Dynamic behavior Analysis of Rotor System with Regenerated Disc

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Abstract— *Rotating machines are extensively used in engineering applications. Detection of damage in rotor systems is an important concern to engineering communities. The importance of early detection of cracks has led to continuous efforts due to the fact that unpredictable occurrence of damage may cause failure. In this paper Dynamic behavior analysis of crack rotor system is investigated, Experimental studies were performed on a rotor. The vibrations are analyses in terms of velocity, displacement and frequency was measured at different speeds by vibration sensor.*

Keywords— rotor system, cracked rotors, Natural frequency, critical speed etc

I. INTRODUCTION

Rotor dynamics is the branch of engineering that studies the lateral and torsion vibrations of rotating shafts, with the objective of predicting the rotor vibrations and containing the vibration level under an acceptable limit. The principal components of a rotor-dynamic system are the shaft or rotor with disk, the bearings, and the seals. The shaft or rotor is the rotating component of the system A crack in the rotor will change the dynamic behavior of the system but in practice it has been found that small or medium size cracks make such a small change to the dynamics of machine system that they are virtually undetectable by this means.

A. Cracked Rotors:

The most common structural defect is the existence of a crack. If a structure is defective, there is a change in the stiffness and damping of the structure in the region of the defect. Usually, stiffness decreases and damping increases if the defect appears in the form of a micro- or macro crack. A reduction in stiffness implies a reduction in the natural frequencies of vibration. Hence it is possible to use natural frequency measurements to detect cracks.

B. Natural Frequency:

Natural frequency is the frequency at which a system tends to oscillate in the absence of any driving or damping force. It is also defined by a number of cycles per unit time.

C. Critical Speed:

All rotating shaft, even in the absence of external load, deflect during rotation. The combined weight of a shaft and wheel can cause deflection that will create resonant vibration at certain speeds, known as Critical Speed.

Sanxing Zhaoa et [6] Symmetrical single-disk flexible rotor-bearing System and non-linear oil-film forces of finite journal bearings are calculated. The rotor's stiffness and damping are considered. The motions of journal and disk have been simulate with fourth-rank Runge-kutta method. The threshold speed of the system based on linear oil-film forces has been derived. Non-linear transient simulation and unbalanced responses are investigated. The threshold speed of the system is a bit larger compared with that when the rotor's damping is ignored. The threshold speed of the system is 6247 rpm if the damping of rotor is taken into account, or it will reduce to 5960 rpm. In this case, when the damping of rotor is considered the threshold speed of the system will increase by 4.8% compared with that when then damping is ignored. Jerzy. Sawicki Michael. Friswell, Zbigniew Kulesza, Adam Wroblewski, John Lekki [2]This paper investigates the modeling and analysis of machines with breathing cracks, which open and close due to the self-weight of the rotor, producing a parametric excitation. After reviewing the modeling of cracked rotors, the paper analyses the use of auxiliary excitation of the shaft, often implemented using active magnetic bearings to detect cracks. this paper suggests an alternative approach based on the harmonic balance method, and validates this approach Using simulated and experimental results.Jean-Jacques Sinou [1] the purpose of this paper is to investigate the use of the 2·and 3· super-harmonic frequency components for detecting the presence of a single transverse breathing crack in a non-linear rotor system. This procedure is based on the detection of the super-harmonic frequency components of the non-linear dynamical behavior at the associated sub-critical resonant peaks. The non-linear behavior of the rotor system with a breathing crack is briefly analyzed numerically: it will be illustrated that the effects of the crack size and location induce the variation of non-linear responses and the emerging of new resonance– ant resonance peaks of the cracked rotor at second, third and fourth harmonic frequency components. Then, the influence of the crack–unbalance interactions and more particularly the relative orientation between the front crack and the unbalance are also undertaken with considerations of various crack depths, and unbalance magnitudes. Oh Sung Juna, Mohamed S. Gadalab[3], In the present study, the additional slope is used to consider the crack breathing, and is expressed explicitly in the It is shown that region on the crack front line having the dominant stress intensity factor value moves from the central area to both ends, as the crack depth increases. The result matches well with the crack propagation pattern shown in a bench mark test in the literature. Whirl orbits near the critical and sub-critical speed ranges of the rotor are discussed. Zbigniew Kulesza a,n, Jerzy T. Sawicki b[8] The article introduces a new mathematical model for the cracked rotating shaft. The model is based on the rigid finite element (RFE) method, which has previously been successfully applied for the dynamic analysis of many complicated, mechanical structures. The proposed method is illustrated with numerical and experimental results. The experiments conducted for the untracked free–free rotor as well as the numerical results obtained with other software confirm the accuracy of the RFE model. The numerical analysis conducted for a set of cracked rotors has shown that, depending on the eccentricity and its angular location, the breathing behavior of the crack may take different forms. G. Bamnios & A. Trochides [4]The influence of a transverse surface crack on the dynamic behavior of cantilever beam is studied. Analytical and experimental investigations provide a link between the change in natural frequencies of vibration and in mechanical impedance to the location and size of the crack for flexural vibrations. It is shown that the mechanical impedance of the beam changes substantially due to the presence of the crack and can be used as an additional defect information carrier. The results have been used to propose an improved method of non-destructive testing for simple beam structures.

D. Experimental Setup:

The experimental setup used in this experiment is shown in fig 1 and the disc which we have used in our experiment is shown in fig 2and fig 3. The motor with belt driven system drives a rotor shaft system. The setup consist a rotor, disk, vibration sensor, and bearing. The rotor can be run at different speeds below and above critical speed.

Fig. 1: Setup of Rotor system with crack disc

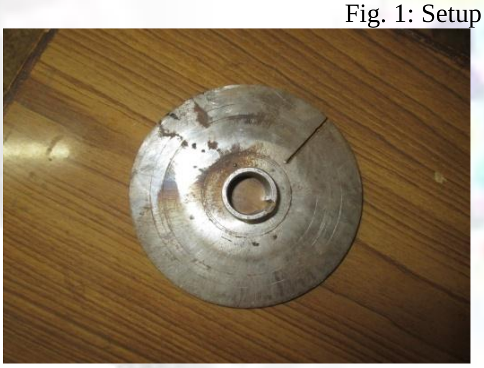


Fig. 2: crack disc

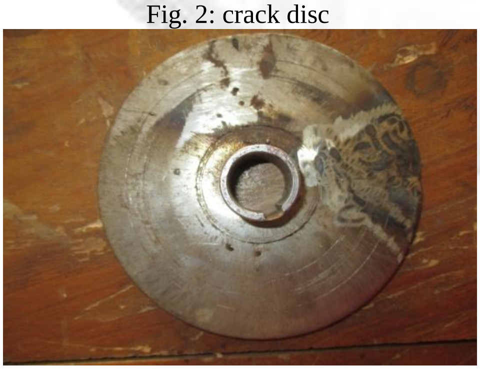


Fig. 3: regenerated disc

E. Experimental Procedure:

The Experimental setup is shown Figure.1 It consists of a 1 hp A.C. Induction motor 1500 rpm speed with a belt pulley arrangement and disc. The rotor shaft is supported by two identical ball bearings and has a length of 560 mm with a bearing span of 420 mm. The diameter of the rotor shaft is 23 mm. A disk of 120 mm in diameter and 8 mm in thickness is mounted on the rotor shaft at 140 mm at the each bearing end. The rotor shaft is driven by 1 hp A.C. motor. The speed of the motor is controlled by using speed regulator which is mainly used for A.C motors, to increase or decrease the speeds of the motor in the range of 0 to 1500 rpm. The instrument used in experiment includes vibration sensor connected to indicator which measures the vibration in terms of velocity, displacement and frequency. The Experimental setup Consist a “without crack disc “attach in mid position of the rotor shaft and supported by two bearings. Then different vibration velocity, displacement and frequency reading has to be taken by vibration indicator in 600-1500 rpm. Then we followed the same procedure by placing the” with crack” and “regenerated disc” on the same position of the without crack disc**.**

s.no	Speed(rpm)	Velocity(mm/sec)		
		Without crack	With crack disc	regenerated disc
1	600	4.8	4.8	4.8
2	800	6	6	6
3	1000	6.9	7.1	7
4	1200	12	13.5	12
5	1400	14	14.2	14.2
6	1600	14.2	14.8	14.3
7	1800	14.8	14.9	15
8	2000	14.9	16.4	15.7
9	2200	19.2	23.1	20.3
10	2400	24.7	29.8	25
11	2500	28.4	33.5	28.8

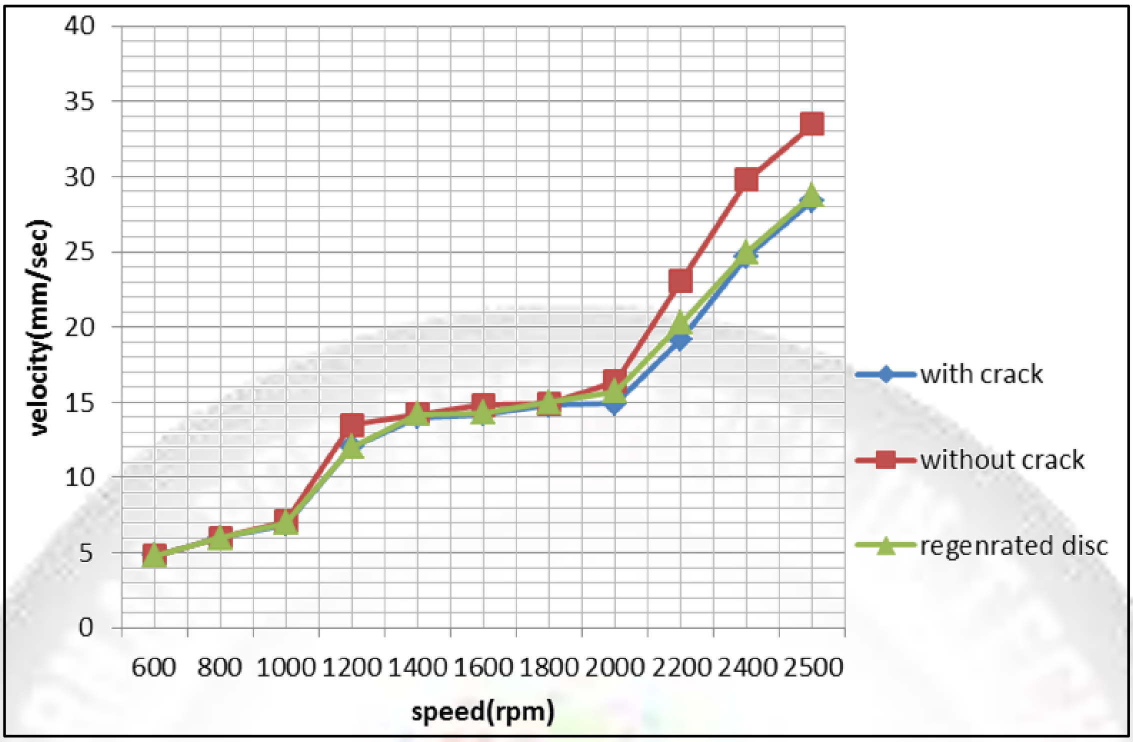
Table 1: Velocity (mm/s) without crack, with crack and regenerated disc

s.no	speed(rpm)	Displacement(micron)		
		Without crack	With crack disc	regenerated disc
1	600	900	980	910
2	800	1020	1040	1030
3	1000	1400	1440	1405
4	1200	1800	1820	1830
5	1400	2100	2480	2190
6	1600	2650	2900	2690
7	1800	3100	3300	3130
8	2000	3500	4440	3600
9	2200	4050	4620	4090
10	2400	4570	4750	4600
11	2500	4800	5220	4910

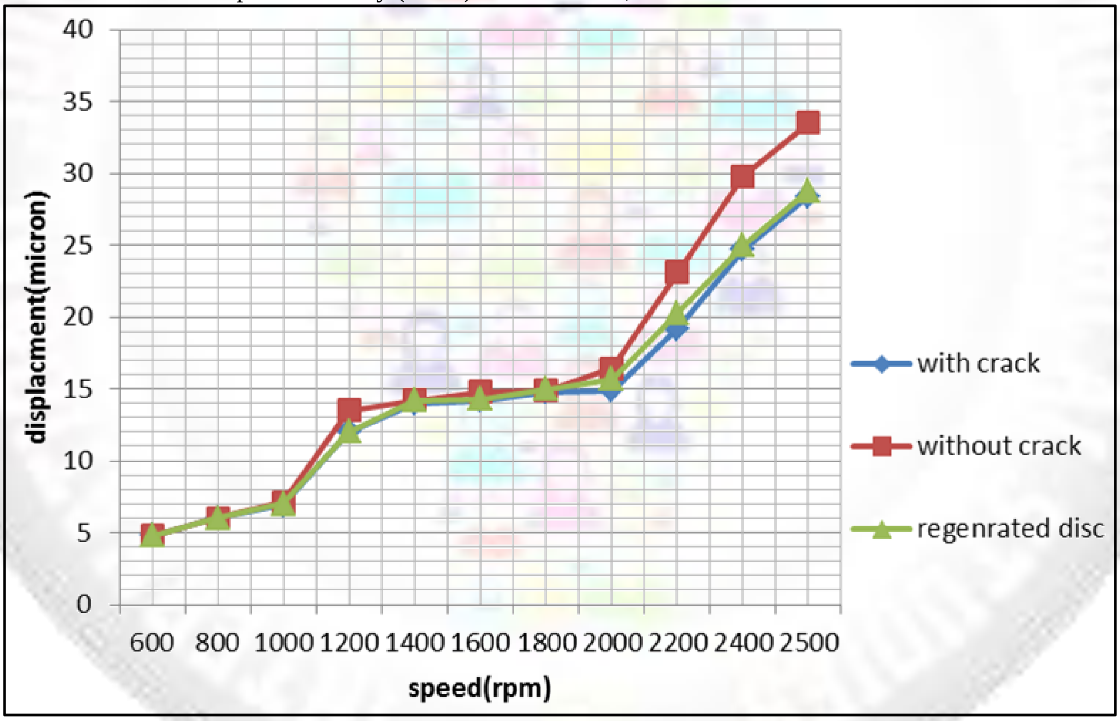
Table 2: Displacement (micron) without crack, with crack and regenerated disc

s.no	speed(rpm)	Frequency(Hertz))		
		Without crack	With crack disc	regenerated disc
1	600	2	2.4	2.1
2	800	3.9	4	3.9
3	1000	3.9	4.1	4
4	1200	4.28	4.3	4.28
5	1400	4.3	4.8	4.3
6	1600	4.62	5.1	4.7
7	1800	5.3	5.9	5.4
8	2000	5.72	6.8	5.9
9	2200	6.1	7.4	6.8
10	2400	6.5	8	6.6
11	2500	6.8	8.3	7.3

The graph 1 shows that vibration in terms of velocity in crack, with crack and crack filled condition. This graph shows that the maximum vibration velocity found in “disc with crack” compare to “without crack disc”. But after filled the “crack disc”, the maximum vibration Velocity found in “with crack disc” compare to “crack filled”.

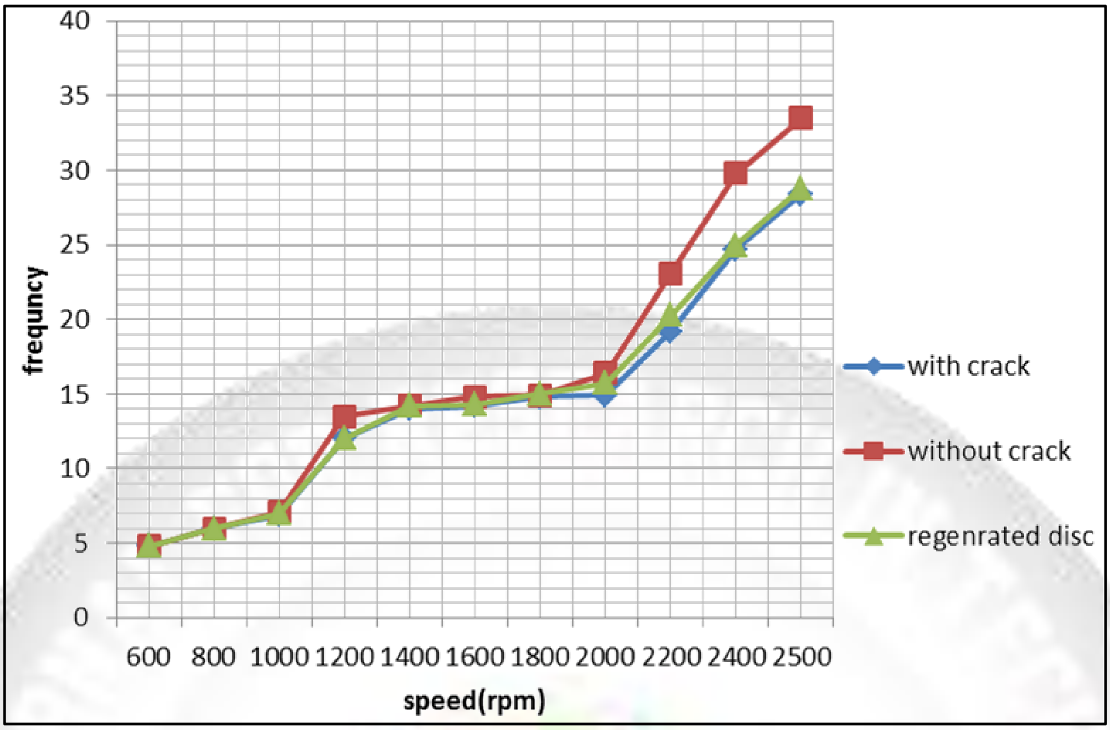


Graph 1: Velocity (mm/s) without crack, with crack and crack filled



Graph 2: Displacement (micron) without crack, with crack and regenerated disc

The graph 2 shows that vibration in terms of Displacement in crack, with crack and crack filled condition. This graph shows that the maximum vibration Displacement found in “disc with crack” compare to “without crack disc”. But after filled the “crack disc”, the maximum vibration Displacement found in “with crack” disc compare to “regenerated disc.



Graph 3: Frequency (Hertz) without crack, with crack and regenerated disc

The graph 3 shows that vibration in terms of frequency in crack, with crack and crack filled condition. This graph shows that the maximum vibration frequency found in "disc with crack" compare to "without crack disc". But after filled the "crack disc", the maximum vibration frequency found in "with crack" disc compare to "regenerated disc.

II. Conclusions

The following are the main conclusions of this experimental investigation

1) The maximum vibration velocity found in "disc with crack" compare to "without crack disc". But after filled the "crack disc", the maximum vibration Velocity found in "disc with crack" compare to "regenerated disc".
2) The maximum vibration frequency found in "disc with crack" compare to "without crack disc". But after filled the "crack disc", the maximum vibration frequency found in "with crack" disc compare to "regenerated disc".
3) The maximum vibration Displacement found in "disc with crack" compare to "without crack disc". But after filled the "crack disc", the maximum vibration Displacement found in "with crack disc" compare to "regenerated disc".

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