of low carbon-structural steel and chrome vanadium steel and suggested the suitability for optimum design. The results show the reduction in overall stress and deflection of spring for chosen materials.

Manjunatha, TS and Budan, D Abdul, [5] in 2012 deals with the applicability of fiber reinforced plastic in springs. Three different types of springs were manufactured using glass fiber, carbon fiber and glass/carbon fiber in +45 degree orientation. Tests were conducted on the springs to study the mechanical behavior. The spring rate of the carbon fiber spring is found to be 24% more than the glass fiber spring and 10% more than the glass/carbon fiber spring. Stresses acting on the composite springs were less compared to steel spring. The weight of the composite spring is almost 70% less than that of the steel spring. The specimen preparation and experiments were carried out according to ASTM standards.

Singh Niranjan,[6] in 2013 Studied the main functions of automobile suspension systems are to isolate the structure and the occupants from shocks and vibrations generated by the road surface. The suspension systems basically consist of all the elements that provide the connection between the tires and the vehicle body. A spring is an elastic object used to store mechanical energy. It is an elastic body that can be twisted, pulled, or stretched by some force. It can return to their original shape when the force is released. It is a flexible element used to exert a force or a torque and, at the same time, to store energy. The force can be a linear push or pull, or it can be radial, acting similarly to a rubber band around a roll of drawings. The torque can be used to cause a rotation. The literature review discussed above depicts that the design of mechanical springs used in automobiles is quite necessary to do it's deign analysis which involves stress distribution analysis, maximum displacement and different mode of failure. The springs undergo the fluctuating loading over the whole span of service life. In addition, various Design softwares like ANSYS, SolidWorks, Pro-E, CATIA, Autodesk Inventor, etc., have been used for performing the stress analysis of mechanical springs. Comparison of the theoretical results obtained by the shear stress equation and Finite Element Analysis (FEM) of springs provides the better solution of the problems arises in the existing design of the mechanical spring. In future, it will help the designers for predicting the safe design of mechanical springs used in the automobiles to get better and comfortable ride.

Setty Thriveni, G and Gowd, G Harinath, [7] in 2014 Choosen the mono suspension system for various two wheelers in their study. The present work focuses mainly on obtaining the optimal spring dimensions without affecting the riding comfort for mono suspension system. To meet the above objective, first the existing springs of Honda CB Unicorn & Yamaha FZ springs will be tested for its strength by conducting the compression test. Later its

3D model drawn using SOLIDWORKS will be imported to HYPERMESH for meshing the spring & to apply the required loads on it. Finally by importing it into the ANSYS software to evaluate the stresses, strains and its load carrying capacity by doing static analysis. Mainly, this paper deals with the coil spring which is used in the Mono Suspension system. Then further analysis using the above softwares will be done by changing the spring dimensions and by using alternate materials. Thereby the optimal dimensions will be identified.

Vijayeshwar BV, Preetham B M, Bhaskar U,[8] in 2017 Performes a comparative study and analysis of suspension helical coil spring with two different materials (chrome silicon and hard drawn carbon steel) static analysis using finite element analysis to determine the optimum material to reduce the stress and deflection. Suspension model is created in Pro E CREO 2.0 and the model is structurally analysed using ANSYS 15.0. The results and comparative study shows the optimum material that can be selected as spring material for efficient function and long life.
It is proved theoretically and through ANSYS that the spring in which maximum shear stress is induced. Deflection induced in chrome silicon spring is very much less than deflection induced in hard drawn carbon spring, the weight and density of chrome silicon spring is lesser than hard drawn carbon spring. So Chrome silicon spring steel is the optimum suitable material with low weight and high stiffness for helical spring application like mono shock suspensions in bikes and many more.

H. Douville, P. Masson, A. Berry,[9] in 2006 Presents a methodology for the analysis of the structure-borne noise transmission paths for an automotive suspension assembly. First, a fully-instrumented test bench consisting of a wheel/suspension/lower suspension A-arm assembly was designed in order to identify the vibro-acoustic transmission paths (up to 250 Hz) for white noise excitation of the wheel. Second, frequency response function measurements between the excitation signal and each suspension/chassis linkages are used to characterize the different transmission paths that transmit energy through the chassis of the car. Results obtained from the on-resonance transmissibility methodology of a Ford Contour 1998 suspension assembly cannot be transposed directly to any other suspension assembly. On-resonance transmissibility factors (ORTF) and on-resonance participation factors (ORPF) of any other suspension assembly can be computed by the use of the presented on-resonance transmissibility

Artificial Neural Network Algorithms used for present work

Levenberg-Marquardt (LM) Training Algorithm-

MATLAB consist of this method where the command used for training network using LM back-propagation algorithm is "trainlm" This algorithm representatively requires memory to a great extent but lower time. Training stops instantaneously when generalization stops improving, as marked by an increase in the mean square error (MSE) of the validation samples.
This neural network is shaped for seven input layers, distinct number of hidden layers and three output layers. The following table 4.1 shows the various results obtained for LM training. Hidden layer neurons are here 8, 12, 16, 20, 24, 28 and 32 with these all their corresponding results are noted. The perfect of these observations is selected as final network model. Number of epochs and overall regression is shown in table as their value also have certain significance and it also changes with change in hidden layers. After observing the results from the above table, it has been clear that for the data utilized in this study, the best results will be obtained for the hidden layer having number of neurons will be 8 at least MSE i.e. 6.995263. Following figure 4.17 shows the diagram of the proposed neural network for LM training.

Table 4.1
Comparison of network performance of proposed model with various neurons using LM training algorithm

Algorithm	No. of Hidden Layer Neurons	Epochs	MSE	Overall Regression
LM	8	4	6.995263	0.95584
LM	12	7	2111479930832914	0.97225
LM	16	4	4401204665416147	0.93628
LM	20	572	558461955458.3831	1
LM	24	28	1872333224.0448	1
LM	28	12	342577841922.3085	1
LM	32	1000	32138531107.1437	1

Response for the different input parameters can be seen by using this fitting tool in LM training algorithm in figure 4.18. This network consists of seven inputs, 8 hidden layers and 3 output layers for different type of condition in input parameter.

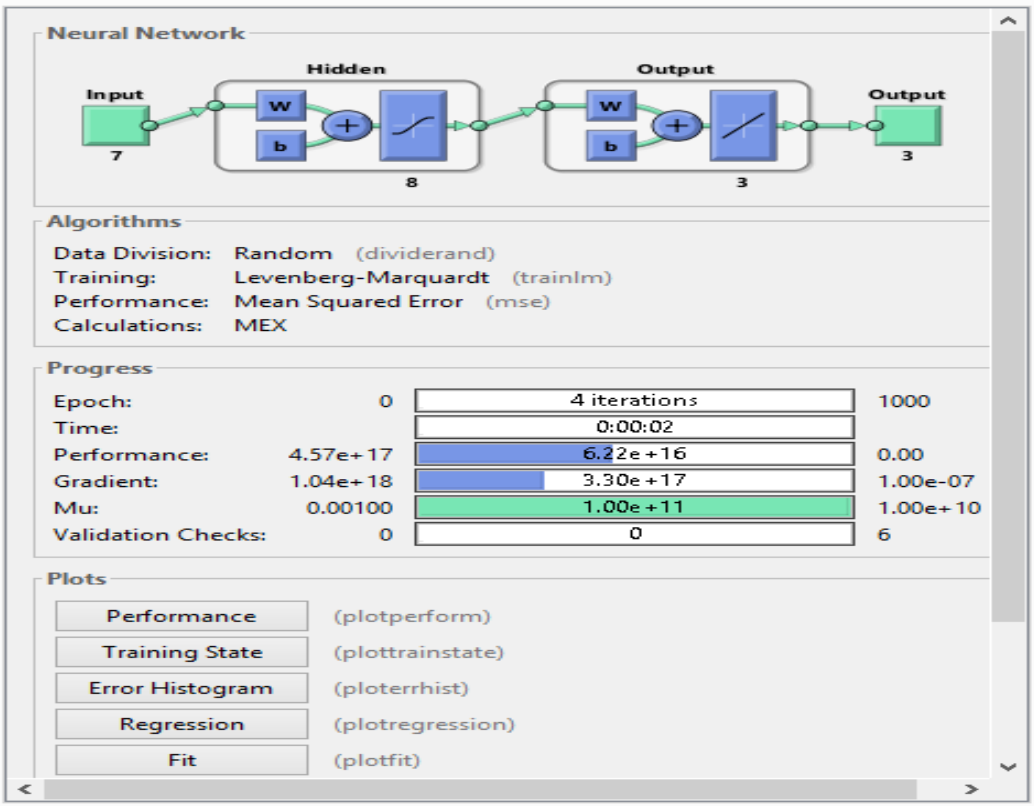


Figure 4.18 ANN window of LM training method

Training performance of neural network for 8 hidden layers as shown in figure 4.19
This shows training, validation, testing and best on epoch basis.

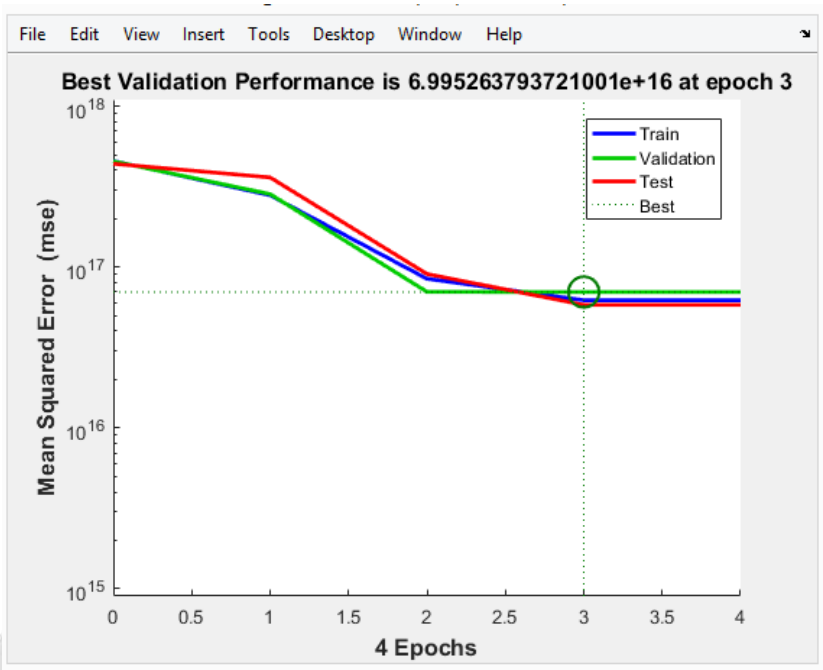


Figure 4.19 Computed MSE value using the proposed LM training neural network

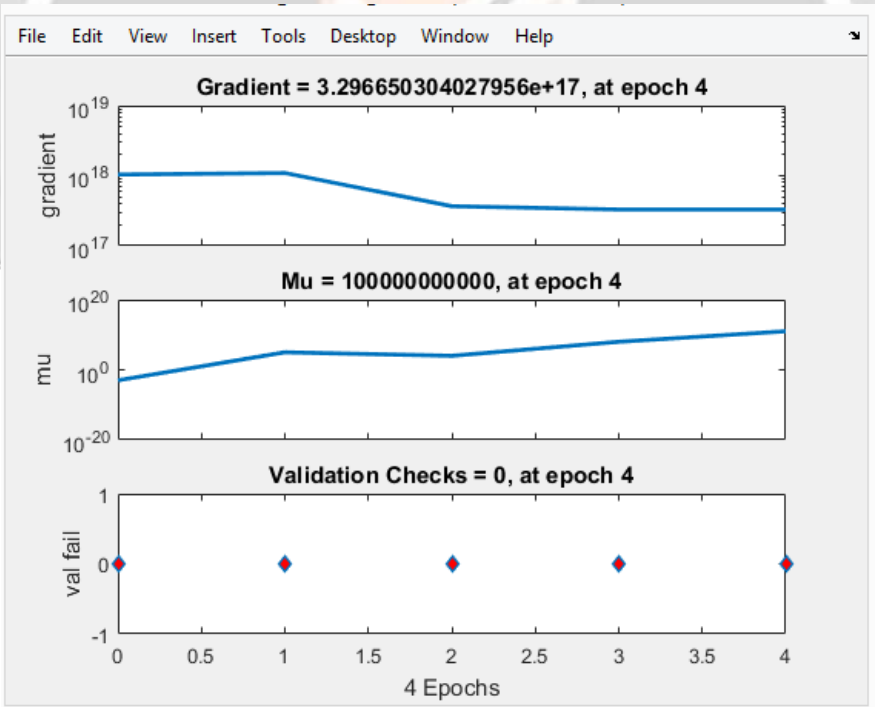


Figure 4.20 Training state plots for LM trained neural network

Errors generate when output is not accurate or the output is different as compared with Target then errors comes in errors histogram as shown in figure 4.21.

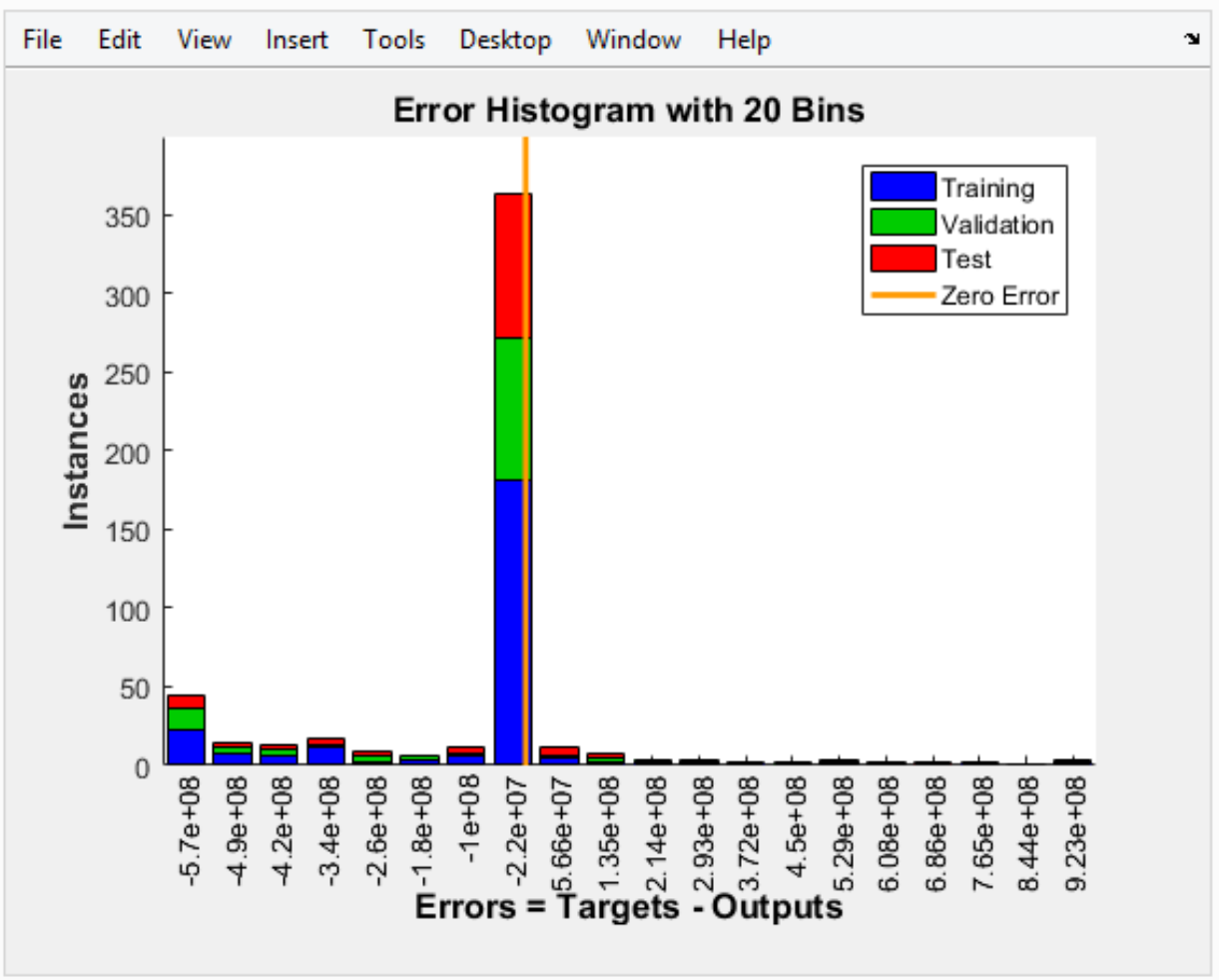


Figure 4.21 Error histogram for LM training neural network

Regression curve of fitting tool for 16 hidden layers is shown in figure 4.22 which shows Training, validation, test and combined curve.

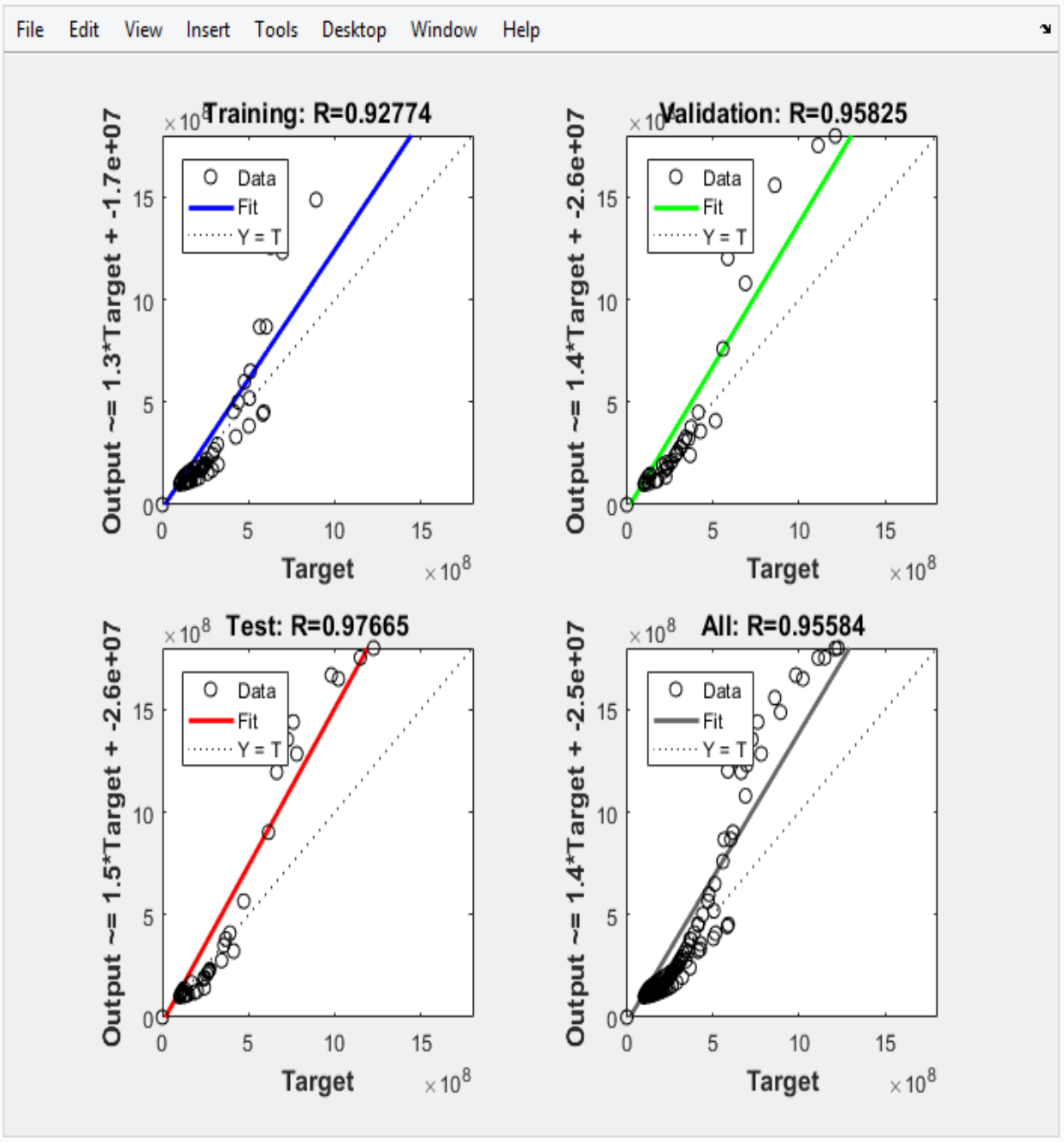
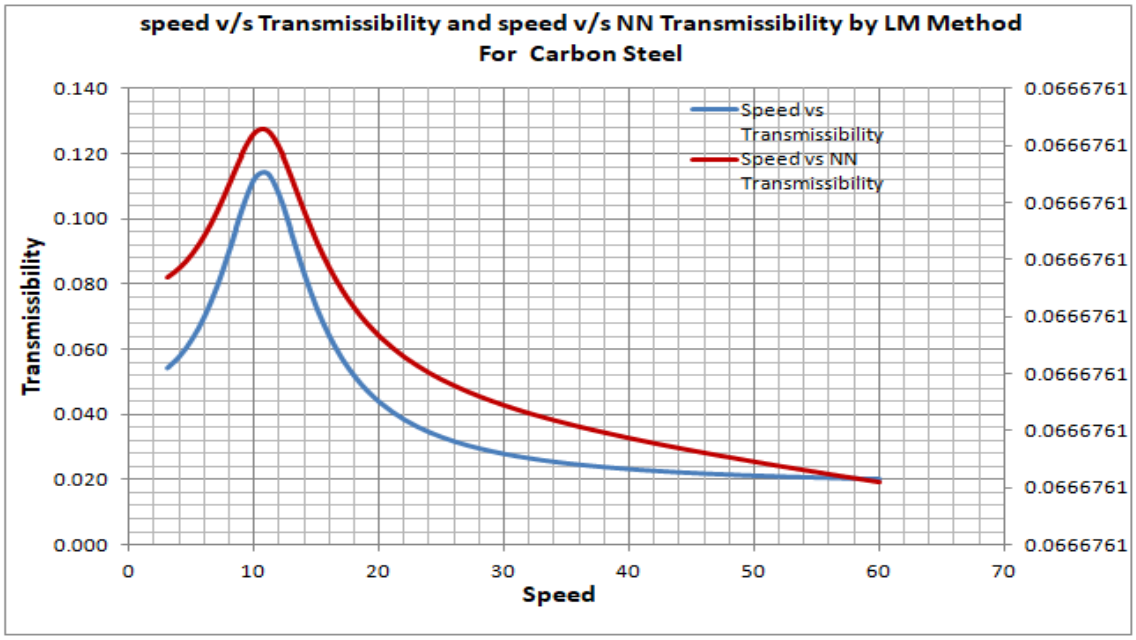


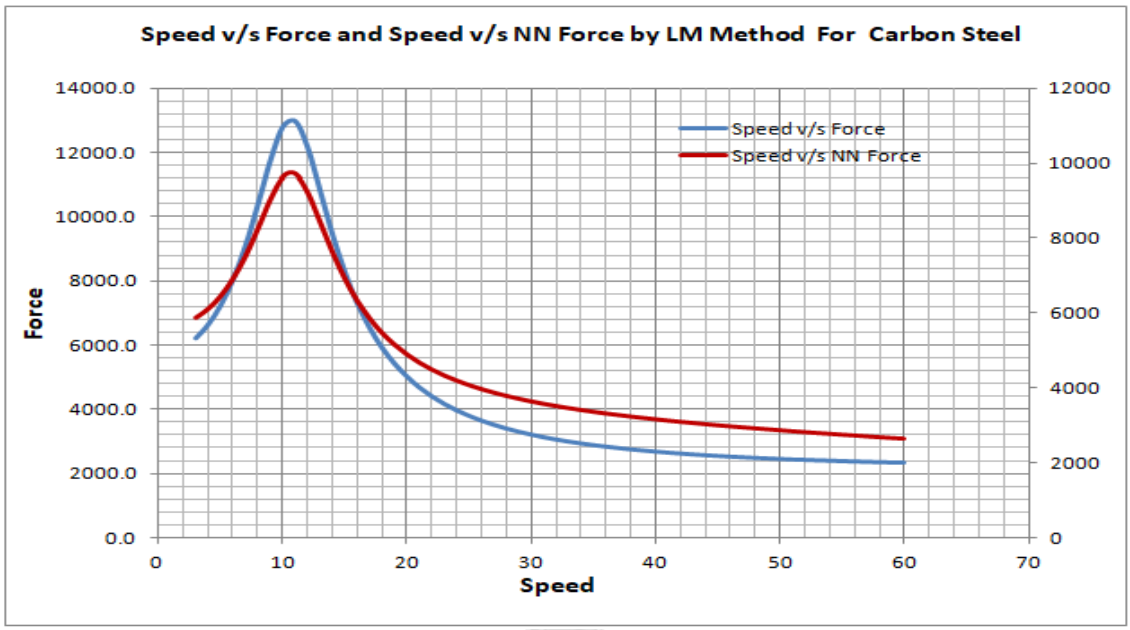
Figure 4.22Regression curve during training, testing & validation for proposed LM training algorithm

RESULT AND DISCUSSION

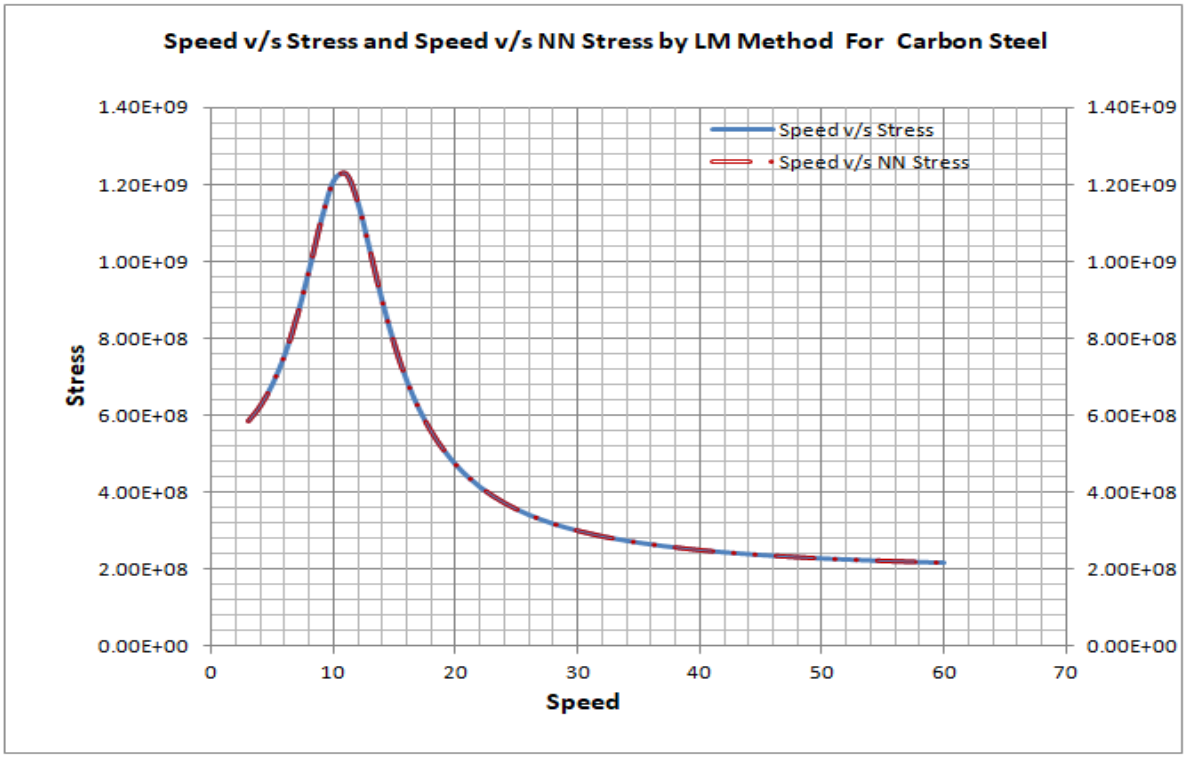
The relative figures are drawn on the basis of these tables and the one obtained numerically, are represented in the subsequent figures below.



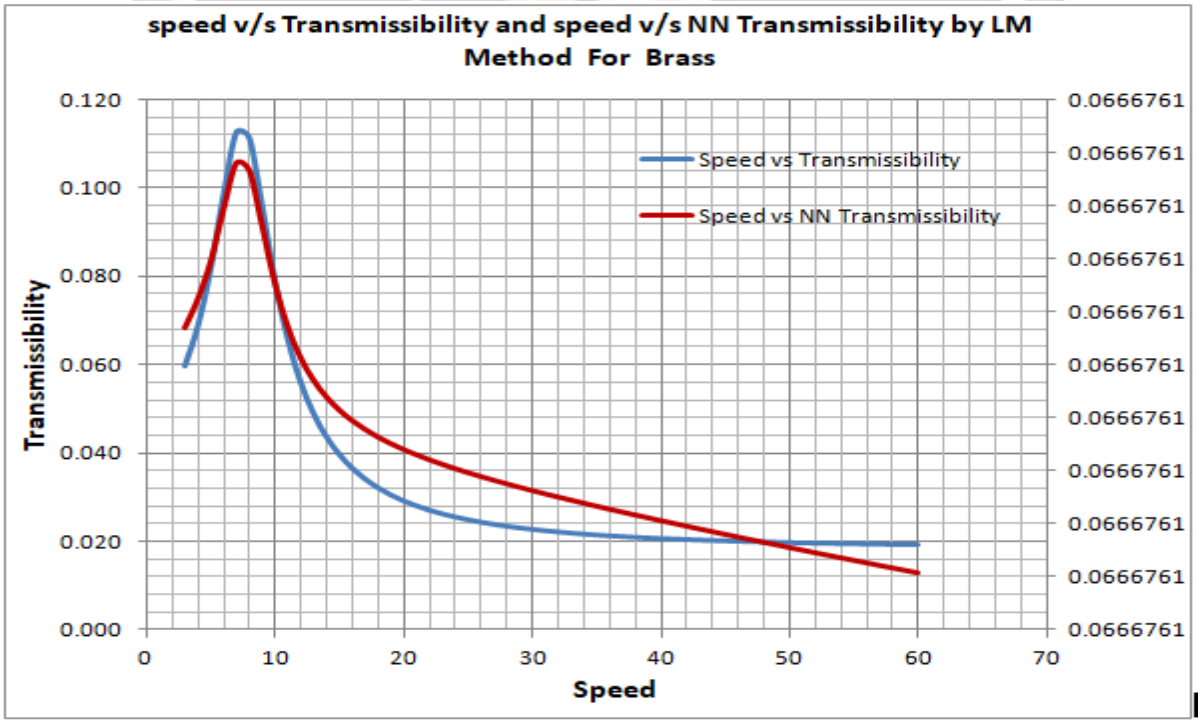
Graph 1 represents comparison between input speed v/s transmissibility and input speed v/s forecasted transmissibility by LM method for carbon steel



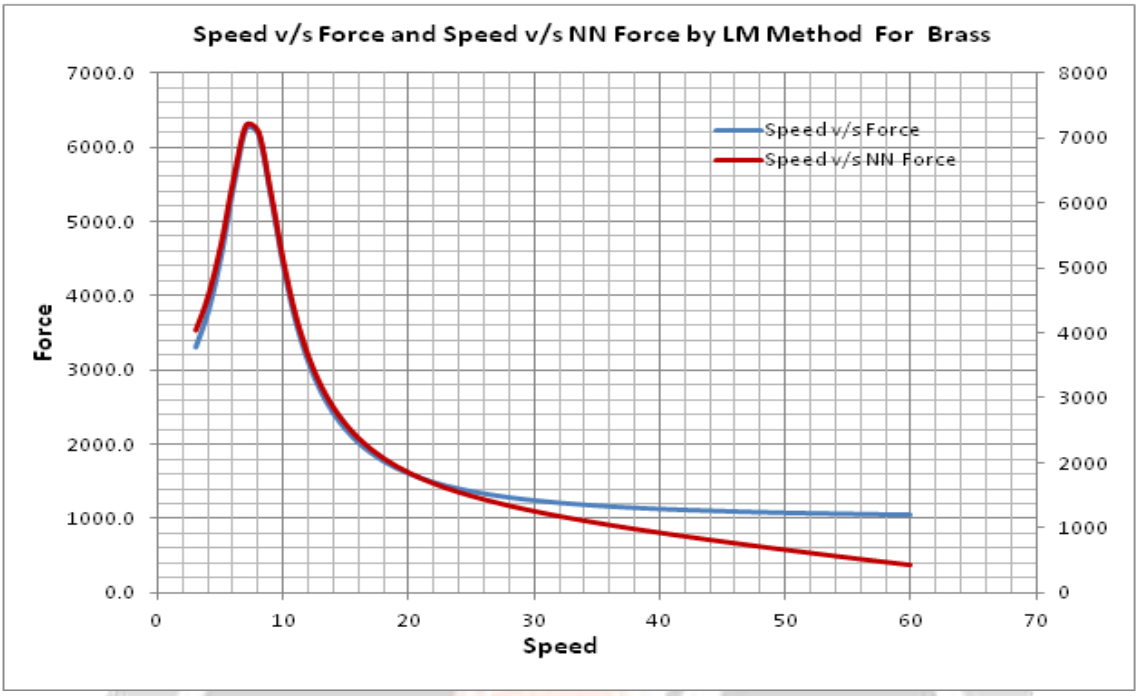
Graph 2 represents comparison between input speed v/s force and input speed v/s forecasted force by LM method for carbon steel



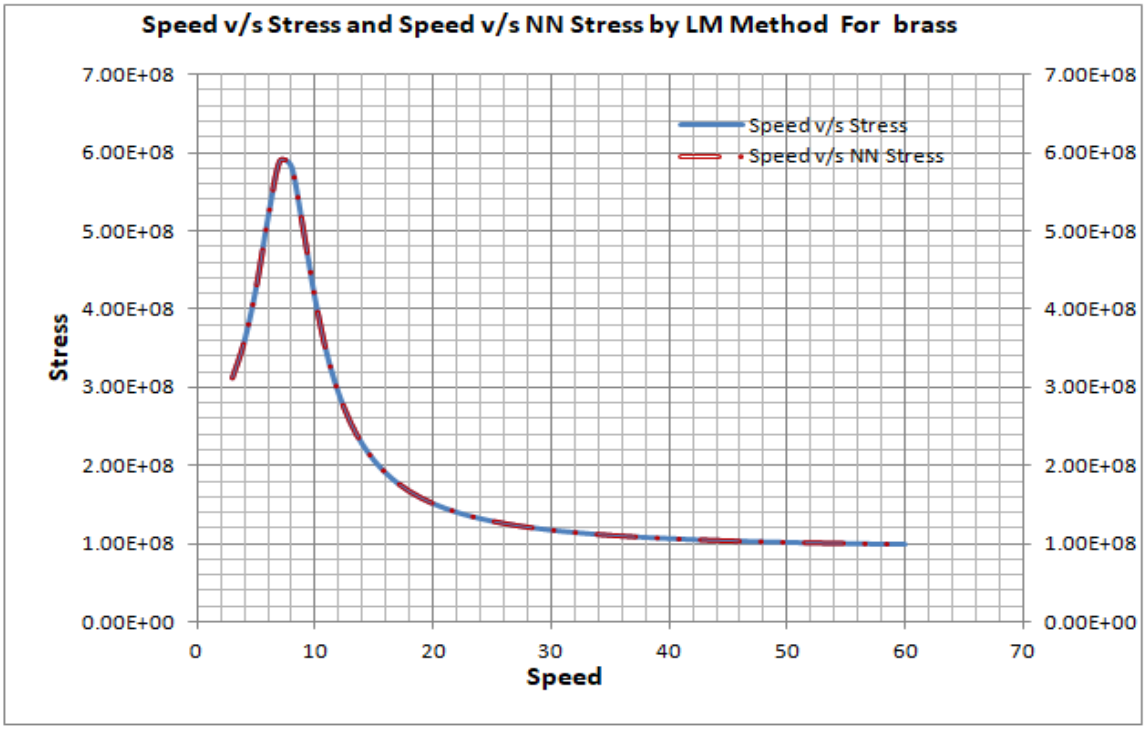
Graph 3 represents comparison between input speed v/s stress and input speed v/s forecasted stress by LM method for carbon steel



Graph 4 represents comparison between input speed v/s transmissibility and input speed v/s forecasted transmissibility by LM method for Brass



Graph 5 represents comparison between input speed v/s force and input speed v/s forecasted force by LM method for Brass



Graph 6 represents comparison between input speed v/s stress and input speed v/s forecasted stress by LM method for brass

Conclusion:

ANN forecasting methods gives almost the same results as obtained by the complex numerical calculations and can be used for more accurate design of a vehicles suspension system moreover it also saves time and money by reducing experimental setup cost by minimizing the testing on material of suspension system. It easily forecast the best available result in terms of material and calibration of vehicle suspension system. From the present work it is observed that out of LM, SCG and BR forecasting method the _____ method gives the best forecasting results.

Future Scope:

All present neural network technologies will most likely be vastly improved upon in the future. Everything from handwriting and speech recognition to stock market prediction will become more sophisticated as researchers develop better training methods and network architectures.

NNs might, in the future, allow:

- robots that can see, feel, and predict the world around them
- improved stock prediction and verification
- common usage of self-driving cars
- composition of music
- handwritten documents to be automatically transformed into formatted word processing documents
- trends found in the human genome to aid in the understanding of the data compiled by the Human Genome Project
- self-diagnosis of medical problems using neural networks and much more!

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