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COMPOUND FAULT DIAGNOSIS OF BEARINGS USING AN IMPROVED SPECTRAL KURTOSIS BY MAXIMUM CORRELATION KURTOSIS DECONVOLUTION (MCKD)

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ABSTRACT

This paper discusses the use of Maximum Correlation kurtosis deconvolution (MCKD) method as a pre-processor in fast spectral kurtosis (FSK) method in order to find the compound fault characteristics of the bearing, by enhancing the vibration signals. FSK only extracts the resonance bands which have maximum kurtosis value, but sometimes it might possible that faults occur in the resonance bands which has low kurtosis value, also the faulty signals missed due to noise interference. In order to overcome these limitations FSK used with MCKD, MCKD extracts various faults present in different resonance frequency bands; also detect the weak impact component, as MCKD also dealt with strong background noise. By obtaining the MCKD parameters like, filter length & deconvolution period, we can extract the compound fault feature characteristics.

KEYWORDS: MCKD, FSK, Fault frequency, Filter length, Deconvolution period, Envelope analysis, Resonance bands.

1. INTRODUCTION

Rolling element bearings are one of the most widely used elements in almost all rotating machines and the most frequent reasons for machine breakdown is bearing failure. Due to this reason bearing failure needs to studied and diagnosed. Various researches done on vibration-based diagnostics of Rolling element bearings over the last few decades, and the area is now quite well understood, with a number of powerful diagnostic techniques available [9]. Yet researchers continually strive to develop improvements on established diagnostic methods. The data set provided by Case Western Reserve University (CWRU) Bearing Data Center [11] has become such a standard reference in the bearing diagnostics field.

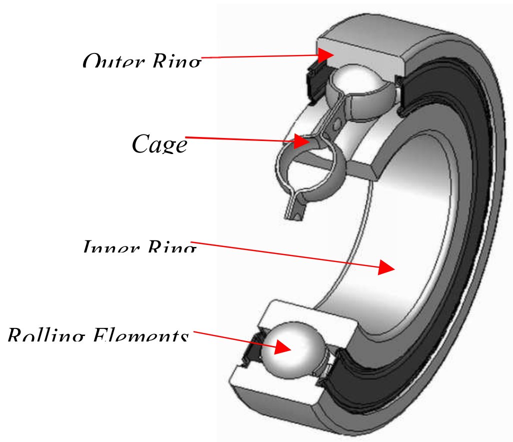

Figure 1: Construction of Bearing

Fault diagnosis means to diagnose, the bearing fault level & to distinguish bearing fault from other components like gear & shaft [4]. As vibration is one of the parameter that can easily sense the condition of machine (Mainly rotating parts), so while diagnosis of bearing faults we will use the vibration monitoring techniques.

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For bearing incipient fault, we need to find some methods which can extract or enhance the impulsive signal enabling the fault easily been found.

Bearing is a main source of system failure; almost more than 40% of the induction motor's failure is due to motor bearings faults, major failure cause in wind turbines is gearbox bearing failure. The earlier fault detection saves production loss as well as money.

2. METHODOLOGY

In order to overcome the limitations of FSK, we have a pre-processing method known as MCKD. When FSK used with MCKD, we will be able to extract the fault feature present in various resonance frequency bands irrespective of kurtosis value. The process chart of fault feature extraction of the rolling element bearing is shown in figure 2. The fault feature extraction process using FSK with MCKD are as follows:

1. Calculate the theoretical fault frequencies of bearing, according to the parameter of bearing. The formula of fault characteristic frequency is defined as

$$\text{Outer Race Defect}, f_o = \frac{Z}{2} f_r \left(1 - \frac{RD}{PD}\cos\alpha\right)$$

$$\text{Inner Race Defect}, f_i = \frac{Z}{2} f_r \left(1 + \frac{RD}{PD}\cos\alpha\right)$$

   Where, Z is the number of rolling elements (ball/roller),
   PD is the pitch circle diameter,
   RD is the rolling element diameter,
   α is the contact angle
   f_r is the rotational frequency, Hz

2. The Deconvolution period is obtained by the formula shown below, it is the ratio of sampling frequency and the theoretical fault frequency.

$$T_* = \frac{f_s}{f_*} \qquad (* \text{ is } i \text{ or } o),$$

   Where, f_s is the sampling frequency,

3. Find the filter length of the MCKD. In the process, the maximum correlation kurtosis is used as the parameter to optimize the target, with 10 as the step length and 10 to 300 as the search range. Finally, L_* is determined to be the optimum filter length.

4. The original signal is filtered by the combination of the MCKD parameters [T_*, L_*]. After filtering, we will obtain various sets of time domain signals with different fault. That is, the fault information located in the different resonance bands is separated.

5. The signals obtained by MCKD are analyzed by FSK, respectively, and the resonance frequency bands of each signal are determined. The bands are filtered, respectively, and the filtered signals are analyzed by envelope spectrum. The characteristic faults frequency spectrum is obtained from the envelope analysis.

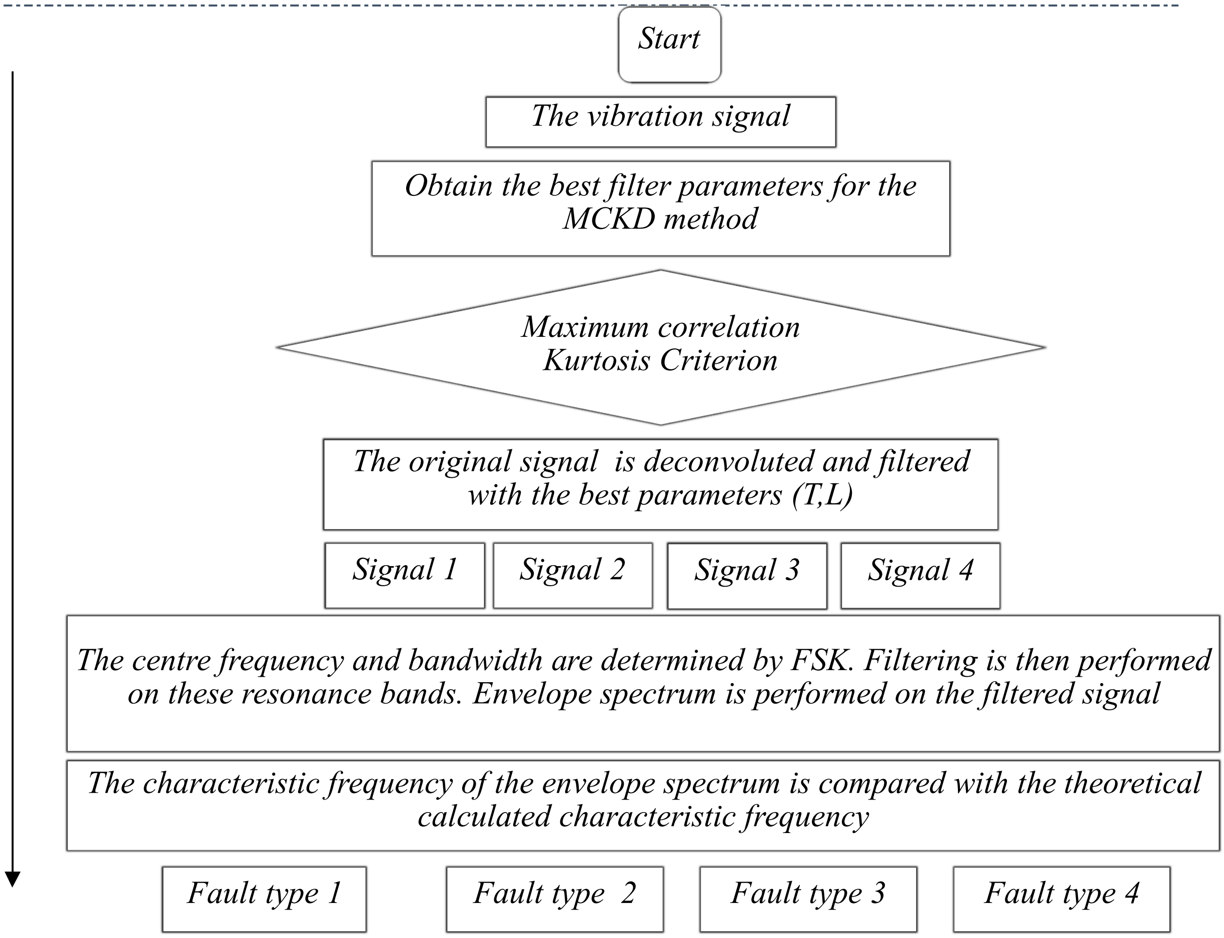

Figure 2: Procedure for Bearing fault feature extraction

3. EXPERIMENTAL ANALYSIS

The experimental data of rolling bearings at Case Western Reserve University in the United States verified the effectiveness of the method [11]. The experimental Equipment is shown in Figure 3. The bearing model is 6205-2RS JEM SKF. The sampling frequency is 12800 Hz, and the rotation speed of the shaft is 1466r/min. The bearing parameter dimensions are shown in Table 1, and the frequency of each fault characteristic of the bearing is shown in Table 2. The MCKD is used to separate the fault features by selecting the optimum filter length L and the deconvolution cycle T. Among them, the filter length is within the range of [10, 300], and 10 is chosen as the step size. Finally, the parameter of MCKD is determined, the filter length of the outer ring is 120, and the filter length of the inner ring is 200. The deconvolution period is the ratio of the sampling frequency to the characteristic frequency of the fault, which can be calculated as shown in table 2.

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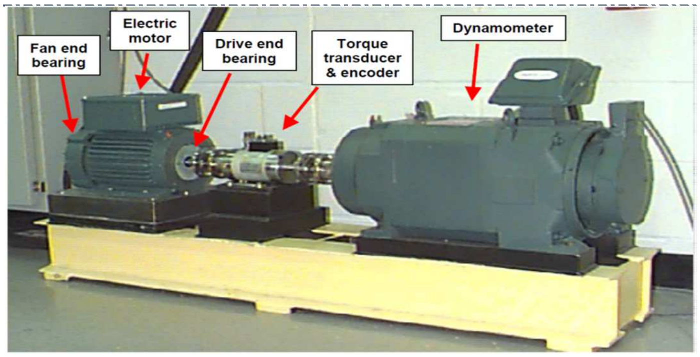

Figure 3: the bearing test stand in case western university, USA

Table 1: Bearing Data Information

BEARING INFORMATION FROM CASE WESTERN RESERVE UNIVERSITY, USA					
Drive end bearing: 6205-2RS JEM SKF, deep groove ball bearing					
Size: (inches)					
Inside Diameter	**Outside Diameter**	**Ball Diameter**	**Pitch Diameter**	**No. of balls**	**contact angle**
0.9843	2.0472	0.3126	1.537	9	0

Calculation Table

Bearing standard data taken from table 1 and applied to above formulas, in order to obtain the values of the defect frequency of the inner and outer ring, deconvolution period, & filter length.

Table 2: Parameters required for Pre-processor method MCKD

Rotational freq. fr = rpm/60, @1466rpm , Sampling frequency 12800 Hz, Filter length, L range [10, 300]		
Parameter	**Inner Ring**	**Outer Ring**
Theoretical Defect frequency (Hz)	132.2	87.7
Deconvolution period (T)	96.82	145.95
Filter length (L)	200	120

Figure 4 is the variation of the compound signal with time before MCKD. Figure 5 is the variation of the outer ring fault signal with time after MCKD. Figure 6 is the variation of the inner ring fault signal with time after MCKD. From the time domain waveform, it can be seen that MCKD revealed the fault characteristics to a certain extent.

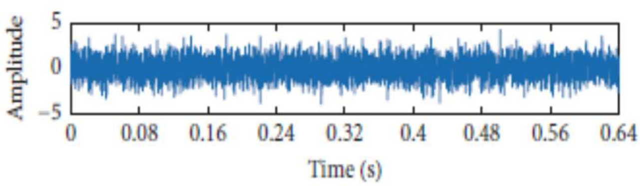

Figure 4: Time domain waveform of the compound signal before MCKD

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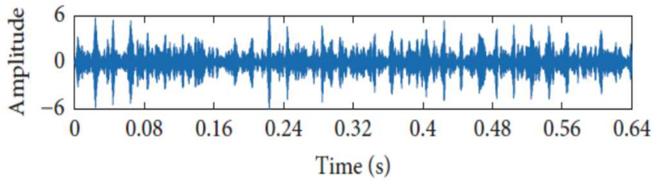

Figure 5: Time domain waveform of the compound signal (outer ring) after MCKD

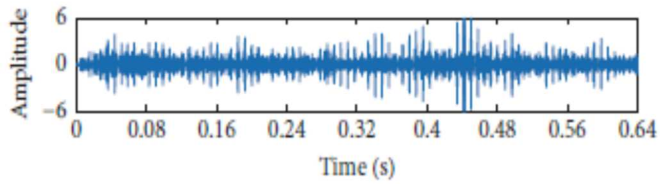

Figure 6: Time domain waveform of the compound signal (inner ring) after MCKD

The FSK analysis of the outer ring and inner ring fault after deconvolution is carried out, and the spectral kurtosis resonance band can be clearly seen in the spectral kurtosis. Figure 7 shows the resonance band & envelope spectrum determined by the FSK before MCKD, Figure 8 shows the resonance band & envelope spectrum of the outer ring fault signal determined by the FSK after MCKD and Figure 9 shows the resonance band & envelope spectrum of the inner ring fault signal determined by the FSK after MCKD.

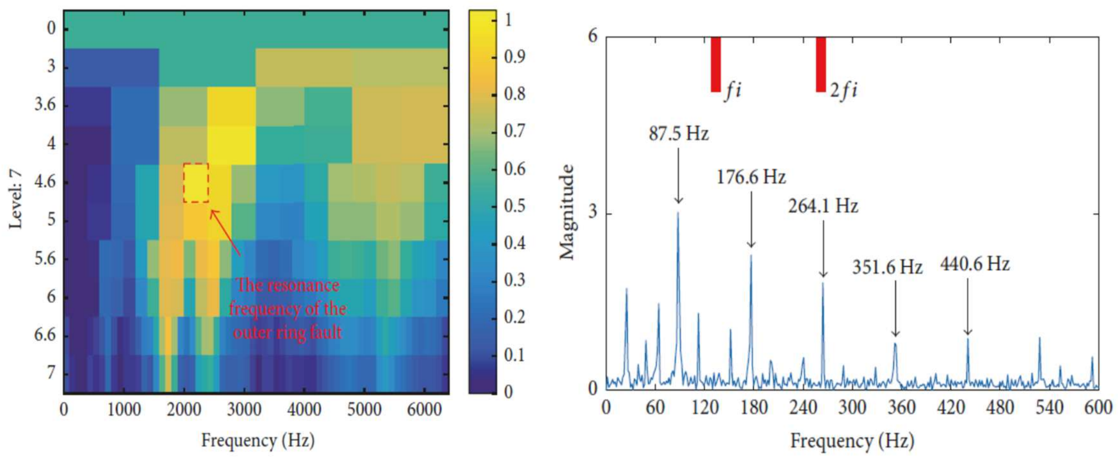

Figure 7: the fast spectral kurtosis & Envelope spectrum analysis of the compound fault signal before MCKD

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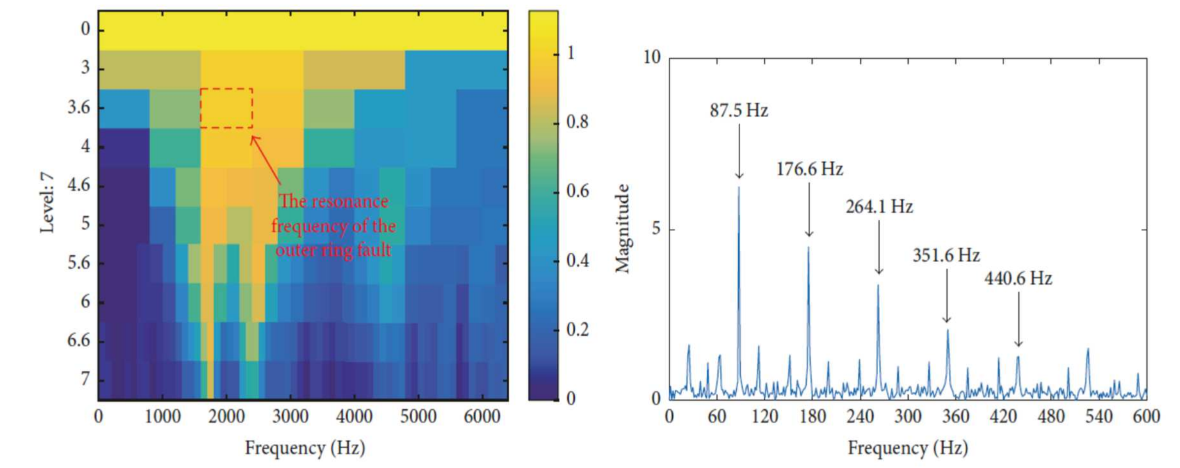

Figure 8: the fast spectral kurtosis & Envelope spectrum analysis of the outer ring fault signal after MCKD

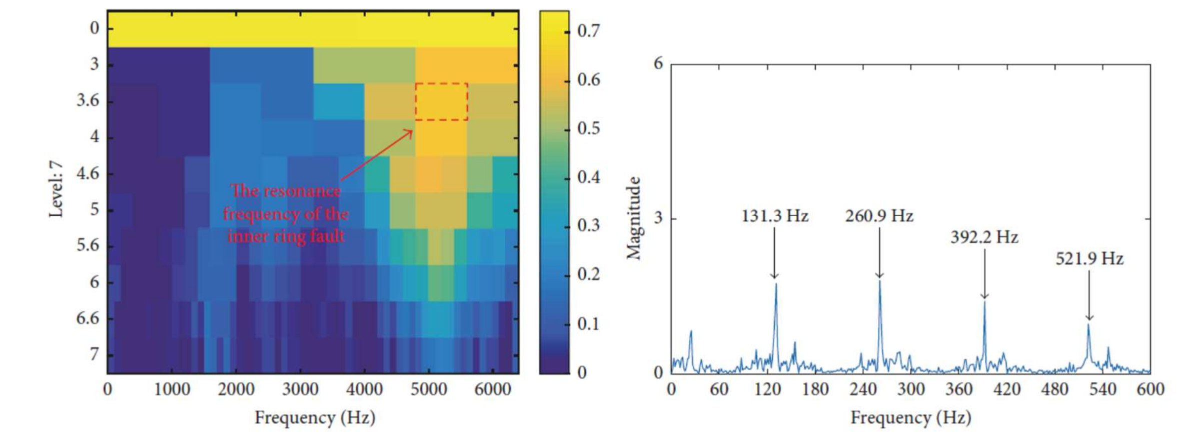

Figure 9: the fast spectral kurtosis & Envelope spectrum analysis of the inner ring fault signal after MCKD

4. RESULTS AND DISCUSSIONS

Table 3 shows the theoretical fault frequencies, fault frequencies obtained by FSK & fault frequencies obtained by FSK after filtering with MCKD of outer and the inner ring of rolling element bearings. From figure 7, 8, & 9 we find the different values of fault frequencies before & after MCKD.

On comparing the output frequencies of bearing fault before and after using MCKD with theoretical frequency, **figure 10 shown a chart which proves that while using FSK with a pre-processor known as MCKD, we get more precise results for compound fault feature extraction of bearings.**

Table 3: fault frequency of the inner and outer ring of bearing before and after MCKD

Parameter	Inner Ring	Outer Ring
Theoretical Defect frequency (Hz)	132.2	87.7
Defect frequency by FSK	176.6 (Almost nil)	87.5
Defect frequency by FSK after filtering with MCKD	131.3	87.5
Fault detection % before MCKD	74.85	99.77
Fault detection % after MCKD	**99.31**	**99.77**

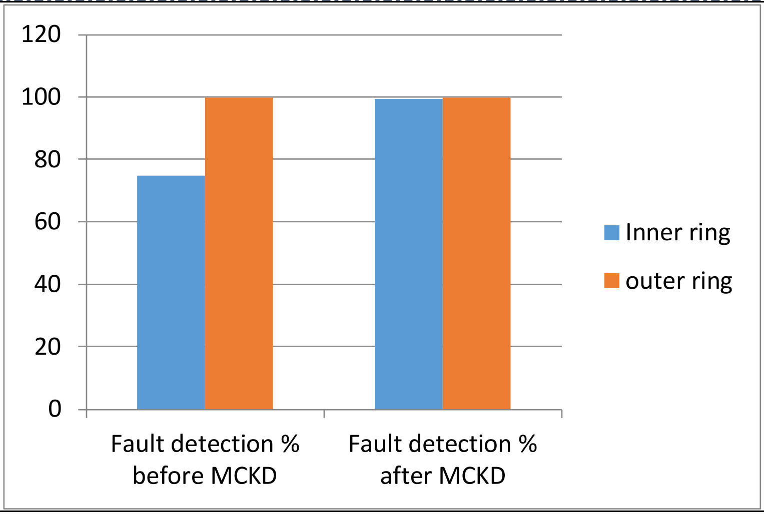

Figure 10: Chart showing comparison of inner and outer ring, fault detection % before and after MCKD

5. CONCLUSION

On comparing the Experimental data of the method with theoretical fault characteristic values, we find that the method with MCKD extracts more accurate fault frequencies. The method of maximum correlation kurtosis deconvolution (MCKD) is used to extract the compound faults in bearing and, also effective in extracting the weak impact characteristics from high background noise

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