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FAULT CLASSIFICATION OF DIFFERENTIAL GEARBOX BASE ON MULTI CLASS SVM FROM TIME–FREQUENCY VIBRATION DATA

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Application of new methods of maintenance such as condition monitoring by vibration analysis provides useful information about machine performance for the engineers to help them to support, control and optimize the production. This study an efficient and reliable method based on vibration analysis was presented for fault diagnosis in differential. The effects of healthy and defective gears condition with vibration signals from the differential were studied. The differential conditions were considered to be normal differential, broken and worn crown wheel, broken and worn pinion.The vibration spectrums using statistical parameters in different conditions were obtained for differential. Support Vector Machine classifier was used in fault diagnosis. The highest accuracy was obtained, which equals to 97.33%.

Keywords: Crown Wheel, Pinion, Vibration, Wavelet Transform, SVM

1. Introduction

Gears are part of the machines or transmission that to move and be driven of transfer to other gear by his teethes are used. Spiral bevel gears are one of the main and important parts in power transmission, gearbox and differential or engineering equipment such as airplane, ships, automobiles and etc systems (Bibo et al., 2011). On the other hand, due to the role of the conical gears in the performance of many systems that in plants may be great damage due to them conks. Fault detection has very important method (Farokhzad et al., 2013). Lu & Wei (2013) A new method of adaptive approach feature extraction and classification support vector machine to monitor and condition monitoring and troubleshooting of insights gearboxes that are offered in varying with speedy work. Chen et al., (2015) using neural networks convolution of vibration analysis and classified defects of gear box smartly. they are in them study considered the statistical features , standard deviation, skewness and Kvrtvsys of signal in time domain and frequency domain signal and used as inputs to the neural network. the results of 12 different classes of classification showed that the highest classification accuracy of neural network convolution was 80/98%. Using neural networks convolution and vibration analysis for intelligent defects of gear box was classified. In this study statistical features of standard deviation, skewness and Kvrtvsys and RMS of the time domain and frequency domain signals extracted and considered as inputs to the neural network. 12 different classes of classification results showed that the highest classification accuracy of neural network convolution was 80/98% (Ziani et al., 2011). In a study using vibration analysis and genetic algorithm techniques and SVM, For classification and

intelligent fault detection of gear box of air force helicopter CH_46 model in United States of America (Hizarci et al., 2016). For fault detection of gear box by vibration spectrum analysis checked out the gearbox failure in the wheel set and snail gearbox. (Waqar & Demetgul, 2016). Fault diagnosis of helical Gear box by compilation method of thermography and vibration signals (Yaguo et al, 2009).
A combination of multi-dimensional approach to intelligent fault detection gear provided. The combination of multi-dimensional methods include: Hilbert transform method, wavelet analysis and experimental models. Bangalore (2015) by offering a method based on vibration signals and artificial neural networks used as online method for fault detection of wind turbine gearbox. Each of the above researches was focused on a part of the fault detection of gears. In this study, we want to diagnosis of defects in the vehicle differential collection using Support Vector Machine classifier.

2. Material and methods

2.1. The test bed and data acquisition

In order to vibration data collection from a differential in healthy and failures condition in gear wheel cone-shaped the substrate 1 was prepared in fig1, that original components, including electric motors, coupling, differential and frames.

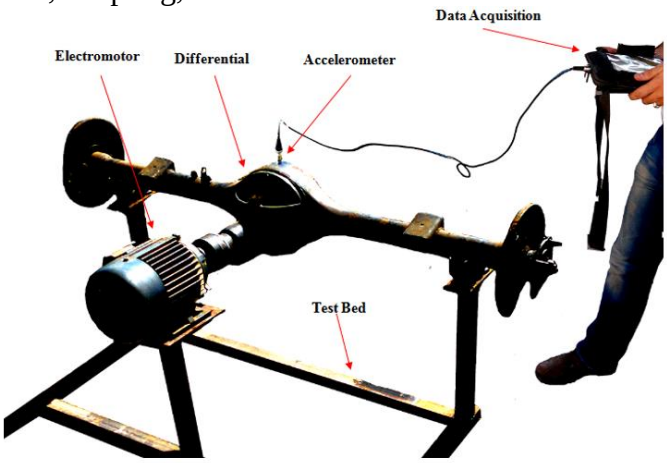

Figure1. The bed test

In this study, vibrations data were measured as offline method. For this purpose data acquisition system was used by Easy-Viber VMI system with a piezoelectric accelerometer and a tachometer to measure of speed and record it made in Switzerland. Vibration signals within SpectraPro4 software transfer into the computer and with use of Excel software and loaded in MATLAB software.

2.2. Defects imperfections review

In this study defects tested with studies and articles previous research on the gear were selected and to the extent possible, we tried to check that selected the important and common failure in conical gears and apply the main components of the differential gear. Defects that were studied in the collection include breakage and abrasion in conical Crown Wheel and breakage and abrasion in conical pinion gear.

Figure2. Defects condition

2.3. Signal processing and feature extraction

Before from the signal processing, for better feature extraction used a pre-processing features on the signals, the wavelet transform is applied. In all modes consist of healthy and failure the wavelet analysis was applied. The wavelet approach selected after a review of previous research. We use wavelet db4 type with three levels that were tested on all treatments (Bagheriet al., 2011; Farokhzad., 2013). After applying wavelet coefficients on the vibration signals, from the components and is approximately ten important features for data analysis were extracted to distinguish and separate the each signal behavior. These features were in study by Farokhzad et al., 2012.

2.4. Modeling with SVM

Performance of support vector machine depended on many factors such as multi-class, kernel type parameter, auxiliary variables and kernel parameter choice. For the decision by SVM and to find the best model, the following of factors affecting in this performance were selected and diagnostic accuracy rate was calculated for each model as exact and completely. To create a network used of multi-class one against one and a one against all method with Gaussian radial basis kernel with a width of 0.1 to 1 was used. The results of this study evaluated by degree of compliance parameters that is number of correct decisions divided to the total number of possible decisions.

3. Results and discussion

In Figure 3 fast signals in time domain in various conditions of differential in 1500 rpm speed is shown. Amplitude of total signal at the tooth fractures in crown wheel, has highest rate. We can see that due to the high range, the differential is in dangerous situations.

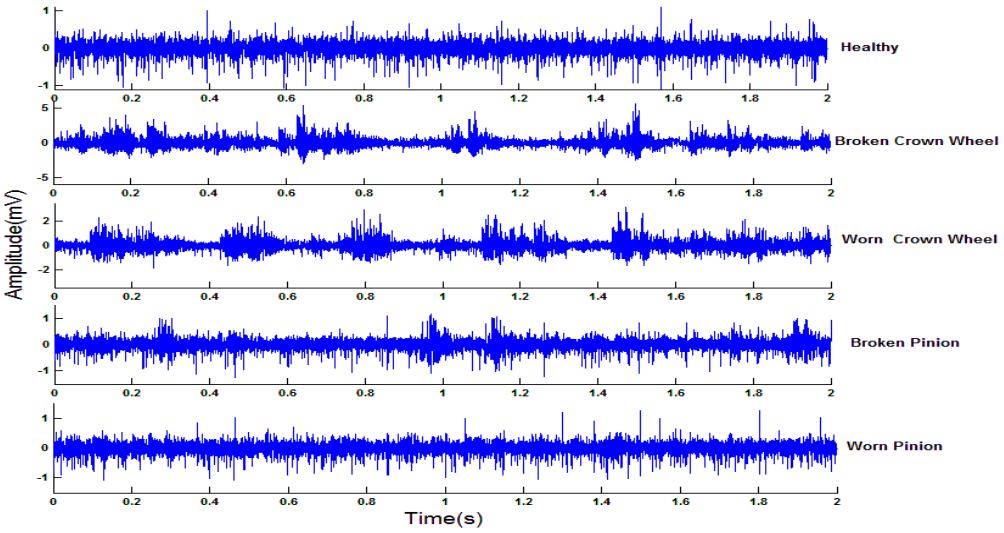

Figure3. Vibration signals in different conditions of differential.

As stated each of the states of differential used from wavelet decomposition method in three levels. A total set of 200 features were extracted for different states that all these features are informative and effective. On the other hand many useful features these features increase caused increase of time of the signal processing. Accordingly, using Weka software and CFS approach extracted the best statistical features that have the most information in different states of failure. Output Weka software and superior features are shown in Figure 4.

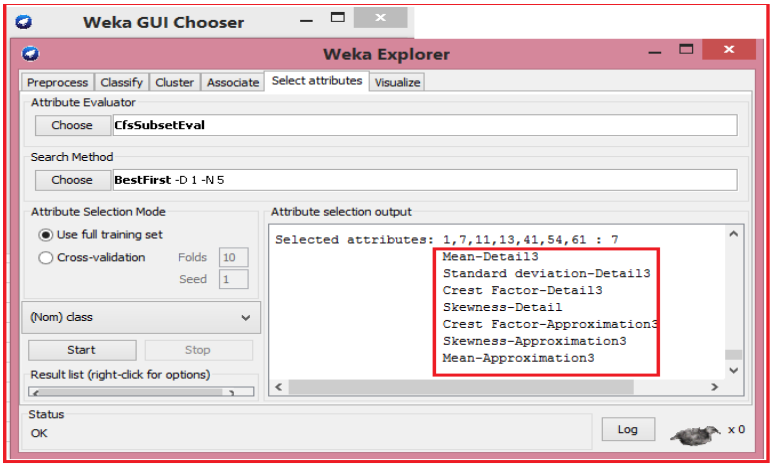

Figure4. Better features

3.1. The results of classification by support vector machine

In the table 1, the precision of support vector machine using a multiple-class are shows for tow method one against one and one against all method with o.1 to 1 the radial basis kernel size.

Generally, the precision of support vector machine using a multiple-class the one against all method was better than one against one. As we see with increasing amounts of kernel size (σ), accuracy in both method and a one against one and one against all, in most cases has declined. The classification accuracy of SVM with radial basis kernel with kernel size o.1 and was one against all method. The confusion matrix of best performance is shown in Table 2.

Table1. Accuracy of support vector machine with radial basis kernel

Classification method with SVM	Classification accuracy	
0.1	one against all	one against one
0.2	97.33	92
0.3	93.33	92
0.4	92	89.33
0.5	86.67	90.67
0.5	81.22	86.67
0.6	76	85.33
0.7	72	80
0.8	70.67	68
0.9	66.67	68
1	66.67	64

Table2. Confusion matrix for data tests

Real class					condition
H	BC	WC	BP	WP	
75	0	0	0	0	Healthy =H
0	75	0	0	0	Break crown wheel tooth =BC
0	0	75	0	0	Worn abrasion crown wheel =WC
0	0	0	73	2	Break pinion tooth =BP
0	00	0	0	75	Worn abrasion pinion =WP

Table2 is shown that the SVM classifier from all condition just one case in break in pinion tooth recognized abrasion pinion tooth mistakenly but this method can be used for fault detection of differential by 100 percent accuracy.

4. Conclusion

In this study important and acceptable of detects in spiral conical gear in differential set were studied. Vibrating signal by wavelet decomposition had been analyzed and statistical features extracted from tem that of these features number of seven features was selected and was used for train of support vector machine. The results showed that the best method of support vector machine classifier with Gaussian radial basis function with a width of 0.1 and one against one method was the best method. This method is able to classified of modes of differential condition with accuracy 97.33%.

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