PREDICTION OF CRACKS PRESENT IN THREE-WHEELER FRONT AXLES

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The risk of accidents due to mechanical failures of vehicles is a significant concern. Failures in the steering or braking system can pose a significant life threat to both pedestrians and passengers. The number of three-wheelers on the road has increased drastically in the recent past and the inherent design features of the three-wheeler itself pose a high risk. Especially the single wheel in front is of significant concern. The front wheel axle of a three-wheeler refers to the shaft connecting the front wheel and is responsible for supporting the weight of the vehicle. The front wheel axle is typically designed to withstand the forces and stresses encountered during normal operation with a significant safety factor. Factors such as poor maintenance, overloading, rough roads, or manufacturing defects can lead to the initiation of cracks and subsequent fatigue failures. Regular inspection, proper maintenance, and adherence to load limits are essential for ensuring the safety and integrity of the Three-wheeler's front wheel axle.

This research aimed to develop an advanced system that can accurately predict potential damages in the front wheel axles of three-wheelers before they propagate to a critical length that may cause a sudden final failure. It is expected to minimise accidents caused by front wheel axle failures thereby reducing the risk to passengers, drivers, and pedestrians by implementing this early prediction system.

Since the primary sources of acoustic emissions are damage-related, the detection and monitoring of these emissions are commonly used to predict and estimate material failures. An experimental setup was designed and developed. The setup consists of a holder, to which a wheel hub could be mounted, a hammer which would generate an acoustic signal with a consistent constant amount of energy for each repetitive experiment. The acoustic emission was captured utilizing a microphone and a digital recorder. In this particular application, a smartphone was used for recording. The signal obtained in the time domain was converted to the frequency domain through MATLAB software.

The fundamental frequency for metallic components is typically in the range of 100 kHz to 1MHz, and when cracks are present in shafts, the amplitude of harmonics of the fundamental frequency may become predominant. In the experimental investigation, harmonics were observable in all three experiments. As the crack length increases, the amplitude of harmonics also increases. A predominant frequency of around 5500 Hz could be observed. The variation of the peak amplitude with the corresponding crack length relationship can be used to develop a machine learning algorithm, in order to predict cracks present in wheel hub shaft without dismantling.

Keywords: Pedestrian safety, Three wheeler front axle, Prediction, Maintenance

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INTRODUCTION

The risk of accidents due to failures in three-wheeler is a significant concern. Failures in critical components like the front wheel axle can lead to loss of control, instability, and potential accidents, posing risks to the safety of passengers, drivers, and pedestrians on the road. The front wheel axle of a three-wheeler refers to the shaft connecting the front wheels. It is responsible for transmitting power from the engine to the wheels and supporting the weight of the vehicle. The front wheel axle is typically designed to withstand the forces and stresses encountered during normal operation. However, factors such as poor maintenance, overloading, rough roads, or manufacturing defects can lead to failures like bending or breaking of the front wheel axle. These failures can compromise the vehicle's stability and control, increasing the risk of accidents. Figure 1 depicts a typical front wheel axle that has been broken while in operation. Regular inspection, proper maintenance, and adherence to load limits are essential for ensuring the safety and integrity of the three-wheeler's front wheel axle. The failure of a three-wheeler's front wheel axle, such as bending or breaking, poses a significant risk of accidents. It can result in loss of control, sudden veering, and potential rollovers, endangering the passengers and others on the road. Timely maintenance and inspection are crucial for safe operation.

Figure 1 - a typical front wheel axle that has been broken while in operation

The aim of this research was to develop an advanced system that can accurately predict potential damages in the front wheel axles of three wheelers before they propagate to a final failure. By implementing this early prediction system, the project aims to enhance road safety by minimizing accidents caused by front wheel axle failures, thereby reducing the risk to passengers, drivers, and pedestrians.

METHODOLOGY

Crack initiation occurs at the microstructural level, the most robust analytical models may not predict crack initiation accurately due to the random distribution of inclusions and flaws. Small cracks originating at these defects propagate and converge on the machined surface of the notch over many cycles before becoming visible (Gupta and Ray 2009).

Acoustic emissions are the stress waves that are produced due to sudden redistribution of the stress inside the material structure. Some of the possible causes of the changes in the internal structure of the material can be dislocation movement, crack initiation and growth, and crack opening and closure. Since the primary sources of acoustic emissions are damage-related, the detection and monitoring of these emissions are commonly used to predict and estimate material failure. As such, the acoustic emission technique is commonly used to monitor defects and causes of failures in structural materials. (Gupta and Ray 2009).

The traditional analysis methods using acoustic emission technique include monitoring the acoustic-emission counts, the peak levels, and the energy of the signal. These parameters are used for correlation with the defect formation mechanisms and for providing a quantified estimate of faults. Acoustic emission technique has been investigated by several researchers for early detection of fatigue and fracture failures of materials (Bassim et al 1994) and (Huang et al 2020). The acoustic emission technique has also been widely used for the detection of faults or leakage in pressure vessels, tanks, and piping systems and for monitoring the welding and corrosion progress in materials. One of the advantages here is that acoustic emissions are sensitive to the activities occurring inside the material microstructure. Moreover, acoustic emission sensors are compact and can be easily mounted on the surface of a specimen being examined for online testing and continuous monitoring of evolving damage. The major drawback of the acoustic emission technique is that the acoustic emission signals are usually very weak and give poor performance in noisy environments where signal-noise separation becomes a difficult task.

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RESULTS AND DISCUSSION

An experimental setup was designed and developed as shown in Figure 2. The setup consists of a holder, to which a wheel hub could be mounted, and a hammer which would generate an acoustic signal with consistent constant amount of energy for each repetitive experiment. The acoustic emission was captured utilizing a microphone and a digital recorder. In the particular application, a smartphone was used for recording.

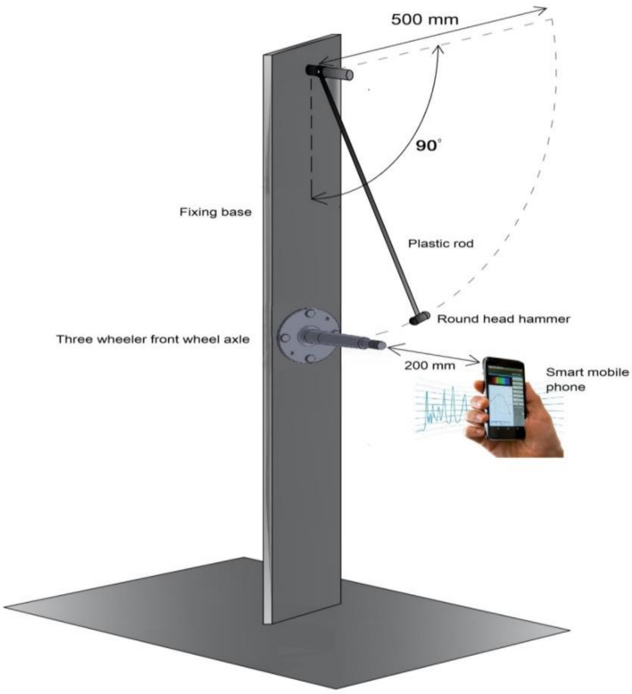

Figure 2 – Experimental setup

The signal obtained in the time domain was converted to the frequency domain using MATLAB software. The results for the condition without a crack, a 4 mm crack and a 9 mm crack are presented in Figure 3, Figure 4 and Figure 5 respectively.

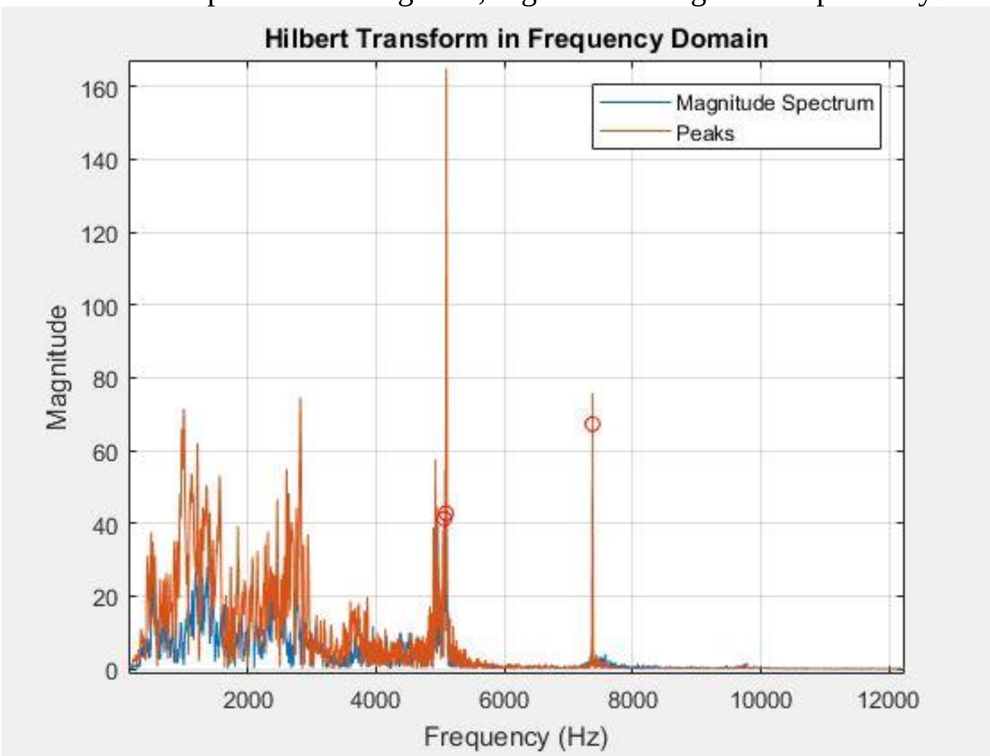

Figure 3: Frequency domain for axle without any defect

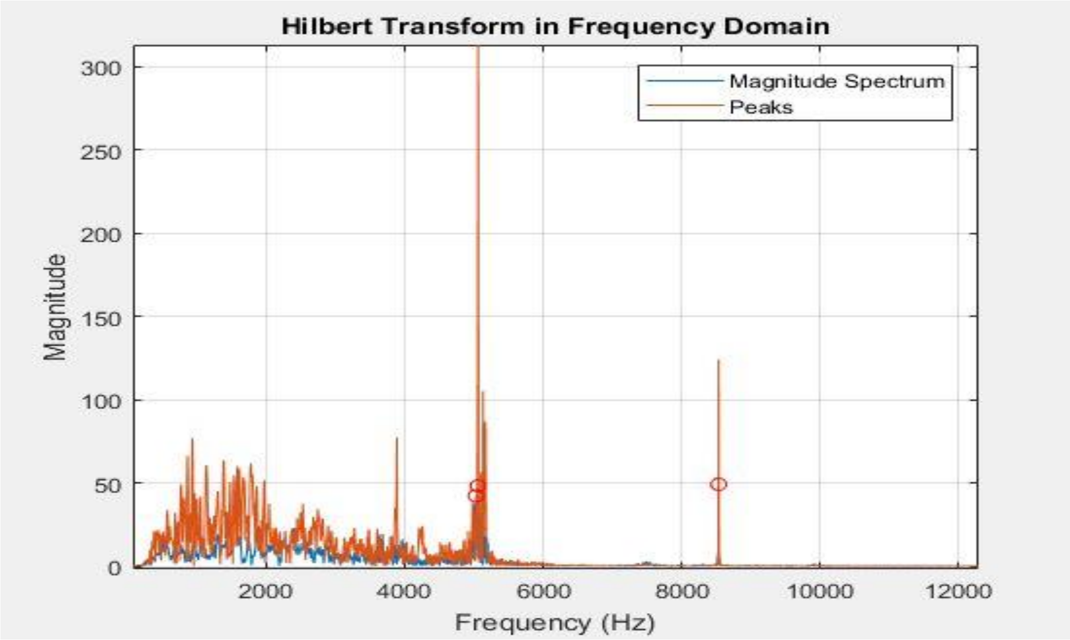

Figure 4- Frequency domain for axle with 4mm depth defect

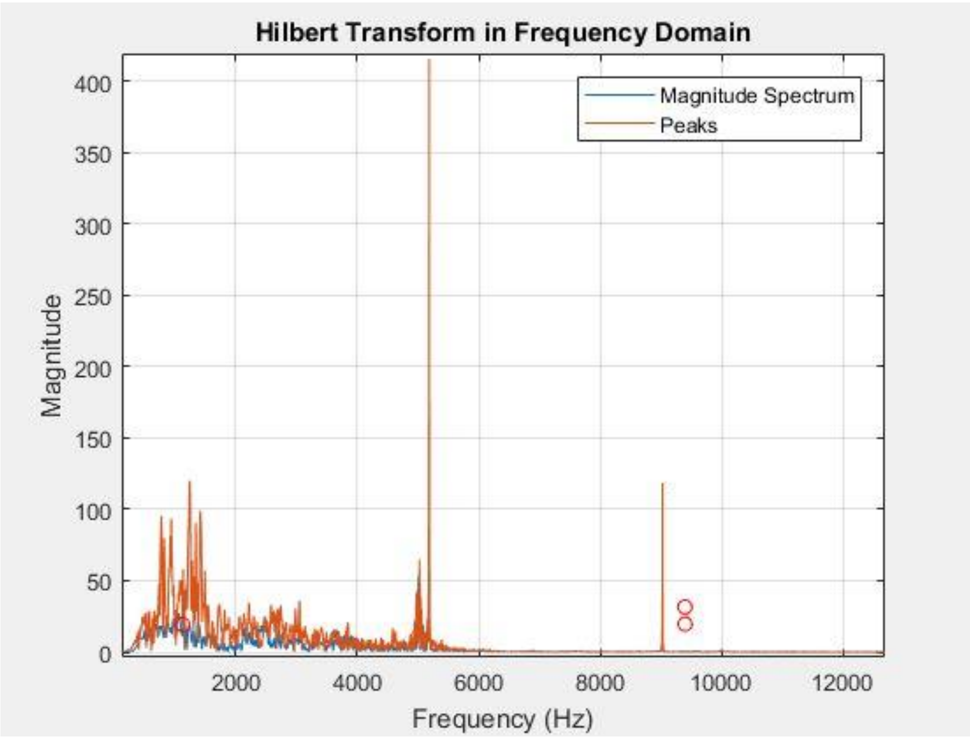

Figure 5- Frequency domain for axle with 9mm depth defect

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CONCLUSIONS/RECOMMENDATIONS

The fundamental frequency for metallic components is typically in the range of 100 kHz to 1MHz, and when cracks are present in shafts, the amplitude of harmonics of the fundamental frequency may become predominant (Randall 2011). In the experimental investigation, harmonics were observable in all three experiments. As the crack length increases, the amplitude of harmonics also increase. A predominant frequency of around 5500 Hz could be observed. The variation of the peak amplitude with the corresponding crack length is shown in Figure 6.

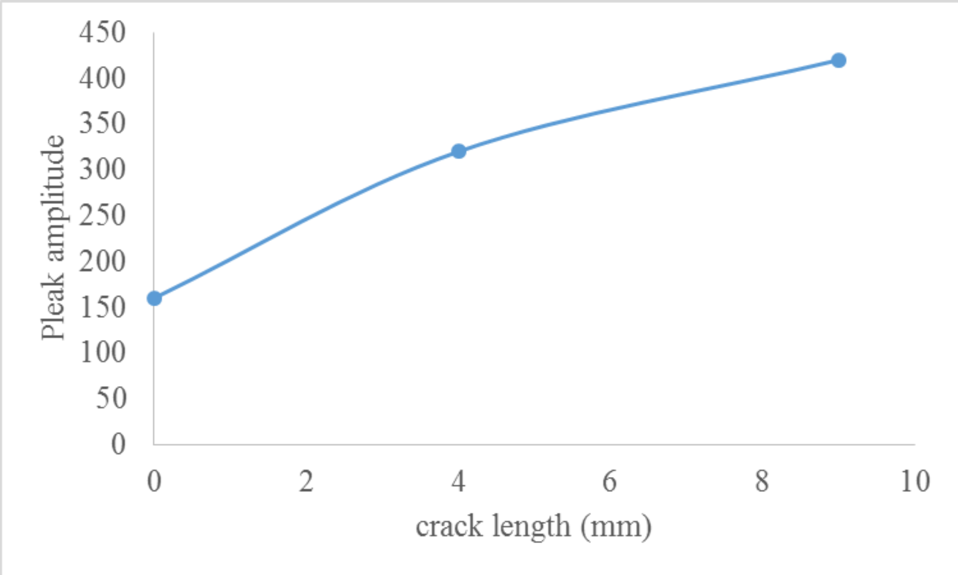

Figure 6 - Variation of the peak amplitude with corresponding crack length

The relationship can be used to develop a machine learning algorithm, to predict cracks present in wheel hub shafts without dismantling.

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