Neuro Fuzzy Study of Crack Growth Rate for a Vibrating Copper Cantilever Beam

J N Maht[1], S C Roy[2], R S Prasad[3], D Mishra[4]

[1, 2]*Department of Mechanical Engineering, BIT, Sindri, Jharkhand, India*

[3, 4]*Department of Mechanical Engineering, RKGIT, Ghaziabad, Uttar Pradesh, India*

ABSTRACT

Crack growth rate is an important criterion to predict life of a component and is very important in order to avoid costly and time consuming destructive testing. It provides prior warning to repair or replace the damaged machine parts in time so as to avoid catastrophic failure. But, it is obviously is a challenging job to the communities involved with vibration work because, the physical interpretation of damage due to vibration is quite ambiguous since it depends on several mechanisms. Further, there are so many factors responsible for the cracks to propagate when subjected to vibration. Therefore, formulation of a universal mathematical model for prediction of life of component in presence of crack growth rate to suit for all the situations is almost impossible. Recently, introduction of various softcomputing techniques in the field of vibration solves the above complex problems in a much better way. In the present investigation a vibrating Copper cantilever beam condition is simulated using ANFIS to develop a method to predict life.

Keywords:Neuro Fuzzy, Crack Growth Rate, Forced Vibration, ANFIS, Crack Propagation

1 INTRODUCTION

Crack position can be an important parameter to observe in a vibrating cantilever beam because; severity of crack in a component depends on location of crack. There are many critical components where it is important to know that till when it can serve without fail. Also it is very important that if there is a crack initiated then till when it can serve without fracture. Therefore, it is very important to know the effect of crack position, velocity of vibration, frequency of vibration and other parameters on the crack growth rate and in turn the life of a machine component in its working condition.

1.1Literature review

In the recent past, it has been observed that both crack location and crack depth has noticeable effect on the modal parameters of the cracked beam [1]. The transverse crack is also modelled in a beam as rotational spring having stiffness of negligible mass [2] andfor the computational convenience lumped mass matrix instead of consistent mass matrix is preferred. The effect of vibration is evident in the work of researchers for the applications of Wavelet Transformation to detect crack-like damage in structures [3][4].

Many methods involving algorithm- based programs such as Artificial Neural Network (ANN), Fuzzy-Logic, Adaptive Neuro-Fuzzy Inference System (ANFIS) Genetic Algorithm (GA) have been used in the fatigue crack growth estimation. ANFIS is the combination of ANN and Fuzzy Inference System (FIS) models. Each of the two models has their respective merits and demerits. However, ANFIS as an intermediate between the two, possess the merits of both the two models with none of their demerits [5]. Jarrah, Al-Assaf, and El Kadi[6] have used ANFIS for fatigue life detection in glassfiber/epoxy, their results show a good agreement with limited data set. Vassilopoulos and Bedi [7] in their work have been successfully applied multidirectional composite laminates while modelling fatigue life using ANFIS. Moreover, Nanda et.al [8] has used ANFIS for detecting cracks, their locations and sizes due to transverse loading. Mohanty andVerma[9][10] have applied ANFIS in case of mixed- mode overloads model-I to predict fatiguelife, using 7020T7 and 2024T3 Aluminium alloys. Crack propagation simulated with previously obtained experimental data may be more preferable in that under this situation, the fatigue tests are inexpensive, fast and non-complex in nature. It has proven to be a powerful and versatile soft-computing method which is quite efficient in modelling complicated linear and nonlinear relationships based on of experimental data in a number of engineering fields [11].

Chandrasekhar et al [12] has expounded a fuzzy logic system with a new sliding window defuzzifier for detection of crack signatories. They evaluated the relation between changes in frequency with change in material properties which helped them for developing a robust fuzzy model for detection of crack parameters. Studies, presented by Panigrahi et al [13] studied verifying microscopic fatigue crack in a uniform strength beam using Residual Force Method & Genetic Algorithm. A new formulation presented by Nanda et.al [14] for damage detection of a fixed shaft using MANFIS-GA hybrid controller.

II EXPERIMENTAL WORK

Experimental work specimens were prepared and crack was artificially generated on each specimen. Cracks with cross section 2mmx2mm, across the width of specimen were ground using horizontal grinding machine on a 500 mm long rectangular bar of cross section 50mmx 12mm as shown in Fig.1. Location of artificially generated cracks on the specimenwas 155mm from free end. A setup was fabricated and installed, to mount machined and heat-treated specimen. Specimen was processed through heat treatment process using automatic muffle furnace to ensure material properties to be isentropic. Fig.2 represents the block diagram of the experimental setup. Specimen positioned as a cantilever beam over a base made of bricks and cement. A vibration generating device (RMS Electro-magnetic vibration generators) was positioned below the beam to generate different frequency. Accelerometer (Triaxial accelerometer) was placed over the beam to observe the experimental values using vibration meter (Bruel&Kjaer 2511 Vibration Meter). Experiments were conducted to know crack growth rate(G) in micrometre/hrfor specimen with fixing

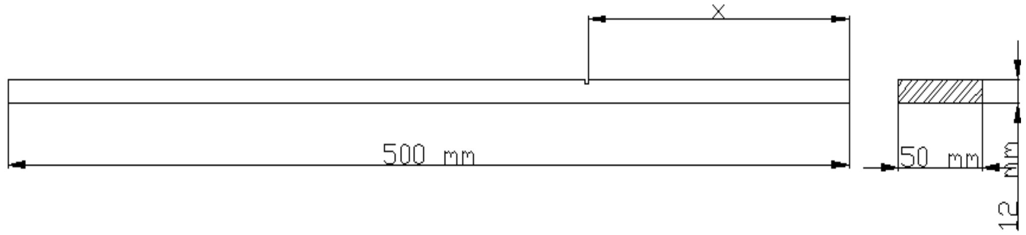


Fig.1. Specimen with a crack at a distance 'x' from free end

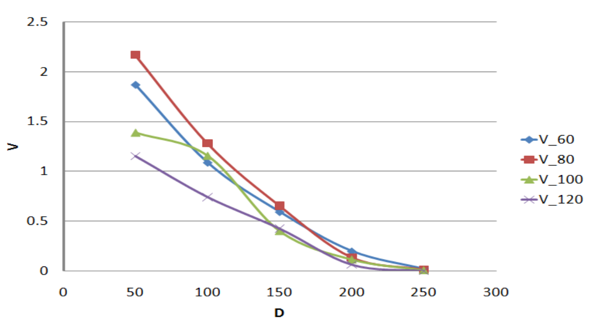


Fig.3.Velocity of Vibration along the beam from free end to fixed end for fixing length 400 mm and crack position 155 mm

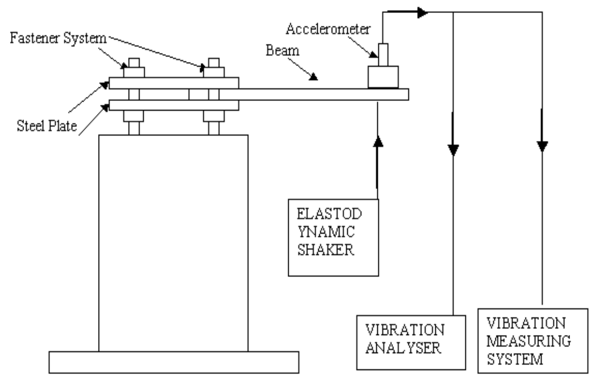


Fig.2. Block Diagram of Forced Vibration

length value of 400mm andposition of crack from free end at 155mm at different forcing frequency of vibration (F), velocity of vibration (V) and distance of accelerometer from free end (D). Total duration of observation was 150 hrs (approximately) and readings were taken every 2 hrs (approximately). The experimental results were plotted (using Microsoft excel) and are shown in the Fig.3 and Fig.4.

Further ANFIS was used to train and generate system model so that wider range of data can be generated and experimental work can be substituted.

III CRACK GROWTH RATE PREDICTION USING ANFIS

ANFIS (Adaptive Neuro Fuzzy Interface System) is an integrated system of Artificial Neural Network (ANN) and Fuzzy Inference System and it utilizes the advantages of both. The technique provide a method for the fuzzy modelling procedure to learn information about data set, in order to compute the membership function parameters that best allow the associated fuzzy inference system to track the given input-output data. ANFIS constructs an input-output mapping based on both human knowledge (in the form of fuzzy if-then rules) and simulated input output data pairs.

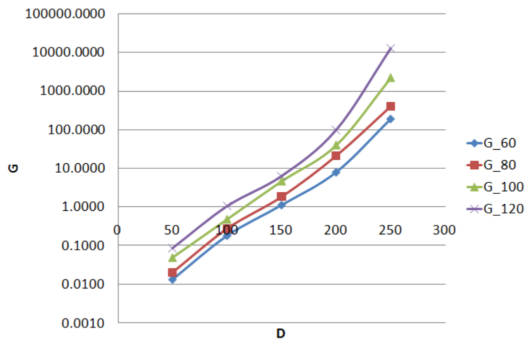
It serves as a basis for building the set of fuzzy if-then rules with appropriate membership functions to generate the input output pairs. The parameters associated with the membership functions are open to change through the learning process. The computation of these parameters (or their adjustment) is facilitated by a gradient vector, which provides a measure of how well the ANFIS is modelling the input output data for a given parameter set. Once the gradient vector is obtained, back-propagation or hybrid learning algorithm can be applied in order to adjust the parameters. Here, system has been trained using experimental data and further verification was done by comparing actual experimental results with the results obtained from the model.

In this work, forcing frequency (F), position of accelerometer from free end (D), velocity of vibration (V), position of crack (B), fixing length have been selected as input variables whereas, crack growth rate (G) has been taken as output variable. A set of linguistic rules formulated in the '*if-then*' form has been derived from expert observation and experimentation.

The ANFIS model has been built and trained based on the experimental data. The experimental data-base consists of the values of the input and out variables as described above. Details of which are shown in the Fig.5.

The model has been applied to simulate the crack growth rate of an unknown input/output data set.

The performance of ANFIS model as compared with actual experimental data are shown in Fig.6(a) to Fig.6(c). It clearly shows that ANFIS models result are in good agreement with the experimental data over entire range.



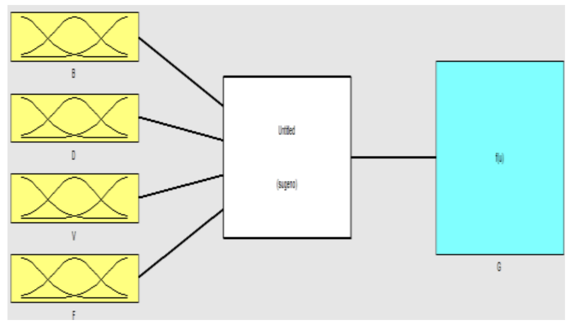
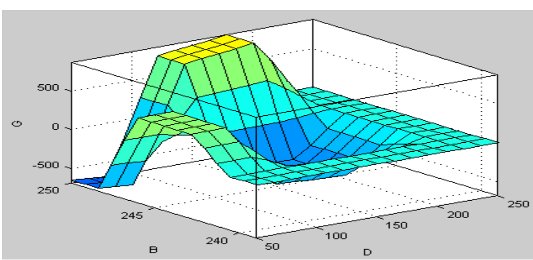


Fig.4. Crack Growth Rate along the beam from free end to fixed end for fixing length 400 mm and crack position 155 mm

Fig.5. Structure of ANFIS Model



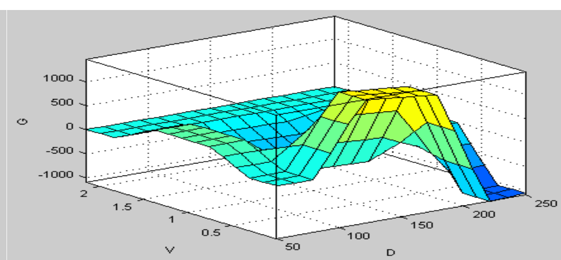


Fig.6(a). Plot using ANFIS Model for Bvs Crack Growth Rate

Fig.6(b). Plot using ANFIS Model for Position of Crack from Free End vs Crack Growth Rate

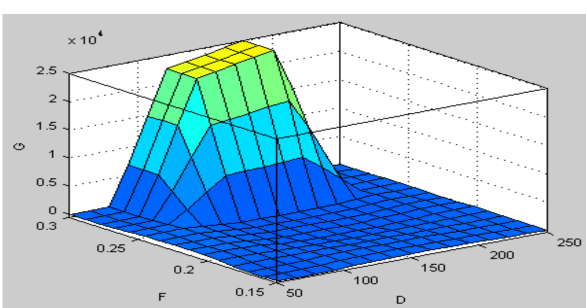


Fig.6(c). Plot using ANFIS Model for Forcing Frequency of Vibrationvs Crack Growth Rate

IV RESULT& DISCUSSION

Fig.3 and Fig.4 shows velocity of vibration and the crack growth rate for specimen with fixing length 400 mm and crack position 155 mm. It can be observed that crack growth rate increases from free end towards fixed end also it can be observed that crack growth rate increases with increase in the value of frequency of vibration. Change in the value of crack growth rate at any frequency is due to superimposition of frequency of vibration. Here in Fig.4 it can be observed that, at frequency of 80 Hz the value of G has a higher value than at 100 Hz.

In the present work, we have applied ANFIS to predict various Crack Growth Rate and effect of different parameters under the given loading condition. The performance of the proposed model was compared with the results of experimental data obtained for copper. It was observed that its prediction accuracy was quite close to the actual values of experimental values.

V. CONCLUSION

From plotted graphs it can be concluded that crack growth rate increases as frequency of vibration increases. It can also be observed that the value of forcing frequency of vibration and fixing length affects crack growth rate significantly. Further an ANFIS model was developed to predict the crack growth rate and the results were compared with actual experimental values. It was found that the ANFIS model results are in good agreement with the experimental data over entire range. As a future work, the above method can be successfully applied to determine the specific growth rate of the non-linear model which in turn may predict the life of vibrating component.

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