Vibration Analysis of Rotating Shaft with Slant Crack

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Abstract:
The papers consist of the vibration analysis of rotating shaft with slant crack on surface of shaft. Slant cracks are produced artificially by using laser technique on surface of shaft with material SS304. For this study, crack located on shaft 150 mm, 300mm and 450mm from bearing1. Experimental results are taken with the help of FFT analyzer. Analysis is done by using these results and finally these results are validated in DEWE software. In this paper the validated results are again explained with the help of graphs. This paper mainly focused on behavior of rotating shaft when it undergoes different conditions such as speed and distance of crack from bearing 1. Cracks: Cracks can be simply defined as, “unwanted cavity present in material which causes the failure of that component and then whole operation related to it.” Cracks cause the unwanted operations in modern day machines. Now a day’s Cracks often occur in rotating shafts while the detection of crack is challenging due to inspection difficulties. The rotating cracked shafts possess two main problems which are having following feathers as: (1), when any crack is present on the surface of shaft, it changes its local flexibility. (2)Breathing mechanism: “The opening-closing phenomenon of the crack during rotation called as breathing mechanism of the crack”. Many researchers have done their study on detection and diagnosis of cracked shafts and the work on the diagnosis of cracks has mainly been depends on the vibration analysis. Changes in vibration response in the form of frequency composition have been found to be useful crack indicators. Practically vibration-based techniques have been applied to a variety of engineering structures, such as, trusses, rotors, beams etc.

Keywords: Healthy shaft, Crack location, cracked shaft, Crack depth FFT analyzer, Slant crack.

I. INTRODUCTION:
Since the mid-eighties the research on dynamic behavior of shaft with crack is increased because the effect of using cracked shafts in day to day operations and in terms of damages in rotors, steam turbines, generators, pumps, and other machines. The continuous use of cracked shaft can cause a costly shutdown to the factory followed by the total loss of the machine. Due to this the standardized level of faith and reliability is in demand for such rotating machines such as turbines and generators which continuously undergoes torsion forces. [1, 2]. For this study the cracked shaft is undergone various conditions such as variation in speed as well as varying the distance of crack from bearing 1. For Explicit dynamic analysis, the shaft having crack is rotated parallel to its central axis with various rotations viz. 500rpm, 1000rpm, 1500rpm and 2000rpm. At start the rotations were applied in rpm and then it was converted to m/s. [4] Afterwards various researches are carried on the abnormal behavior of rotating machinery. They have studied various systems for monitoring failure in the rotating machinery. It is very important for improving the reliability of the rotating machinery and diagnosis of crack. If that crack is not detected and proceed to progress, the crack may be causing a failure of the shaft and also shutdown of machine. Untill now so many applicable results on dynamics of the rotor system with a cracked shaft have been obtained from the previous studies. However, these studies have treated the case where a crack grows transversely toward the axis or the rotor and then converts into slant crack due to torsion forces which acts on shaft during rotating action. [2, 3]

How does the slant crack generates
The slant crack generates due to the torsional vibration of the shaft, and hence the opening / closing behavior of the crack depends on torsional vibration. It is know that slant cracks change the stiffness of the shaft just as transversal cracks. However Then, Firstly, study and find out the relationship between the stiffness of the shaft with a slant crack and the torsional vibration of the shaft. Secondly for qualitative analysis use the characteristics of the shaft with a slant crack to a simple rotor model.

What is an FFT Analyzer
FFT S Analyzers, such as the SR760, SR770, SR780 and SR785, take a time varying input signal, like you would see on an oscilloscope trace, and compute its frequency spectrum. Fourier's theorem states that any waveform in the time domain can be represented by the weighted sum of sines and cosines. The FFT spectrum analyzer samples the input signal, computes the magnitude of its sine and cosine components, and displays the spectrum of these measured frequency components. An FFT spectrum analyzer works in an entirely different way. The input signal is digitized at a high sampling rate, similar to a digitizing oscilloscope. Nyquist's theorem says that as long as the sampling rate is greater than twice the highest frequency component of the signal, the sampled data will accurately represent the input signal. In the SR7xx (SR760, SR770, SR780 or SR785), sampling occurs at 256 kHz. To make sure that Nyquist's theorem is satisfied, the input signal passes through an analog filter which attenuates all frequency components above 156 kHz by 90 dB. This is the anti-aliasing filter. The resulting digital time record is then mathematically transformed into a frequency spectrum using an algorithm known as the Fast Fourier Transform, or FFT. The FFT is simply a clever set of operations which implements Fourier's theorem. The resulting spectrum shows the frequency components of the input signal. Now here's the interesting part.
The original digital time record comes from discrete samples taken at the sampling rate. The corresponding FFT yields a spectrum with discrete frequency samples. In fact, the spectrum has half as many frequency points as there are time points. (Remember Nyquist's theorem.) Suppose that you take 1024 samples at 256 kHz. It takes 4 ms to take this time record. The FFT of this record yields 512 frequency points but over what frequency range? The highest frequency will be determined by the period of two time samples or 128 kHz. The lowest frequency is just the period of the entire record or 1/(4 ms) or 250 Hz. Everything below 250 Hz is considered to be DC. The output spectrum thus represents the frequency range from DC to 128 kHz, with points every 250 Hz.

Experimental set up:

Exercise: DISCRIPTION:

Above fig shows the experimental set up for FFT Analyzer for detection of shaft having slant crack. This setup contains a DC motor, FFT analyzer, computer, probe, shaft, bearings, etc. As shown above the motor is mounted on a concrete base to reduce the vibrations. Then shaft is fitted into motor with the help of two pedestrian bearings to have proper rotation with minimum vibration. For example if the shaft is having total length 760 mm and then mount the shaft in such a way that the distance between two bearings is 700 mm and leave 30 mm distance on both sides. The probe is mounted on first bearing because the vibration on the first bearing is more than the second one. Then probe is connected to FFT analyzer with the help of a cable. FFT analyzer is connected to computer. FFT analyzer is converts the dynamic vibrations of shaft into physical quantity that can be measured and proceed it to the computer. Then readings are taken from computer in the form of amplitude and length.

Advantages of FFT Analyzers:

The advantage of this technique is its speed. Because FFT spectrum analyzers measure all frequency components at the same time, the technique offers the possibility of being hundreds of times faster than traditional analog spectrum analyzers. In the case of a 100 kHz span and 400 resolvable frequency bins, the entire spectrum takes only 4 ms to measure. To measure the signal with higher resolution, the time record is increased. But again, all frequencies are examined simultaneously providing an enormous speed advantage. In order to realize the speed advantages of this technique we need to do high speed calculations.

Analysis of slant crack having distance 150 mm from bearing 1 and 4.2 mm crack depth:-

Speed 500 rpm

![Graph](image1)

Speed 1000 rpm

![Graph](image2)

Speed 1500 rpm

![Graph](image3)

Speed 2000 rpm

![Graph](image4)

Analysis of slant crack having distance 300 mm from bearing and 4.2 mm crack depth:-

![Graph](image5)
Analysis of slant crack having distance 150 mm from bearing and 4.2 mm crack depth:

### Table 1. Readings for SS304 shaft having slant crack

<table>
<thead>
<tr>
<th>Crack location from bearing</th>
<th>Rotation speed in rpm</th>
</tr>
</thead>
<tbody>
<tr>
<td>150 - (4.2)</td>
<td>0.14  0.209  0.464  0.67</td>
</tr>
<tr>
<td>300 - (4.2)</td>
<td>0.218  0.542  0.849  1.39</td>
</tr>
<tr>
<td>450 - (4.2)</td>
<td>0.264  1.09  1.54  2.01</td>
</tr>
</tbody>
</table>

III. CONCLUSION:

1. As speed of Shaft increases, amplitude of vibration also increases.
2. Amplitude of vibration depends on crack location; it is different for different crack location.
3. As distance of crack from bearing 1 increase, amplitude of vibration increases.
4. Slant crack shows less vibrational response as compared to the shaft having transverse crack on its surface

IV. REFERENCES:


V. Books:
