# CRACK DETECTION AND LOCALIZATION IN A COMPOSITE SHAFT USING ML APPROACH - A REVIEW

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## ABSTRACT

Identification of crack depth and crack location is an area of concern for researchers across the world. This article presents a critical review of recent research done on crack identification and localization in rotary shaft using numerical and experimental modal analysis. Crack detection and localization in transmission shaft are very essential in various engineering applications. Excessive Vibrations in rotary shaft cause catastrophic failure of machine parts. To avoid catastrophic failure of rotary shaft it is required to recognize the damage in time. Experimental analysis is used to study the vibration characteristics of structures like natural frequency, damping and mode shapes. Natural frequency of rotary shaft can be obtained using the modal analysis method. Also artificial neural network can be used to identify crack depth and crack location. From the review of different research papers, it is observed that a lot of the research done on machine shaft with open transverse crack. Critical speed and natural frequency for known crack location and crack depth can be used to train an artificial neural network. With the help of artificial neural network crack location, and crack depth will be identified accurately.

***Keywords:*** *Crack Detection, Crack Identification, ML Approach, Artificial Neural Network.*

## I. INTRODUCTION

The present machine components are designed based on optimizing of multi-objectives such as high strength, more life, and least weight with minimum cost. Due to this they are flexible and subjected to a very high level of stresses. This leads to development of cracks in machine component. Crack is one of the major factors that lead to failure of a machine component. Also, Excessive Vibrations in machine shaft cause catastrophic failure of machine parts. Vibration reduction is a major concern in the industries for the safe and efficient functioning of all rotating machines. Vibration in the machine part increases due to crack generation and propagation in machine shaft. It is important to find out a crack depth and crack position accurately in the rotary shaft, to avoid catastrophic failure. In recent years, the dynamic behavior and diagnostic of cracked rotor have been gained momentum. Dynamic properties of rotor shaft such as natural frequency of vibration and critical speed get altered due to change in crack depth and crack location. Nowadays crack detection and localization has been a common topic among researchers to enhance the stability, durability and safety of mechanical component. A wide range of damage identification methods have been used in the mechanical engineering researches during last decades. Crack identification and localization in shaft are very crucial in various engineering applications such as ship propeller shafts. It is necessary to identify the damage in time; otherwise, there may be serious consequences like a catastrophic failure of the mechanical component. Identification of crack location and crack depth also helps in preventive maintenance activity.

**Types of cracks and importance of crack identification:**

Cracks in various configurations and severity can be developed on the shaft during the operation of rotating machines. These cracks are classified according to their direction with respect to the shaft axis and are called as transverse cracks, longitudinal cracks and slant cracks. The transverse crack has remained the most dangerous and important type of cracks, as the safety and the dynamic behavior of machines are significantly affected by its occurrence. This type of crack has been intensively investigated because; it is perpendicular to the rotational axis of the shaft and reduces the moment of inertia of the cross-section of shaft which leads to considerable changes in the dynamic behaviour of the system.

The presence of cracks in rotary machine shafts is one of the most dangerous and critical defects. They are caused by cyclic fatigue loads and manufacturing defects or high stress concentrations due to defects in the manufacturing process. If a crack propagates constantly and is not detected, sudden failure, may occur and finally lead to a catastrophic failure with enormous costs in down time, significant damage to equipment and potential injury to personnel. There are various non-destructive monitoring methods such as vibration testing, thermography, visual inspection, ultrasonic and process monitoring employed to diagnose and monitor the critical behaviour of rotary machines components during maintenance spells. Among those predictive maintenance methods, vibration testing is the very powerful non-destructive maintenance method used with maintenance programs.

## II. LITERATURE SURVEY

A.K. Jain (2016) et al. indentified the effect of location of crack position on stiffness of shaft [1]. M.J. Gomez (2016) et al. identified crack in rotary shaft combined wavelet packet transform with artificial neural network [2]. M.J. Gómez (2016) et al. experimented that wavelet packet transform energy analysis for location of crack in rotary shaft. It was indentified that wavelet packet transform energy rises as the crack grows [3]. A.A. Mohamed (2011) et al. identified variation in vibration signal with respect to crack propagation [4]. V. S. Kumar (2015) et al. identified displacement curve by changing distance of crack position from bearing support. It was observed that, there was maximum displacement when a crack was near to bearing support and minimum displacement at when it was away from bearing support [5]. K. Vigneshwaran (2014) et al. identified that by changing mode shapes position between the cracked & uncracked one, crack can be found. It was also experimented that there was a change of natural frequency of vibration due to the change of crack position [6]. A.R.Biswal (2016) et al. used Timoshenko beam theory to create a finite element model of a beam with crack. It was indentified that the amplitude of vibration depends on crack depth [7]. S. Das (2016) et al. observed crack depth and crack location by using Adaptive Nero Fuzzy Interface System (ANFIS). It was identified ANFIS gives more precise result as compared to theoretical method and finite element method [8]. M. Gomez, (2016) et al. used wavelet packet transform energy to create the crack detection method. This method is helpful for condition monitoring [9]. T.S.Kumar (2013) et al. observed frequency response analysis for composite beam. This technique gives a non-destructive method for identification of crack depth and crack position [10]. K.M. Saridakis (2008) et al. observed crack in a rotary shaft with an artificial neural network, fuzzy logic and genetic algorithm [11]. S.K. Singh (2014) et al. observed the crack depth and the crack position in a rotary shaft using slope discontinuity in elastic line of shaft [12]. J. Fernández-Sáez (2016) et al identified single crack detection in a simply supported beam by using natural frequencies [13]. H. Khorrami (2017) et al. observed the effect of the occurrence of the second crack on the dynamic performance of the system, by developing an analytical model of a shaft with two cracks [14]. C. Guo (2017) et al. observed variation in amplitude of vibration by using FFT analyzer. Detection of crack was carried out with the help of amplitude variation [15]. D. Gayen (2017) et al. created shaft with transverse crack and identified an effect of crack depth on critical speed and natural frequency [16]. D.K. Rao (2016) et al used Timoshenko beam theory to model functionally graded shaft. It was indentified that instead of conventional shaft functionally graded shaft was more suitable for rotating shaft subjected to high speed and heavy duty environments [17]. P. Stawiarski (2017) et al. carried out fatigue crack detection and localization using wave propagation technique [18]. D. Satpute (2017) et al observed that as natural frequency of vibration decreases with increasing depth of crack. With help of a change in natural frequency crack position can be found [19]. D.I.Sampio (2016) et al. identified that depth of crack greater than 5 percentages can be detected by using approximate entropy method [20]. A.P.Bovsunovsky (2018) et al. created new technique of vibration-based damage detection. Crack in shaft observed with the help of variation in shaft compliance [21]. P. Stawiarski (2017) et al. performed a relative study of proposed a simple analytical damage detection method and all damage detection method with the help of varying in shaft compliance due to the occurrence of crack [22]. J. Xiang (2008) et al. identified natural frequency of vibration of a shaft for different crack sizes. Error between practical natural frequency and analytical natural frequency of rotary shaft can be removed by using genetic algorithm [23]. E.H. Flaieh (2020) et al. observed that the shaft's natural frequencies are decreased as the crack depth is increased. The deviation between the neural network and finite element results was not significant, indicating that the designed ANN can confidently be used for predicting the natural frequencies of rotating systems [24]. Abhijjet H. Kekan (2019) et al. experimentally identified as a crack depth increases a critical speed of shaft and frequency of vibration of the shaft decreases [25]. M. J. Jweeg (2019) et. al observed natural frequencies in bending as well as in torsion by FEA and experimentally. Also the fundamental natural frequency decreases when the depth of cracks increases [26]. M.J. Gomez (2016) et al. identified wavelet packet transform energy by changing depth of crack. Wavelet packet transform energies used to identify depth of crack in rotary shaft by using artificial neural network [27]. D. Satpute (2017) et al identified natural frequency of vibration with the help of finite element analysis. The change in natural frequencies is a function of crack location and crack depth [28]. L Deng and R Zhao (2013) used hybrid techniques for vibration analysis method. Condition monitoring of rotor bearing system carried out by using vibration signal. Vibration analysis is carried out with the help of Local mean deformation technique and Fourier transform [29]. B James Prasad Rao (2016) et al. investigated composite hollow shafts for automobile. Failure analysis out with the help of maximum stress criteria and observed that the failure torque is well above the design torque [30]. D siano (2018) et al. performed spectral analysis based on Fast Fourier Transformer (FFT) of the vibrational signal. Artificial Neural Networks (ANN) applied for modeling system behavior based on NonLinear AutoRegressive (NLAR) approach [31]. V. S. Kumar (2015) et al. identified displacement curve by changing distance of crack position from bearing support. It was observed that, change in displacement curve as crack depth increases, there was maximum displacement when a crack was near to bearing support and minimum displacement at when it was away from bearing support [32]. R. Sino (2007) et al. developed a simplified homogenized beam theory (SHBT) to consider symmetrical and balanced stacking sequences. Prepared homogenized finite element model of composite shaft. Finite element model used to evaluate natural frequency and critical speed by changing stacking sequence, fiber orientation and transversal shear effect [33]. S. B. Arab (2017) et al. prepared new multi-layer finite element model of a rotating laminated shaft to obtained natural frequencies and critical speeds. By changing of stacking sequence and fiber orientation observed variation in critical speed and natural frequency. Author observed that fiber orientations, stacking sequences and shear normal coupling have a major influence on the dynamic behavior of functionally graded material shafts [34]. Alzbeta Sapietova and Vladimir Dekys (2015) used frequency spectram analysis for dynamical analysis of misalignment of rotating shaft processed by Fourier transformation [35]. A. Teter and J. Gauryluk (2016) determined natural frequencies and the corresponding modes of free vibrations with the help of finite element method. Experimental modal analysis carried out of composite blade with LMS analyzer [36]. M. T. Das and Ays Yilmaz (2018) identified experimentally and numerically and free vibration analyses of curved composite beams for various transverse crack depths and its locations cracks. Observed that natural frequency of vibration decreases as the crack depth increases depend on the crack position [37]. J. Yao (2016) et al. carried out new harmonic analysis approach of rotor shaft using FFT analyzer. New approach proposed to extract harmonic with discrete Fourier transform algorithm. Observed that this method is faster and more precise than both the DFT-based methods and the FFT-based methods to extract harmonic components of rotor shaft [38]. H. P. Phadtare and Barun Pratiher (2016) used time history and FFT analysis to determine the fundamental frequencies of rotating shaft with variation of shaft diameter. Excessive vibration avoided with the resonant conditions by understanding and realization operational zones of rotational speed of the shaft which occurred as the natural frequencies come closer to the frequency of the rotational speed. At high speed of rotational shaft bearing system observed the resonance behavior [39].

## III. PROPOSED METHODOLOGY

The major role of conducting an experimental analysis and FEA to get critical speed and natural frequency values of the rotary composite shaft. Experimental analysis and FEA is used to measure critical speed and natural frequency of vibration. Experimental analysis is to be carried out on rotary composite shaft to track the changing in vibration characteristics using FFT analyzer as shown in figure 1.

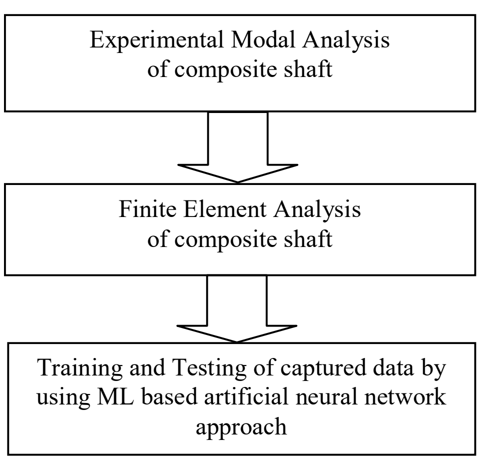


**Figure 1 Methodology for Proposed Work**

## IV. CONCLUSION

This paper focuses only on the literature review of previously published studies. From the review of various research papers, it is identified that change in vibration characteristics can be used as a tool to detect the catastrophic failure in the rotor shaft. Most of the researchers worked on transverse open cracks, on the other hand a small number of worked on inclined cracks. It has been identified that many have studied the effect of crack position, depth, and crack orientation on the critical speed and natural frequency of shaft. Most of the researchers used the three natural frequencies of the rotor shaft, fuzzy logic and artificial neural networks to detect the crack depth and crack position. It is observed that lot of work done to predict the residual life of rotar shaft by FEA, numerical and experimental modal analysis.

## V. FUTURE SCOPE

1. Investigate the identification and location of cracks of various depths at different location along the shaft through simulations and experimental analyses.
2. The effect of crack depth and relative crack positions on dynamic behaviors of composite shaft and steel shaft.
3. Determine natural frequencies of composite shaft by experimental modal analysis when crack depth varies.
4. Create logic for five natural frequencies as an input to ML based ANN (Artificial Neural Network) give very precise prediction of crack depth and its location as comparison to three natural frequencies.

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