The data points and variation of RMS and Kurtosis values of acceleration with speed for the Case II are given in Table 4.3 and Figure 5.8 respectively.

4.2.2 Case II: Healthy bearing with one bolt

Table 4.4: Data points for RMS and Kurtosis values of acceleration with speed

Speed(RPM)	*RMS value(m/s²)*	*Kurtosis value*
300	0.06	-0.055
600	0.92	-0.182
900	1.0	-0.165
1500	2.2	0.423
2100	2.4	-0.133
2500	3.6	0.685

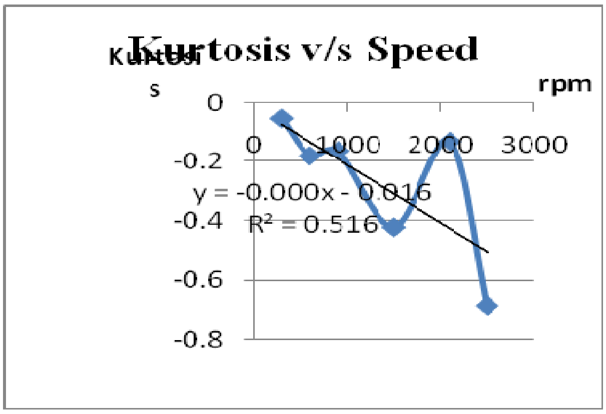


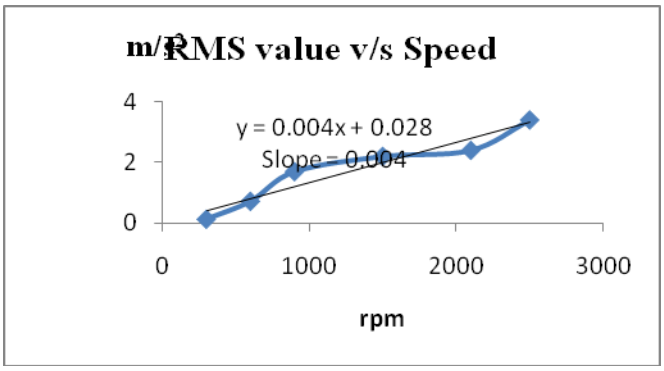
Figure 4.8: Variation of RMS and Kurtosis values with speed and their "Best Fit"for Case II

The data points and variation of RMS and Kurtosis values of acceleration with speed for the Case II are given in Table 4.4 and Figure 4.8 respectively.

4.2.3 Case III: Healthy bearing with two bolts

Table 4.5: Data points for RMS and Kurtosis values of acceleration with speed

Speed(RPM)	*RMS value(m/s²)*	*Kurtosis value*
300	0.13	-0.651
600	0.72	-0.237
900	1.7	-0.265
1500	2.2	-0.073
2100	2.4	-0.204
2500	3.4	-0.366



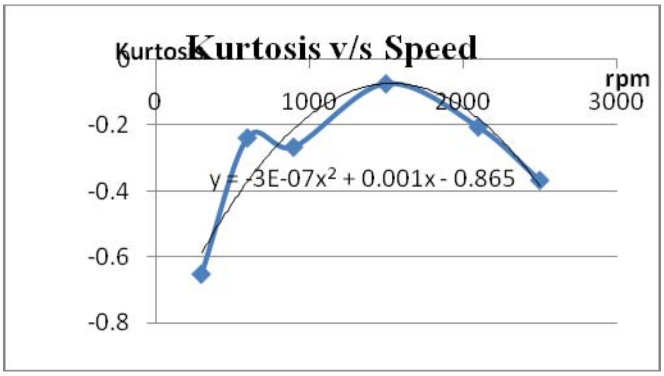


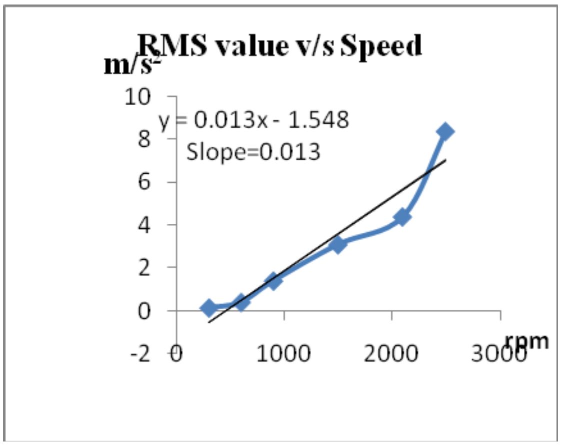
Figure 4.9: Variation of RMS and Kurtosis values with speed and their "Best Fit" for Case II

The data points and variation of RMS and Kurtosis values of acceleration with speed for the Case II are given in Table4.5 and Figure 4.9 respectively.

4.2.4 Case IV: Defective bearing with no bolt

Table 4.5: Data points for RMS and Kurtosis values of acceleration with speed

Speed(RPM)	RMS value (m/s²)	Kurtosis value
300	0.14	1.456
600	0.4	1.895
900	1.4	0.654
1500	3.1	0.183
2100	4.4	0.288
2500	8.4	0.464



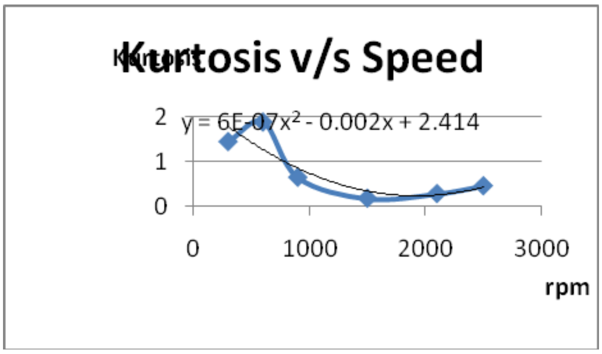


Figure 4.10: Variation of RMS and Kurtosis values with speed and their "Best Fit"for CaseIV

The data points and variation of RMS and Kurtosis values of acceleration with speed for the Case II are given in Table 4.6 and Figure 4.11 respectively.

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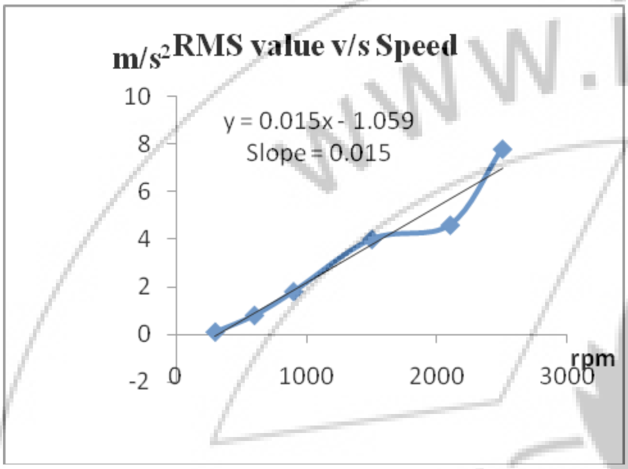
4.2.5 Case V: Defective bearing with one bolt

Table 4.6: Data points for RMS and Kurtosis values of acceleration with speed

Speed(RPM)	RMS value(m/s^2)	Kurtosis value
300	0.1	1.595
600	0.8	2.057
900	1.8	-0.070
1500	4.0	0.300
2100	4.6	0.380
2500	7.8	0.305



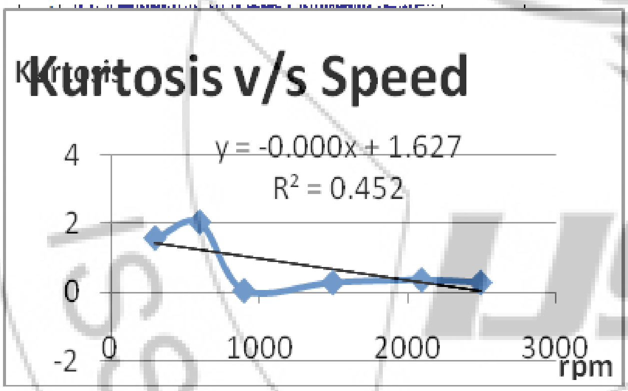


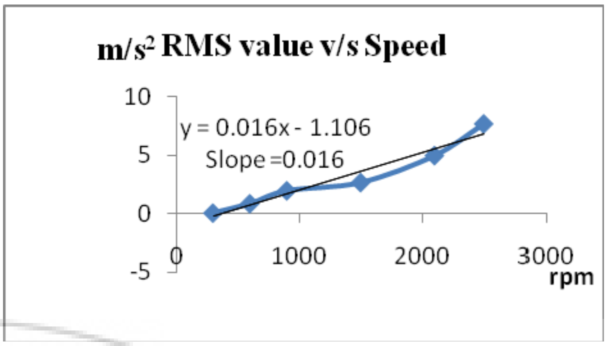
Figure 4.11: Variation of RMS and Kurtosis values with speed and their "Best Fit"for caseV

The data points and variation of RMS and Kurtosis values of acceleration with speed for the case II are given in Table 5.7 and Figure 5.12 respectively.

4.2.6 Case VI: Defective bearing with two bolt

Table 4.7: Data points for RMS and Kurtosis values of acceleration with speed

Speed(RPM)	*RMS value(m/s^2)*	*Kurtosis value*
300	0.1	1.867
600	0.9	0.076
900	2.0	0.653
1500	2.7	0.207
2100	5.0	0.397
2500	7.7	0.728



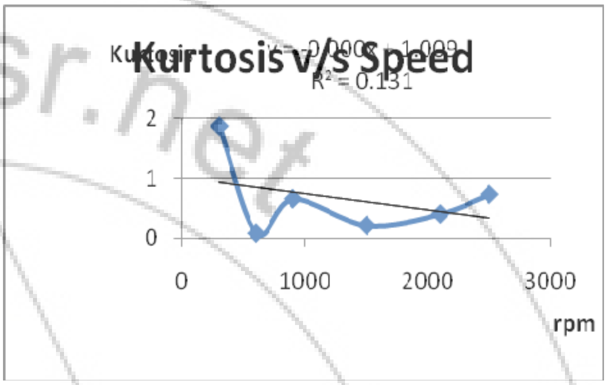


Figure 4.12: Variation of RMS and Kurtosis values with speed and their "Best Fit" for Case VI

Inference

a) From the above figures it is seen that the values of Kurtosis for healthy bearing is close to 0 with negative values which indicate the fault free state of the bearing. For defects on the inner race lies with positive values between 0.1 and 3. This is the clear indication of the defects in the bearing.

4.3 Inference from RMS Value and Kurtosis Analysis

Table 4.8 shows the slopes of RMS value v/s speed "Best Fit curve for the six cases considered.

Table 4.8: Slopes of RMS value v/s speed "Best fit" curves for the six cases

Case	*Description*	*Slope of the RMS value v/s Speed "Best fit"*
I	Healthy bearing with No Bolt	0.002
II	Healthy bearing with One Bolt	0.001
III	Healthy bearing with Two Bolt	0.004
IV	Defective bearing with No Bolt	0.013
V	Defective bearing with One Bolt	0.015
VI	Defective bearing with Two Bolt	0.016

Inference

1) For healthy bearings, slope of the RMS Value v/s Speed best fit curve gradually increases as unbalance increases.
2) As the defect is introduced in the bearing, the corresponding slope values shoot approximately to 10 times of their values for healthy bearings subjected to same unbalance.

Table 4.8: Regression Values of Kurtosis v/s Speed " Best fit" curves for the six case

Case	*Description*	*Regression value of the Kurtosis v/s Speed "Best fit"*
I	Healthy bearing with No Bolt	0.264
II	Healthy bearing with One Bolt	0.516
III	Healthy bearing with Two Bolt	--
IV	Defective bearing with No Bolt	--
V	Defective bearing with One Bolt	0.452
VI	Defective bearing with Two Bolt	0.131

Inference

1. For healthy bearings, regression values of the Kurtosis v/s speed best fit curve decreases with unbalance. The trend is reverse of the trend of RMS Values with speed. This can be validated by the Equation (7).

$$Kurtosis = \frac{\sqrt{\sum_{i=1}^{N} \frac{(x_i - x_m)^2}{N}}}{RMS^4} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

2. For defective bearings, regression value of the Kurtosis v/s speed best fit curve decreases with unbalance.
3. Bearing signals are not periodic but stochastic (or random) having indeterminacy. This allows them to be separated from deterministic signals such as from gears [v]. Thus, the kurtosis curves reflect an uncertainty in their trend.

5. Conclusion

The development of bearing condition monitoring test rig was successfully carried out which can be used to determine the health of a bearing used in the rotating machinery. The RMS value analysis validates that the ball bearing health can be fairly monitored using frequency domain analysis. The Proposed Statistical analysis proves to be a simple, quick and cost effective method in the condition monitoring of ball bearings. The method proves to be most suitable for random signals obtained from bearings. The RMS value shows that as the speed increases, the magnitude of vibration response also increases. Additionally, the Kurtosis value for new bearing is close to 0 with negative values which is a clear indication that no defects in the bearing. For inner race defect the value lies with positive values between 0.1 and 3, indicating moderate defect in the bearing. Hence kurtosis value shows the state of the bearing.

Based on the studies carried out on frequency response analysis of Deep groove ball bearings, it can be concluded that FFT spectrum indicate the location of the fault. Additionally, Kurtosis, one of the statistical parameters is evaluated for the above cases of the defects on the bearing. Kurtosis though indicates state of the bearing; it cannot detect the location of faults. Also, it is not suitable for detecting fault on outer race of rolling bearing. The results reveal that vibration based monitoring method is effective in detecting the faults in the bearing.

The RMS value analysis validates that the ball bearing health can be fairly monitored using frequency domain analysis. The proposed statistical analysis proves to be a simple, quick and cost effective method in the condition monitoring of ball bearings.

Experimental study reveals the frequency response analysis is an effective tool in analyzing the frequency signal obtained from bearing in order to characterize and condition monitoring of rotary equipments.

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