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GEAR BOX FAULTS

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Abstract—
Gearbox is one of the most important components in an automobile, enabling power transmission from the engine to the wheels. Gears and bearings are prone to failure. The impending case of failure can be predicted by performing vibration analysis of a gear box, usually done by acquiring data in lab conditions. Objective: This paper proposes an idea to enable fault detection in the gearbox by acquiring data under on road conditions without having to remove the gearbox, thereby simplifying the condition monitoring of a gearbox.
Keywords—Decision Tree, Gearbox, Normalization, On-road Testing, Statistical Features, Vibration.

I. Introduction

Everyday technological advances are being made in thefield of automobile engineering. The most common needof a customer in the case of an automobile is a vehicle withlong life and less maintenance. Although maintenance cannotbe completely minimized, the best possible solutionisto predict the impending failure so that adequate maintenance,if possible, can be done. Hence predictive analysisis an important technological advancement. Conditionmonitoring is a form of predictive analysis which usesdata acquired from the component to predict failure.

A gearbox consists of mechanical components that areessential in power transmission. The main componentsthat can fail in a gearbox are the gears and bearings.Various bearing faults have been simulated previously andtheir vibrations were used to simulate fault signals whichcan be used for prognostic algorithms. Propagation ofcracks in the outer race of the bearing and tooth chippingin gears are the common faults that occur in a gearbox.Studies showing the effect of fault in the outer race andtheir effects on the gear have been done and was validatedusing experiments. The effect of tooth chipping due toexcessive load and the resulting effect of fault on gearmesh stiffness were also studied by analysing the vibrationsand an analytical model was developed to representa time varying gear mesh stiffness. Comparison betweenthe analytical and finite element model was done. Faultdiagnosis were done on both helical and spur gearboxesby using multimodal feature from the obtained vibrationsand high efficiencies were achieved using multimodaldeep support vector classification using fault classes suchas faulty bearing and faulty gear.

Vibrational analysis has been found to give consistent and accurate results. Conditional monitoring of a gearbox used in wind turbine was performed by combining vibrational and acoustic signals and worst case standard deviation for the signals were calculated to avoid false alarms and the results can be used to develop a correlation between health of

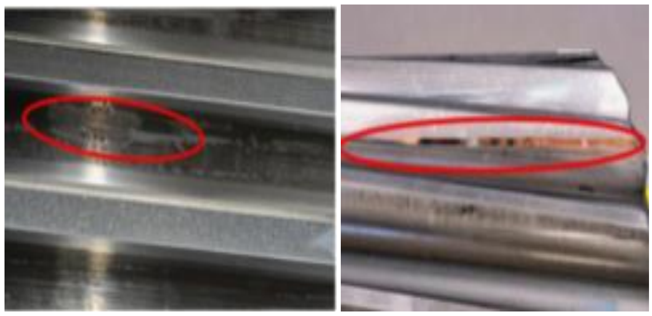

Fig. Examples of the local gearfaulty problems

machinery and the vibrations at a given time. Vibrational analysis for fault diagnosis of a gearbox by using discrete spectrum correction has been done and its effectiveness was validated using simulation and experiments. Time domain based diagnostic algorithm have been developed for improving the efficiency of extracting information from the vibrations and also to determine the position of fault. Vibration signals along with decision tree classifiers have been used to monitor the health of bearings and high accuracy of 95.64 % has been achieved and the kurtosis values were used to detect the presence of gear tooth cracks and the statistical model developed was found to be efficient9.This paper uses vibrational analysis for predicting the most common bearing and gear faults. The vibration signals from the gearbox are acquired and the raw data is normalised. Features were extracted from the data and statistical feature extraction was preferred.

Statistical features are frequently used for the condition monitoring of hydraulic brakes and Self Aligning Carrying Idler and high accuracy of 99 % was obtained. Statistical features of the acquired vibration signals have been used to strengthen the predictive analysis of lifetime of bearings

II. Review of Literature

R. Satishkumaret.al., [1] had studied a predictive model based on a classification approach to assess the remaining useful time of bearing. In the present study, the vibration signals were acquired from the bearing continuously till it fails naturally. Statistical features were extracted and best contributing features are selected using decision tree. With the selected feature, the predictive model was built. The classification accuracy was found to be 95.64% and error percentage is less than 5% which can be accepted practically. Hence, the proposed model can be used for predicting the remaining lifetime of bearings successfully.

FakherChaari et.al. [2] studiedthat an analytical formulation of the gearmesh stiffness is derived from bending, fillet-foundation and contact deflections.

The effect of a tooth crack on this stiffness was modelled.

The effect of this defect is a decrease of the gearmesh stiffness when the affected tooth is in mesh. It is also now possible to quantify analytically the severity of the stiffness loss for this fault.

A comparison with the finite element method showed good agreement associated with a reduced computation time. The obtained time varying gearmesh stiffness can be used to model a complete gear set in order to check the dynamic behaviour in the presence of such a fault.

N. Gangadharet.al., [3] had studied that the fault diagnosis of HSS cutting tool was investigated from vibration signal. Statistcal features were classified from acquired vibration signals, J48 algorithm was used to understand and categorize the condition of the tool, found its accuracy as of 89.38%. Hence J48 algorithm can be practically utilized to monitor the condition of HSS cutting tool.

Liu Honget.al., [4] determined that the Industrial gearboxes usually exhibit small fluctuations in speed and load around nominal operating conditions. Under these real industrial conditions, the usual Fourier transform based approach has limitations as the fault signature often appears to be blurred and is difficult to identify. To address the problem of real fast varying speed fluctuations within small range, a new time domain approach to detect the local gear faults and identify their location from measured vibration signal is presented in this paper. This new time-domain fault detection method combines the fast dynamic time warping (Fast DTW) as well as the correlated kurtosis (CK) techniques. The performance and applicability of the proposed approach is investigated using analytical and dynamic simulation of fixed axis and planetary gear systems, as well as measured vibration signal from a planetary gearbox. The mathematical modeling, computer simulation and experimental results indicate that (a) the proposed approach is able to detect gear faults, identify their location and have potential to assess the degradation level of the gear mesh stiffness, (b) only the correlated kurtosis corresponding to particular time interval that is related to the fault signature is sensitive and shows a significant increase in its value in presence of gear tooth fault, and (c) the residual signal obtained after application of Fast DTW to experimentally measured vibration signals highlights fault signals more clearly as compared to evaluated residual signal without the application of Fast DTW. Thus, the presented diagnosis approach in this paper is useful for developing automatic diagnostic process in complex industrial machinery systems include both practical fixed axis as well as epicyclic gearboxes.

R. Jegadeeshwaranet.al., [5] determinedthe fault diagnosis of the hydraulic brake system can be performed, using the vibration signals and machine learning techniques. Only the most frequently occurring faults were considered. Under static condition of the test rig, the simulated faults were tested in our laboratory. Using the C4.5 decision tree algorithm and the SVM classifier algorithm, the classification accuracy was found for different numbers of statistical features. If a small misclassification is tolerable, then the top (good) five statistical features, namely, minimum, standard error, sample variance, kurtosis, skewness are sufficient. For more accurate fault diagnosis, seven good statistical features, namely, minimum, standard error, sample variance, kurtosis, skewness, standard deviation, mean are required. If the top five features are selected, the RBF kernel of the C-SVM classification model seem to be better, compared to other kernel functions which were taken for the study of the statistical features. Comparing the results of the SVM based on the kernel functions, radial basis function (RBF) has more classification accuracy in both types of SVM, and can be suggested for practical applications. However, one should note that there are more statistical features available, which are not considered in the present study. Due to the encouraging results, future study on brake fault diagnosis is possible on real vehicles under real road conditions.

M. Saimuruganet.al., [6] explained Fault diagnosis of shaft and bearings is one of the core research areas in the field of condition monitoring of rotating machines. Many researchers reported the fault diagnosis of either shaft or bearing, but here both the shaft and the bearing have been considered. The statistical features for 12 different conditions were extracted from the vibration signals. Decision tree is used to select the best features. The best features were classified using four different SVM kernel functions of two SVM model in support vector machine. The RBF of c-SVC model gives the better classification efficiency for four different speeds. From the above result one can conclude that c-SVC model of SVM classifier with RBF kernel function is a good candidate for fault diagnosis of rotational mechanical system.

N. Saravanan et.al., [7] studied the definition of the discrete wavelet transforms and then demonstrated how it can be applied to the analysis of the vibration signals produced by a bevel gear box in various conditions and faults. Statistical features were extracted for all the wavelet coefficients and for all the signals using the Daubechies wavelets db1–db15. The features selection and classification of various conditions of gear box was done using J48 algorithm. The maximum average classification efficiency of Daubechies wavelets was 98.57% and it was found that among the 15 levels of Daubechies wavelet, db1 and db5 gives the maximum classification efficiency and it is around 98.667%.

Abhishek Sharma et.al., [8] determined Misfire in an IC engine can be detected by various methods. Machine learning approach is arguably one of the better methods that can be employed for misfire detection. Decision tree algorithms are easier to implement as an on board system due to their inherent simplicity. One of the viable techniques using linear model tree (LMT) was suggested in the study after comparing the competencies of various decision tree algorithms available. LMT algorithm offers high overall classification accuracy with 100% accuracy in differentiating between normal and fault conditions. Use of vibration signals from engine block ascertains great accuracy and lower cost. The setup suggested in this study requires less effort, is easy to understand and is less capital intensive. It does not require very sophisticated and delicate instruments. Hence, it is robust and facilitates ease of operation. All these advantages make the system a viable option for on board diagnosis (OBD) system employed for misfire detection in an IC engine.

Slim Souaet.al., [9] determinedFirst measurements on the in service acquisition of the vibration and AE signature on a healthy wind turbine generator and gearbox have been presented. The standard deviations for the averaging of the time dependent sensor signals, namely s{VRMS} and the quality factor q, have been calculated. These quantities represent the uncertainty in the healthy turbine signature and they determine the minimum detectible signal i.e. the minimum detectable defect size. This result forms an excellent basis for the development of an alarm based CM process for wind turbines usable over a wide power operational range of 50-300 kW.

Juliang Yin et.al., [10] studiedA statistical model of synchronous signal average has been developed in this paper. It has been shown that the model cannot only fit the synchronous signal average of measured vibrations signals well for both healthy and faulty gears, but also is very efficient for detecting gear faults. The optimal model order of the signal model is determined by means of conventional AIC or BIC. Since the two criteria are all based on the concept of information entropy, it seems feasible to determine the optimal model orders by means of fuzzy entropy. Although the residual signals have a lower energy distribution, the corresponding kurtosis values have provided useful information for diagnosing the gear faults. The technique proposed in this paper has distinct advantages over traditional vibration analysis methods and model-based approaches because of its versatility and flexibility. It is worth mentioning that various fault detection and diagnosis approaches based on fuzzy rules for dynamical systems have been developed in the past five years. However, it is uncertain whether these approaches can be applied to detect and diagnose faults in gear systems.

III. CONCLUSION

Thus the tests were conducted on the gearbox in a test vehicle run in real time conditions and data was acquired for different conditions of gearbox. The time-domain data acquired was extracted to obtain statistical features and decision tree classifier was used to classify the different conditions. Also, the time-domain data was normalised and features were extracted from the normalised data. The features obtained from the normalised data were then used to train the decision tree algorithm. The classification efficiency of the decision tree was found to increase significantly when features extracted from normalised data were used. It is to be noted that data normalization has highly improved the efficiency of the decision tree classifier. Also, the high classification efficiency shows that vibration monitoring of an automobile gearbox in a test vehicle run in real time conditions is feasible.

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