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Analysis of Smart Crack Detection Methodologies in Various Structures

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Abstract
This paper describes a comprehensive review of various technical papers in the domain of crack detection in Beam-Like Structure. Sensibility analysis of experimentally measured frequencies as a criterion for crack detection has been extensively used in the last decades due to its simplicity. However determination of crack parameters (like depth and location) is not straight forward. The various techniques discussed on the basis of dynamic analysis of Crack. The techniques mainly of fuzzy logic neural network, fuzzy system, hybrid neuro genetic algorithm, artificial neural network, artificial intelligence.
Keywords: *Neural network, fuzzy logic, genetic algorithm, artificial intelligence, cracks detection.*

INTRODUCTION

Since last few decades engineers and scientists are working on various techniques for detection of crack in the beamlike structure. The recent trends in crack detection in beam like structures are generally done by using fuzzy logic, neural network, artificial intelligence...etc. Some of the methods done by Researchers mentioned below: Das et al. (2009) have performed analytical studies on fuzzy inference system for detection of crack location and crack depth of a cracked cantilever beam structure using six input parameters to the fuzzy member ship functions. The six input parameters are percentage deviation of first three natural frequencies and first three mode shapes of the cantilever beam. The two output parameters of the fuzzy inference system are relative crack depth and relative crack location Experimental setup has been developed for verifying the robustness of the developed fuzzy inference system. The developed fuzzy inference system can predict the location and depth of the crack in a close proximity to the real results. Taghi et al. (2008) have proposed a method in which damage in a cracked structure was analyzed using genetic algorithm technique. For modeling the cracked- beam structure an analytical model of a cracked cantilever beam was utilized and natural frequencies were obtained through numerical methods. A genetic algorithm is utilized to monitor the possible changes in the natural frequencies of the structure. The identification of the crack location and depth in the cantilever beam was formulated as an optimization problem. (Bakhary et al., 2007) applied artificial neural network (ANN) for damage detection. In his investigation an ANN model was created by applying Rosenblueth’s point estimate method verified by Monte Carlo simulation, the statistics of the stiffness parameters were estimated. The probability of damage existence (PDE) was then calculated based on the probability density function of the existence of undamaged and damaged states. The developed approach was applied to detect simulated damage in a numerical steel portal frame model and also in a laboratory tested concrete slab. The effects of using different severity levels and noise levels on the damage detection results are discussed. Maity et al. (2004) have presented a method called damage assessment in structures from changes in static parameter using neural network. The basic strategy applied in this study was to train a neural network to recognize the behavior of the undamaged structure as well as of the structure with various possible damaged states. When this trained network was subjected to the measured response; it was able to detect any existing damage. The idea was applied on a simple cantilever beam. Strain and displacement were used as possible candidates for damage identification by a back propagation neural network and the superiority of strain over displacement for identification of damage has been observed.

Saridakis et al. (2008) applied neural networks, genetic algorithms and fuzzy logic for the identification of cracks in shafts by using coupled response measurements. In this research the dynamic behavior of a shaft with two transverse cracks characterized by three measures: position, depth and relative angle. Both cracks were considered to lie along arbitrary angular positions with respect to the longitudinal axis of the shaft and at some distance from the clamped end. A local compliance matrix of two degrees of freedom (bending in both the horizontal and the vertical planes) was used to model each crack.

Huijian Li et al. (2005) has presented a method for crack damage detection. In which he has used a combination of global (changes in natural frequencies) and local (strain mode shapes) vibration-based analysis data as input in artificial neural networks (ANNs) for location and severity prediction of crack damage in beam-like structures and also used finite element analysis to obtain the dynamic characteristics of intact and damaged cantilever steel beams for the first three natural modes.

Panigrahi et al. (2009) has firstly formulate of an objective function for the genetic search optimization procedure along with the residual force method are presented for the identification of macroscopic structural damage in an uniform strength beam. Two cases have been investigated here. In the first case the width is varied keeping the strength of beam uniform throughout and in the second case both width and depth are varied to represent a special case of uniform strength beam. The developed model requires experimentally determined data as input and detects the location and extent of the damage in the beam. Here, experimental data are simulated numerically by using finite element models of structures with inclusion of random noise on the vibration characteristics.

Suh et al. (2000) have presented a method to identify the location and depth of a crack on a structure by using hybrid neuro-genetic technique. Feed-forward multi-layer neural networks trained by back-propagation are used to learn the input (the location and depth of a crack)–output (the structural eigen frequencies) relation of the structural system. With this trained neural network, genetic algorithm is used to identify the crack location and depth minimizing the difference from the measured frequencies. Huai Chou et al. (2001) stated that, the problem is initially formulated as an optimization problem, which is then solved by using genetic algorithm (GA). Static measurements of displacements at few degrees of freedom (DOFs) are used to identify the changes of the characteristic properties of structural members such as Young's modulus and cross-sectional area, which are indicated by the difference of measured and computed Responses. In order to avoid structural analyses in fitness evaluation, the displacements at unmeasured DOFs are also determined by GA. The proposed method is able to detect the approximate location of the damage.

CRACK DETECTION USING ARTIFICIAL INTELLIGENCE TECHNIQUES

Crack detection in various classical methods as well as finite element method has been discussed in various papers. In this paper different types of Artificial Intelligence Techniques adapted by researchers in the domain of crack detection in damaged structures are reviewed briefly.

Neural network method for fault diagnosis of cracked cantilever beam

Das et al. (2009) have performed an analytical studies by on fuzzy inference system for detection of crack location and crack depth of a cracked cantilever beam structure using six input parameters to the fuzzy member ship functions. The six input parameters are percentage deviation of first three natural frequencies and first three mode shapes of the cantilever beam. The two output parameters of the fuzzy inference system are relative crack depth and relative crack location Experimental setup has been developed for verifying the robustness of the developed fuzzy inference system. The developed fuzzy inference system can predict the location and depth of the crack in a close proximity to the real results.

Dynamics of structures with crack has been studied for last four decades intensively. Natural frequencies and modes shapes undergo variation due to presence of crack. The deviations of natural frequencies and modes shapes mainly dependant on location and intensity of the crack. Scientists are focusing their thoughts to find out the damage location and its intensity. The investigations reported in this regards are jotted below. Measurement of flexural vibrations of a rectangular cross-section canti- lever beam having a transverse surface crack extending uniformly along the width of the beam and analytical results are used to relate the measured vibration modes to the crack location and depth (Rizos et al., 1990). From the measured amplitudes at two points of the structure vibrating at one of its natural modes, the respective vibration frequency and an analytical solution of the dynamic response, the crack location can be found and depth can be estimated with satisfactory accuracy. The method of crack localization and sizing in a beam can be obtained from free and forced response measure-ments (Karthikeyan et al., 2007).

A method using singular value decomposition is developed to handle the ill-conditioned system equations that occur in the experimental investigation by using the measured natural frequencies of the modified structure. An extensive study has been done on diagnosis of fracture damage in structure (Akgun et al., 1983). The concept of 'fracture hinge' is developed analytically and the same is applied to a cracked section for detecting fracture damage in simple structures. It is experimentally verified that the structural effect of a cracked section can be represented by an equivalent spring loaded hinge.

Artificial neural networks (ANN) can be used as an alternative effective tool for solving the inverse problems because of the pattern-matching capability (Sahoo et al., 2007). The results of ANN are quite encouraging and prove the robustness of the proposed damage assess- ment algorithm. The fault detection model is developed by using two different artificial neural network approaches, namely feed forward network with back propagation algorithm and binary adaptive resonance network (ART1). The performance of the developed back propagation and ART1 model is tested for a total of seven categories of faults in the centrifugal pumping system. The modal frequency parameters for the flexural vibration of a cantilever beam having a transverse surface crack are analytically computed for various crack locations and depths using a fracture mechanics based crack model (Suresh et al., 2004). The computed modal frequencies are used to train a neural network to identify both the crack location and depth. This modular neural network architecture can be used as a non-destructive procedure for health monitoring of structures. A damage detection algorithm has been developed using a combination of global (changes in natural frequencies) and local (curvature mode shapes) vibration based analysis data as input in artificial neural networks (ANNs) for location and severity prediction of damage in beam- like structures (Sahin et al., 2003). The trained feed-forward back propagation ANNs using the data obtained from the experimental damage case for quantification and localization of the damage is tested. Das et al. (2009) has proposed a new methodology for prediction of crack intensity and its location using neural network technique.

Genetic algorithm method for fault detection in beam-like structures

Taghi et al. (2008) have proposed a method in which damage in a cracked structure was analyzed using genetic algorithm technique. For modeling the cracked-beam structure an analytical model of a cracked cantilever beam was utilized and natural frequencies were obtained through numerical methods. A genetic algorithm is utilized to monitor the possible changes in the natural frequencies of the structure. The identification of the crack location and depth in the cantilever beam was formulated as an optimization problem.

Beams are common structures used to carry and Transfer high loads in machines and civil structures, and cracks are the main cause of structural failure. Sudden failure during high load operation could be disastrous, thus early crack detection is important. Non-destructive inspection techniques are generally used to investigate the critical changes in the structural parameters, so that an unexpected failure can be predicted. Damage can be detected, quantified and localized by on-line damage assessment techniques, through measuring vibration parameters, which indicate the global conditions of the structures. In general a crack causes a reduction in the stiffness and an increase in the damping of the structure.

These changes of physical properties cause a reduction in the natural frequencies and a deviation of the mode shape. Therefore, it is possible to predict the location and the depth of a crack by measuring changes in the vibration parameters. Changes in the natural frequencies are used more often than deviation of mode shapes, since frequencies can be measured more easily than mode shapes, and they are less seriously affected by experimental errors (Morassi et al., 2001). Taghi et al. (2008) have proposed a GA-based procedure for esti- mating crack location and depth in an aluminium beam is described and some guidelines for selecting the GA parameters are presented. The damage effect is modelled as a torsional spring (Rizos et al., 1990), and to develop the equations of the motion of the cracked beam the Hamilton's principle is used. Then the eigenvalue problem is solved to obtain the natural frequencies of the beam. Another way for evaluating the natural frequencies of a cracked beam is based on the use of the finite elements method (Rizos et al., 1990), but it is less accurate than a continuous model which is used in this paper. The identification of crack location and depth in a cantilever beam is formulated as an optimization pro- blem, and the binary and continuous genetic algorithms (BGA, CGA) are used to find the optimal location and depth by minimizing the cost function which is based on the difference of measured and calculated frequencies. In comparison with traditional GAs a GA with small population size combined with large mutation rate is used, so the great exploration of the search space is achieved with a small number of cost function evaluations. We iterate the GA from five different initial points (variables) and choose the best answer and in this way the rate of success in finding the global minimum instead of a local one is increased. In order to compare CGA to BGA we have implemented a set of test points. Both GAs have equal population size and maximum number of iterations. The variables in BGA are represented by a total of 21 bits, while in CGA there is no need to convert the variable values. The obtained results demonstrate higher accuracy of the CGA over the BGA. The various process used in GA as follows:

1. Selecting the variables and cost function
2. The gene size

3. Initial population
3. Cost evaluation
4. Selection
5. Reproduction
6. Mutation
7. Re-evaluating the costs and iterating the algorithm.
8. Stopping criteria (Based upon fitness function)

Artificial neural network method for fault detection using with consideration of uncertainties

Bakhary et al. (2007) applied Artificial Neural Network for damage detection. In his investigation an ANN model was created by applying Rosenblueth's point estimate method verified by Monte Carlo simulation, the statistics of the stiffness parameters were estimated. The pro- bability of damage existence (PDE) was then calculated based on the probability density function of the existence of undamaged and damaged states. The developed approach was applied to detect simulated damage in a numerical steel portal frame model and also in a laboratory tested concrete slab. The effects of using different severity levels and noise levels on the damage detection results are discussed.

Artificial Neural Networks (ANN) have been utilized by many researchers to identify damage location and severity from various types of input and output variables, as they provide an efficient tool for pattern recognition. Wu et al. (1992) explored the use of an ANN to detect member damage in a 3-storey frame. Pandey et al. (1995) provided a more detailed treatment of ANN architecture in their study identifying damage in a 21-bar bridge truss. Zhao et al. (1998) applied a counter-propagation neural network to detect damage and support movement in a continuous beam. Zapico et al. (2001) developed a procedure for damage assessment of steel structures based on ANN. Most of the studies concluded that ANNs are capable of providing correct damage identification, especially when the structural damage and the associated changes in vibration properties are simulated numerically and are error free. However, in practice uncertainties in the FE model parameters and modelling errors are inevitable. The existence of modelling error in the FE model due to the inaccuracy of physical parameters, non-ideal boundary conditions, finite element discretization and nonlinear structural properties may result in the vibration parameters generated from such a FE model not exactly representing the relationship between the modal parameters and the damage parameters of the real structure. On the other hand, the existence of measurement error in the measured data that is normally used as testing data in an ANN model is also unavoidable.

Since the efficiency of an ANN prediction relies on the accuracy of both components, the existence of these uncertainties may result in false and inaccurate ANN Predictions. Therefore, the impact of uncertainties on the reliability of ANN models for structural damage detection needs to be analyzed. The objective of this paper is to study the influence of uncertainty on damage identify-cation using a combination of frequency and mode shape as the input variables. To consider the uncertainties in the FE modelling and the measurement data, an approach introduced by Papadopoulos et al. (1998) is applied. Using this method, the probability of damage existence (PDE) can be estimated by comparing the probability distribution of the undamaged and damaged models. To consider the effect of FE modelling error, a statistical ANN model is trained with vibration data generated from the FE model, but smeared with random variations. To include the effect of noise in the measurement data, the testing data used as input to the statistical ANN model for damage identification are also smeared with random noises.

The probability moments of the undamaged and damaged states of the structural parameters are esti-mated using the point estimation method and verified by Monte Carlo simulation. The Monte Carlo simulation data is also used to determine the type of probability distribution function of the structural parameters of both the undamaged and damaged states. The PDEs are determined from the probability distribution for each structural member.

Damage assessment in structure from changes in static parameter using neural networks

Maity et al. (2004) have been presented a method called damage assessment in structures from changes in static parameter using neural network. The basic strategy applied in this study was to train a neural network to recognize the behavior of the undamaged structure as well as of the structure with various possible damaged states. When this trained network was subjected to the measured response; it was able to detect any existing damage. The idea was applied on a simple cantilever beam. Strain and displacement were used as possible candidates for damage identification by a back propagation neural network and the superiority of strain over displacement for identification of damage has been observed.

The objective of the above method is to locate and assess the damage occurring at any position in a cantilever beam by back-propagation neural network considering displacement and strain as input parameter to the network. The approach here consists of three sub- processes. Firstly, by varying the model parameters of the structure, their corresponding response to the system is calculated through the finite element method. Secondly, a neural network is iteratively trained using a number of training patterns. Here, structural responses are given as input to the neural network, while parameters to be identified are shown to the network as desired data. Finally some structural responses measured are given to the well-trained network, which immediately outputs the appropriate value of parameters for untrained patterns. The model parameter taken here is the EI value of the structural member and the structural responses are displacement and strain for a comparison of the performance of the damage assessment algorithm.

Vibration based damage detection in a uniform strength beam using genetic algorithm

Panigrahi et al. (2009) firstly formulated an objective function for the genetic search optimization procedure along with the residual force method presented for the identification of macroscopic structural damage in an uniform strength beam. Two cases have been investi- gated here. In the first case the width is varied keeping the strength of beam uniform throughout and in the second case both width and depth are varied to represent a special case of uniform strength beam. The developed model requires experimentally determined data as input and detects the location and extent of the damage in the beam. Here, experimental data are simulated numerically by using finite element models of structures with inclusion of random noise on the vibration characteristics.

In this paper the authors used roulette wheel selection criteria for damage identification of uniform simple supported beam as well as for cantilever beam. Fault classification has been done for cylindrical shells with auto associative neural network along with GA in reference (Marawala et al., 2006). As compared with the traditional optimization and search algorithms, GA search from a population of points in the region of the whole solution space, rather than a single point, and can obtain the global optimum. Other advantages of using GA are that it is a self-start method with no special requirement on the initial value of unknown parameters, other than defining a search range, and also it does not need information such as gradients or derivatives of the function to be minimised.

Moreover, GA has the advantage of easy computer implementation. These properties make GA successful and powerful in the field of structural optimization (Rajasekaran et al., 2003). Genetic algorithm (GA) has been established which may be used intelligently to identify and quantify the damage in a uniform strength beam. Rao et al. (2004a, b) have used this procedure for uniform cantilever beam, truss structures and portal frames. Panigrahi et al. (2007) addressed the problem of damage identification in a cantilever beam with uniform thickness only by changing the selection methods in GA. Here GA along with residual force vector method has been used for damage identification of a uniform strength beam with variation of depth along its length and another case with both width and depth varying. In the present paper, first the concept of residual force vector is intro- duced to specify an objective function for an optimization procedure, which is then solved by using G.A. The aim is to formulate an objective function in terms of parameters related to the physical properties and state of the structure. The objective function must be formulated in such a way that the minimum or null value is obtained when evaluated with true parameters of the structure. Here the parameters used are the damage factors which are nothing but the reduction in stiffness factor. GA is employed to determine the values of these parameters by following an iteration process. In this study a method known as steady-state selection is selected for reproduction purpose in GA which requires less number of iterations (Michalewicz, 1994).

The main idea of the selection is that bigger part of the chromosome should survive to next generation. When the objective function is optimized, values of the parameters indicate the state of the structure. Two cases have been investigated in this study. In the first case, a uniform strength beam with inclusion of slope function in width has been discussed. The second case demonstrates this method with inclusion of slope functions for both the depth and width of the beam. For simulating the experimental measure-ment, the vibration characteristics viz. natural frequencies and the mode shapes were perturbed randomly. A computer program using MatLab is employed to find out the location and extent of the damage.

Crack identification by the method of hybrid neuro-genetic technique

Suh et al. (2000) have presented a method to identify the location and depth of a crack on a structure by using hybrid neuro-genetic technique. Feed-forward multi-layer neural networks trained by back-propagation are used to learn the input (the location and depth of a crack)–output (the structural eigen frequencies) relation of the structural system. With this trained neural network, genetic algorithm is used to identify the crack location and depth minimizing the difference from the measured frequencies. The use of neural networks in detecting the damage has been developed for several years, because of their ability to cope with the analysis of the structural damage without the necessity for intensive computation. Recently, neural networks are expected to be a necessity for intensive computation.

Recently, neural networks are expected to be a potential approach to detect the damage of the structure (Furukawa et al., 1995). In these researches, both the modal frequencies and the modal shapes are needed for the training of neural network to detect the structural damage, since the frequency information alone is not sufficient to train the neural network for the inverse problem of the crack identification. To identify the location and depth of a crack in a structure with only frequency information, a method is presented in this paper which uses hybrid neuro-genetic technique.

Feed-forward multi-layer neural networks trained by back-propagation are used to learn the input (the location and depth of a crack)-output (the structural eigen frequencies) relation of the structural system. With this trained neural network, genetic algorithm is used to identify the crack location and depth minimizing the difference from the measured frequencies. This approach needs only the modal frequencies for use of hybrid neuro-genetic techniques.

FUNDAMENTAL STRUCTURE OF THE GENETIC ALGORITHM

There is preparation phase and application phase. In the preparation phase, firstly, the learning data of various sets of crack parameters and the corresponding response of the structure, which is the eigen frequency in this study, are prepared by the computational structure analysis. Figure 1 shows the various processes involved in genetic algorithm.

t=0;
Initialize P(t);
do
Crossover P(t);
Mutate P(t);
Evaluate P(t);
Select P(t);
t=t+1;
While terminal condition is not satisfied

Figure 1. Process of Genetic Algorithm

Fuzzy-genetic algorithm and Fuzzy inference method

In this Various fuzzy inference and fuzzy-genetic algorithm methods followed for crack identification are outlined.

Pawar et al. (2007) have used a genetic fuzzy system to identify the crack depth location in a composite matrix cracking model. As described by him the genetic fuzzy system combines the uncertainty characteristics of fuzzy logic with the learning ability of genetic algorithm and observed that the success rate of the genetic fuzzy system in the presence of noise is dependent on crack density. He has found that the genetic fuzzy system shows excellent damage detection ability even in the presence of noise data.

Das et al. (2008) have proposed a fuzzy inference system for detection of crack location and crack depth of a cracked cantilever beam using the percentage deviation of first three natural frequencies and first three mode shapes by the fuzzy member ship functions. The two output parameters of the fuzzy inference system are relative crack depth and relative crack location. The vibration signatures are used to derive the fuzzy rules and experimental setup has been developed for verifying the robustness of the developed fuzzy inference system. Wada et al. (1991) have proposed a fuzzy control method with triangular type membership functions using an image processing unit to control the level of granules inside a hopper. He has stated that the image processing unit can be used as a detecting element and with the use of fuzzy reasoning methods good process responses are

Fox et al. (1977) have studied the use of fuzzy logic in medical diagnosis and raised a broad range of issues in connection to the role of information-processing techniques in the development of medical computing.

Lo et al. (2007) have developed an intelligent technique based on fuzzy-genetic algorithm (FGA) for automatically detecting faults on HVAC system. The proposed automatic fault detection system (AFD) monitors the HVAC system state continuously by fuzzy system and the optimization capability of genetic algorithms allows the generation of optimal fuzzy rules. As stated simulation studies are conducted to verify the proposed automatic fault detection (AFD) system for the single zone air handler system.

Parhi et al. (2008) have addressed the fault detection of cracked beam using AI technique. In this work fuzzy controller has been used to find out the relative crack depth and relative crack location of the cracked beam. The input parameters to the fuzzy controller are percentage deviation of first three relative natural frequencies and first three relative mode shapes differences. The fuzzy rules are set up with the help of natural frequencies, mode shapes, crack depths and crack location. The output from fuzzy controller has been experimentally validated in this work.

Zimmermann et al. (1978) has applied fuzzy linear programming approach for solving linear vector maximum problem. The solutions are obtained by fuzzy linear programming. These are found to be efficient solutions then the numerous models suggested solving the vector maximum problem.

DISCUSSION

The neural network technique has been discussed for detection of the relative crack location and relative crack

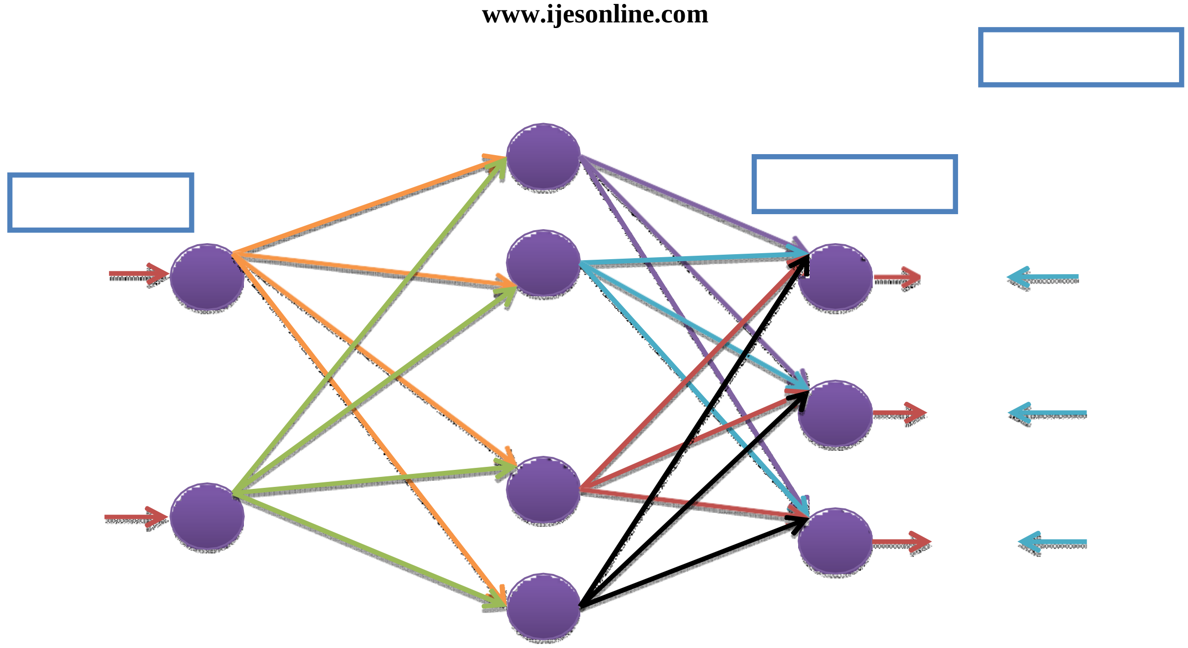

Figure 2. Three layer Neural Network utilized in this study.

depth. The neural network has got six input parameters and two output parameters. The structure of the neural network has been shown in Figure 2. The inputs to the neural network are as follows;

Relative first natural frequency = “fnf”; relative second natural frequency = “snf”; relative third natural frequency = “tnf”; relative first mode shape difference = “fmd”; relative second mode shape difference = “smd” and relative third mode shape difference = “tmd”.The outputs from the neural network are as follows; Relative crack location = “rcl” and Relative crack depth = “rcd”.

The back propagation neural network has got ten layers (that is, input layer, output layer and eight hidden layers). The neurons associated with the input and output layers are six and two respectively. The neurons associated in the eight hidden layers are twelve, thirty-six, fifty, one hundred fifty, three hundred, one hundred fifty, fifty and eight respectively. The input layer neurons represent relative deviation of first three natural frequencies and first three relative mode shape difference. The output layer neurons represent relative crack location and relative crack depth. A genetic algorithm approach for detecting cracks in beam-like structures has been analyzed. The search process proposed in this method utilizes binary and continuous genetic algorithms to find the crack location and depth whose natural frequencies have maximum similarity with the input natural frequencies. Also a new cost function based on natural frequencies was presented. Some guidelines for selecting GA parameters are provided. In comparison with traditional GAs, we use a GA with small population size combined with a large mutation rate, so the great exploration of the search space with small number of cost function evaluation is achieved. A statistical ANN method gives a good value in that accounts for the inevitable FE modeling error and measurement noise for structural condition identification. Rosenblueth’s point estimation method is used to derive the statistical ANN model and to identify the structural condition. Both the modeling error and measurement noise are assumed to have normal distribution and zero means. The accuracy of the statistical approach was proved using Monte Carlo simulation. Using this method, the probability of damage existence can be estimated. The numerical and experimental results demonstrated that, compared with the normal ANN approach, the statistical ANN approach gives more reliable identification of structural damage. Condition monitoring tools like expert system, acoustic emission, shock pulse method and extended neuro-fuzzy schemes are proposed for a real time machinery condi- tion monitoring. The uses of various Artificial Intelligence (AI) methods for fault detection are discussed briefly. The genetic fuzzy system combines the uncertain characteristics of fuzzy logic with the learning ability of genetic algorithm which shows an excellent capability for damage detection even in the presence of noise data. The fuzzy technique can be used for fault detection by feeding the percentage deviation of first three natural frequencies and relative mode shapes as input parameters to the fuzzy controller. Fuzzy control method with triangular type membership functions and image processing unit can be used in a manufacturing environment for optimize the input and output parameters. Probabilistic neural network, artificial neural network, fuzzy proportional integral (PI), genetic algorithm, neuro fuzzy, evolution based fuzzy neural diagnostic can be used for fault diagnosis in mechanical and electrical machines. A computer code is developed in which structural response due to damage is carried out. The response data are fed into the network to determine the damage. It is observed that neural networks can successfully identify and calculate the amount of damage for both single and multiple element damage cases. The main advantage of a neural network is that response measurement is required only at a limited number of points.

CONCLUSION

In this paper different techniques and methodologies used for identification of crack in the domain of dynamic vibration of cracked structures have been comprehen- sively reviewed and their applications for damage detection have been described briefly.

Based on the current analysis, it has been noticed that other than conventional methods like classical, finite element method different Artificial Intelligence (AI) methods like genetic algorithm, neural network, and fuzzy inference technique are successfully used for calculation of damage severity that is the location and depth of the crack of cracked structures.

1. The finite element method has been used to find out the natural frequencies, and mode shapes of the cracked beam which are being used to locate the crack location and size.
2. The fuzzy controller has been used to find out the relative crack depth and relative crack location of the cracked beam.
3. The genetic controller has been used to find out the relative crack depth and relative crack location of the cantilever beam.
4. Some of the researchers have also applied neural network for crack identification in damaged vibrating structures like artificial neural network, hybrid neuro genetic technique.
5. In some of the analysis the fuzzy technique, neural network and genetic algorithm are applied in combination to detect depth and location of the damage.

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