GEARBOX CRACK PROPAGATION LIFE DETERMINATION

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ABSTRACT: The aim of this work is to present an investigation for predicting the state of gear tooth damage (crack) in future for prognostic maintenance. A geared system with artificial cracks is used in the experimental work. The measured torsional vibration responses of the gearbox structure are used to monitor the modal frequencies of the gearbox structure, which represents the past gearbox condition. The mesh frequency of the geared system is calculated and the modal frequency shifts are used as a prognostic observable parameter during testing. These modal frequency shifts have been tracked and the prediction of the life time when the amount of frequency shift indicative of immanent failure. A robust analytic method for predicting remaining propagation time of the geared system is presented where a generalized statistical method is called "Statistical Prognosis Approach (SPA)".

EXPERIMENTAL METHDOLOGY:

A geared system includes a tooth with different crack depths is vibrated until a crack growing in the cracked area causes the tooth to break. On crack development in a gear, a tooth root crack typically starts at the point of the largest stress in the material. The computational model which applies the principles of linear elastic fracture mechanics is used to simulate gear tooth root crack propagation. Based on the computational results, a slight curve extending from the tooth root. Also, a crack propagation paths are smooth, continuous and in the most cases, rather straight with only a slight curvature. In this paper, based on the results ,the gear crack was further simplified to consider the crack path to be straight line. The crack starts at the root of the gear and then proceeds. The gearbox consists of two helical gears with a module of 2 mm, pressure angle 20°, which have 64 and 26 teeth with 40 mm face width. The axes of the gears are supported by two ball bearings each. The entire system is settled in an oil basin in order to ensure proper lubrication. The gearbox is powered by an electric motor and consumes its power on a hydraulic disc brake, while the speed is measured by photo electric probe. Two Bruel & Kjaer accelerometers were used for the vibration monitoring. Both mounted upon the gearbox case, one in each side-axis. By this way the torsional (rotational) vibration is predicted based on the concept presented in . Many tests were conducted on the same configuration yield similar parameters behaviour. A small crack was made artificially with wire electrical discharge machining at the root of gear of one tooth to create a stress concentration which eventually led to a propagating crack. The crack depth is 3.0 mm with thickness of almost 0.5 mm. Recordings every 15 min were acquired and a total of 24 recordings (~ 6.0 h of test duration) were resulted until the termination of the test. This type of test was preferred in order to have the opportunity to monitor bath damage modes, i.e., the natural crack propagation. Damage is assured by increasing the test period to the point of where the remaining metal in the tooth area has enough stress to be in the plastic deformation region. Careful monitoring of the vibration responses reveals some subtle and increasing changes in modal frequencies. When the gear tooth is brought under load, all the modal frequencies are seen declining slightly over initial few hours, or 'break-in period'. Break-in period is followed by a long period with little or no change in the model frequencies, 'or stable period'.

RESULTS AND DISCUSSION

The parameter to be tracked is the observed modal frequency corresponding to the calculated gear meshing frequency. In this study, the gear meshing frequency is calculated as 106.66 Hz at rotational speed of 100 rpm and at 400 rpm is 426.66 Hz. Samples from torsional vibration acceleration response and its zooming at 0.0 h in time are shown in Fig. 1, while at 6.0 h are shown in Fig. 2. In Fig. 3, the predicted hazard rate indicate that the increase of either the testing time or the predicted life time increases the corresponding hazard rate, while. Figs. 4 and 5 depict the influence of crack depths on the hazard rate where the increase of crack depth is accomplished with a decrease with the corresponding hazard rate which is reasonable fact. Figures 6 to 9 show the remaining life time. The remaining life time is calculated as the full time minus the testing time. The influences of crack depth on the remaining life time is illustrated in Fig. 16 at speed of 100 rpm and load of 200 N, while Fig. 7 indicates the one at speed of 400 rpm and load 100 N. The influence of speed and load on the remaining life time are shown in Figs. 8 and 9.These results confirm the above discussion

CONCLUSIONS:

1- The frequency shift down is useful feature of fatigue for the tooth because it indicates that a boundary condition is changing at a specific point.

2- The time-averaged mode probabilities have been used to predict the remaining time. The increase of speed is accomplished by an increase in the remaining life time, while the increase of both crack depth and load decrease it.
3- The capabilities presented herein offer a great opportunity in terms of reducing overall life cycle costs of the geared systems as well as decreasing the operations/ maintenance logistic footprint.

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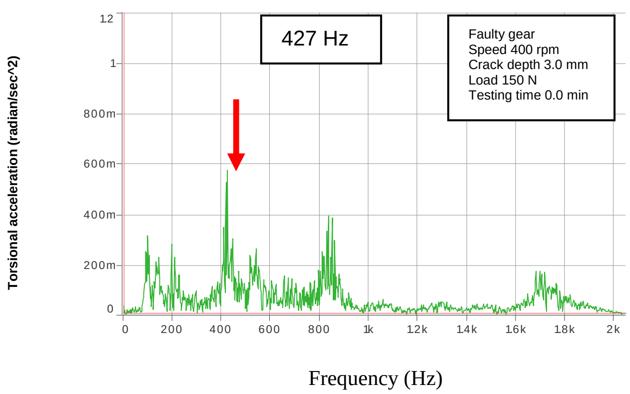

Fig. 1 Frequency-domain torsional acceleration

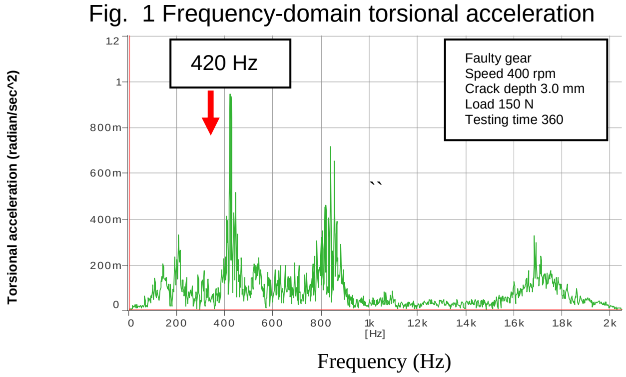

Fig. 2 Frequency-domain torsional

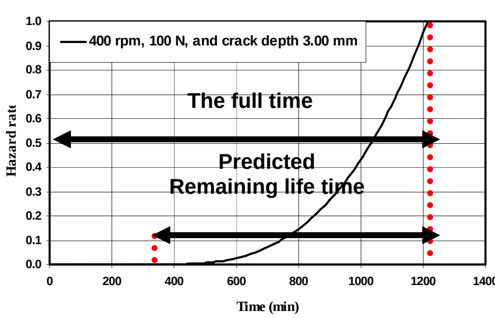

Fig. 3 Hazard rate

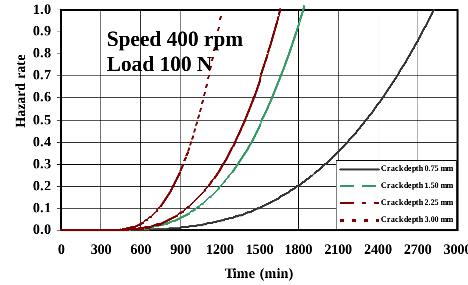

Fig. 4 Hazard rate

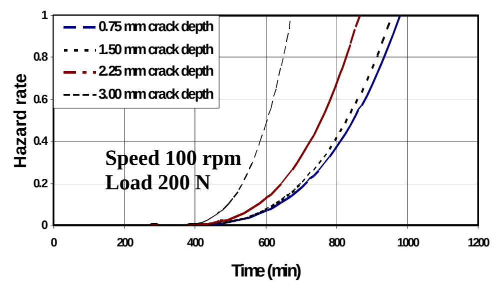

Fig. 5 Hazard rate

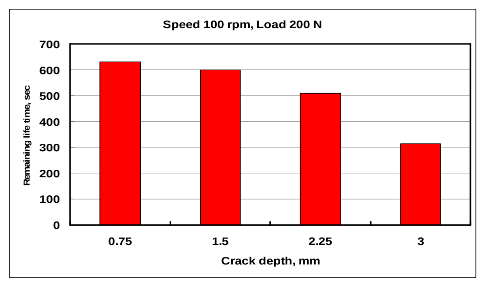

Fig. 6 Remaining life time

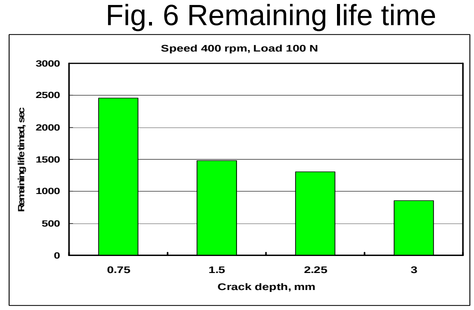

Fig. 7 Remaining life time

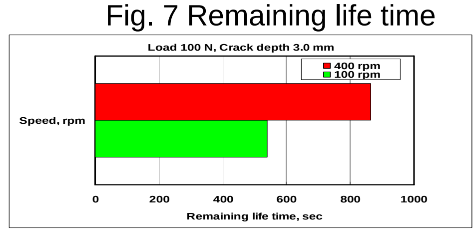

Fig. 8 Remaining life time

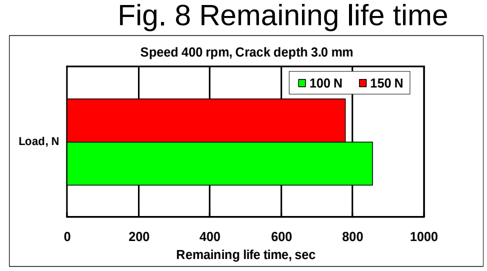

Fig. 9 Remaining life time