SIGNATURE ANALYSIS OF CENTRIFUGAL FAN RESPONSE DUE TO UNBALANCE USING WAVELET ANALYSIS

P. Divyasri [1], K. Depti [2], Dr.D. Srinivasa Rao [3]

[1] *M.Tech Student,* [2]*Assistant Professor, Department of Mechanical Engineering,*
Vikas College of Engineering and Technology, Vijayawada, (India)
[3]*Professor, Department of Mechanical Engineering,*
DMS SVH College of Enginering, Machilipatnam, (India)

ABSTRACT

Condition monitoring is the process used to analyze the operating condition of rotating machines. Vibration Signature Analysis is the most commonly used technique. As a general rule, machines do not breakdown or fail without some form of warning, which is indicated by an increased vibration level. The most general problems in fans used in industry are due to mass unbalance. Mass unbalance occurs in a rotating machine when the center of mass does not coincide with the geometric center and the weight of the object. This improper balancing of the system leads to vibrations of high values on bearings and supporting structure over a period of time. This result in the loosening of components, changes the bearings centerline, and damages the pedestals for the period of starting/stopping. In the present work the Centrifugal Fan (i.e., Combustion Air Fan) of Billet Mill of Vishakhapatnam steel plant is selected for revise. The fan shaft supported between two bearings causes vibration due to unbalance and the velocity vibration of the bearing lie towards fan end was measured in three mutually perpendicular directions. The experimental frequency spectra obtained for both balanced and unbalanced condition of the shaft were further analyzed using wavelet transform to implement condition based maintenance of rotating machinery.

Keywords: Balancing, Condition Monitoring, Frequency Response, Industrial Fans, Wavelet Transform.

I INTRODUCTION

Combustion Air Fans (CAF) are used to supply air for combustion to walking beam furnace of 200Tons/hour in Light and Medium Merchant Mill of steel plant (LMMM).These fans are very critical for running of Billet Mill. In the present work the study of vibration of such fan was considered for the revise. The specifications of the fan are mentioned in the following chapter. The purpose of the work is to identify the behavior of the fan and its supporting structure with unbalance. The natural frequency of the fan as a composite system could be found and study of bearing dynamics is possible. The ide al balancing of rotors cannot be accomplished due manufacturing faults such as increase or decrease of material during operation, non-homogeneous density of material, manufacturing tolerances and porosity in casting [1].The centrifugal force generated due to this unbalance mass must be reacted against bearings and supporting structures. The force caused by the unbalance part is synchronous as it rotates with sane speed [2]. Analytical closed form expressions have been proposed by Rao [3] for major and minor axes of the unbalance response orbit for single rotor bearing system. Study of progressive machine malfunctions can be done using vibration signatures which also form the baseline for further comparative monitoring to identify mechanical defects [4].The present work by following the balancing of unbalanced masses of rotating fan shaft was carried out from the signature analysis obtained in three mutually perpendicular directions. The vibration spectrums were then subjected to Continuous Wavelet Transform (CWT) with ‘sym 2’ wavelet using MATLAB [6] program.

II EXPERIMENTAL SETUP AND PROCEDURE

The LMMM of VSP steel plant has 3 Combustion Air Fans (CAFs) out of which two are in running condition and one standby purpose. These fans supply air for combustion to the walking beam furnace of 200Tons/Hr. Among them the fan number 2 was considered for conduction experiment after fan is assembled with new bearing and installed after removing running fan for maintenance. It consists of a motor of 560 Kw with rated speed of 1485 RPM. The mass of the impeller was 560 kg and the capacity of fan is 1, 00,000 M^3/Hr under ambient temperature. The motor, fan bearings and the impeller of fan are supported by steel structure on isolators. It was observed that the fan started with abnormal vibrations exceeding the limits. IEPE Accelerometer having sensitivity mv/g (0.1 to 10,000) is connected to the vb8 instrument installed with Ascent software. The accelerometer was mounted on the top of the Plummer block casing. The vibration Spectrum in vertical direction was collected by allowing the fan to operate. The data was collected in vb8 data collector. The vibration spectrums were also collected in horizontal and axial directions.

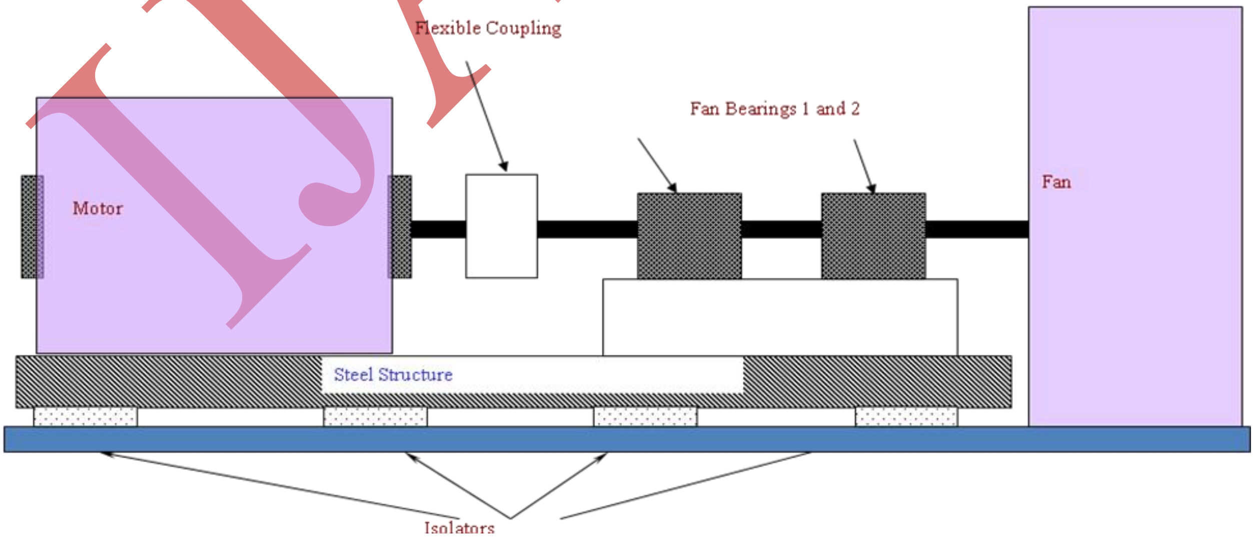

Figure1. Layout of Combustion Air Fan

The analysis found unbalance of the impeller. In- situ balancing was carried out with the provision available with vb8 instrument by removing 816 gms weight from the impeller which was happened to be earlier balancing weight. Final balancing was done later. The frequency spectra were once again collected in balanced condition. Wavelet analysis was carried out on these spectra using CWT with 'sym 2' wavelet.

III WAVELET TRANSFORM

Signal Analysis of Vibration Data – Key for Fault Detection & Monitoring. Signals with sharp sudden changes could be better analyzed with an irregular and asymmetric wavelet than with a smooth sinusoid. Wavelets have limited duration that has an average value of zero. Wavelets are functions that satisfy certain mathematical requirements and are used in representing data or other functions. This idea is not new. Approximation using superposition of functions has existed since the early 1800's, when Joseph Fourier discovered that he could superpose sines and cosines to represent other functions. However, in wavelet analysis, the scale that we use to look at data plays a special role. Wavelet algorithms process data at different scales or resolutions. If we look at a signal with a large "window, we would notice gross features. Similarly, if we look at a signal with a small "window," we would notice small features. The result in wavelet analysis is to see both the forest and the trees, so to speak.

This makes wavelets interesting and useful. For many decades, scientists have wanted more appropriate functions than the sines and cosines which comprise the bases of Fourier analysis, to approximate choppy signals. By their definition, these functions are non-local (and stretch out to infinity). They therefore do a very poor job in approximating sharp spikes. But with wavelet analysis, we can use approximating functions that are contained neatly in finite domains. Wavelets are well-suited for approximating data with sharp discontinuities.

The wavelet analysis procedure is to adopt a wavelet prototype function, called an analyzing wavelet or mother wavelet. Temporal analysis is performed with a contracted, high-frequency version of the prototype wavelet, while frequency analysis is performed with a dilated, low-frequency version of the same wavelet. Because the original signal or function can be represented in terms of a wavelet expansion (using coefficients in a linear combination of the wavelet functions), data operations can be performed using just the corresponding wavelet coefficients. And if you further choose the best wavelets adapted to your data, or truncate the coefficients below a threshold, your data is sparsely represented. This sparse coding makes wavelets an excellent tool in the field of data compression.

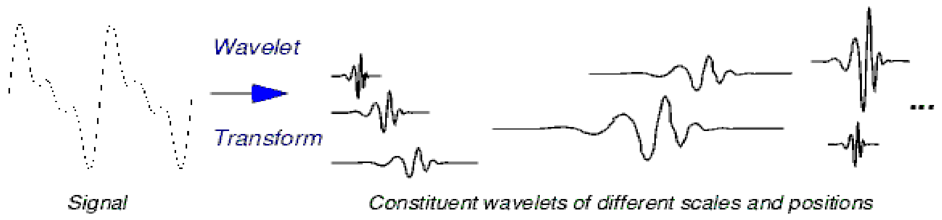

Figure2. Representation of wavelet transform

Signal broken into a series of local basis functions called wavelets, which are scaled and shifted versions of the original (or Mother) wave let. Wavelet transforms are most broadly classified into the discrete wavelet transform (DWT) and the continuous wavelet transform (CWT). The DWT is used for signal coding whereas the CWT is used for signal analysis. Consequently, the DWT is commonly used in engineering and computer science and the CWT is most often used in scientific research. In this project work continuous wavelet transform (CWT) is used [7].

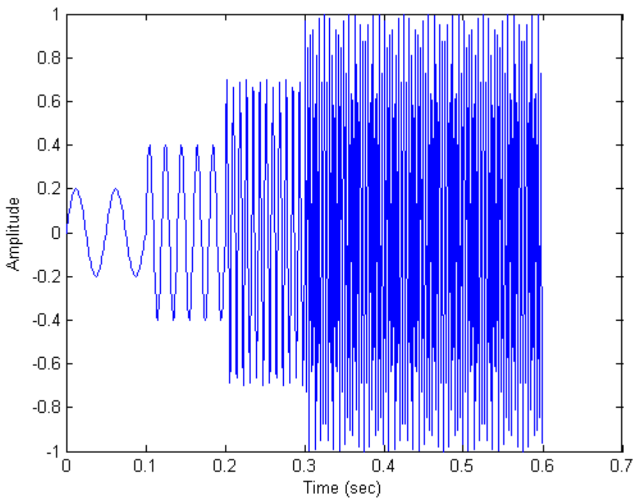

Figure3. Example of Continuous Wavelet Transform

3.1 Functions of Wavelet Transform

1. Convert a signal into a series of wavelets.
2. Provide a way for analyzing waveforms, bounded in both frequency and duration.
3. Allow signals to be stored more efficiently than by Fourier transform.
4. Be able to better approximate real-world signals.
5. Well-suited for approximating data with sharp discontinuities.

IV RESULTS AND DISCUSSIONS

The vibration signature of CAF bearing showed high velocity amplitudes in all directions during unbalanced condition. These vibration signatures are shown from “Fig. 4” to “Fig. 6”. These signatures are subjected to CWT using “sym 2” wavelet using MATLAB. The wavelet coefficients obtained for different scales for axial direction is shown in “Fig.10”. Subsequently the wavelet coefficients for vertical and horizontal vibration signatures were also obtained which are not shown here. It was observed the resonant frequency of CAF as whole in vertical direction is 586 CPM, in horizontal direction it is 672 CPM and in axial direction 764 CPM. Removal of weight 816 gms from the impeller lead to balancing, and these vibration signatures are shown in “Fig.7” to “Fig.9”. These signatures are then subjected to CWT. The drastic reduction of wavelet coefficients were observed during the shaft rotation. These are shown in “Fig.12” to “Fig.14”. In these figures the wavelet coefficients of vibration signatures are drawn at a particular scale 24. The wavelet coefficient of vibration signature of CAF in balanced condition for different scales is shown in “Fig.11”. It is observed that the high values of wavelet coefficients obtained during unbalance which are indications of high velocity amplitudes during rotation of the shaft near the natural frequency of the system. These values are 3.799 in horizontal, 4.1419 in vertical and 4.456 in axial directions due to unbalance. These wallet coefficients reduced to very low values after the completion of process of balancing of the shaft. The above mentioned surveillance can be seen in “Fig.12” to “Fig.14” in respective directions.

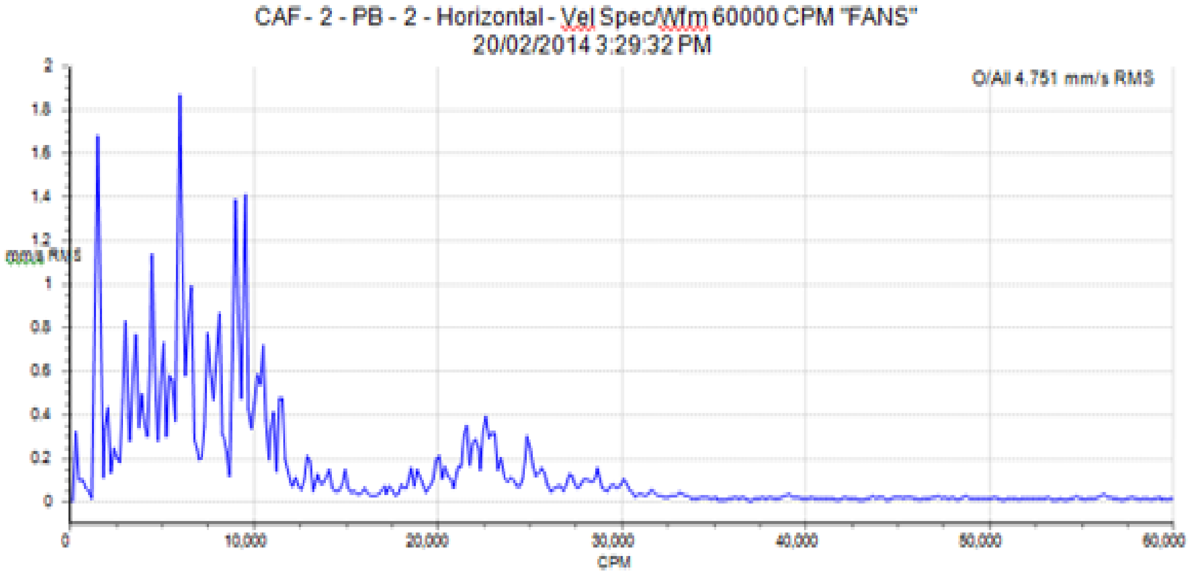

Figure 4. Velocity Spectrum in Horizontal Direction of CAF Bearing in Unbalanced Condition

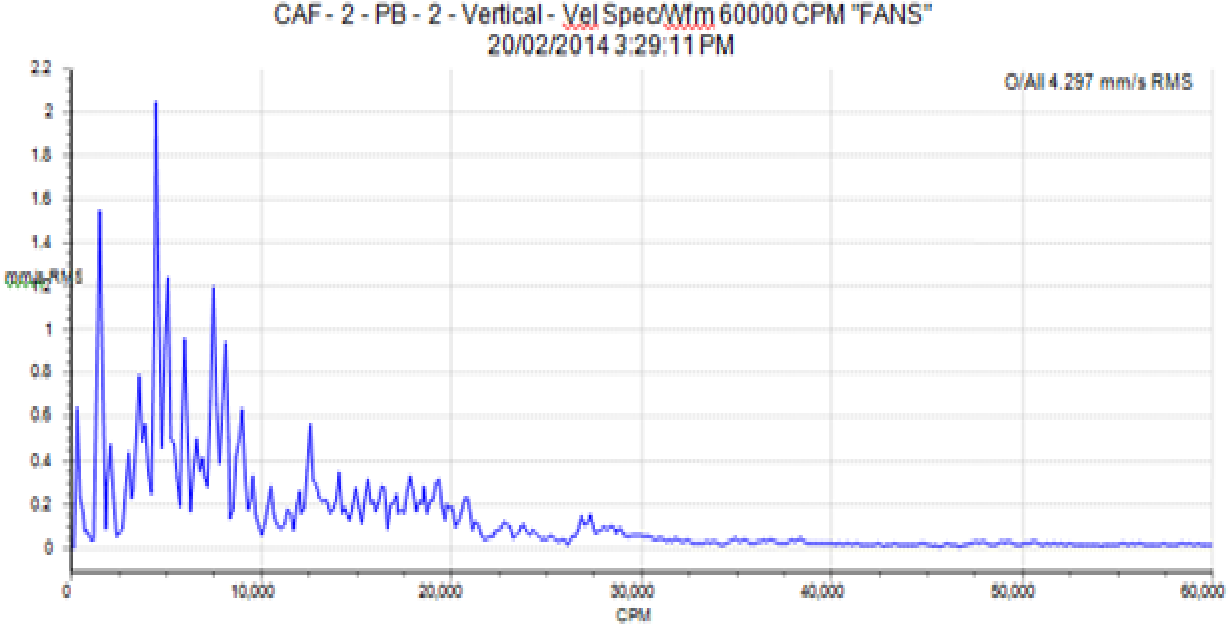

Figure 5. Velocity Spectrum in Vertical Direction of CAF Bearing in Unbalanced Condition

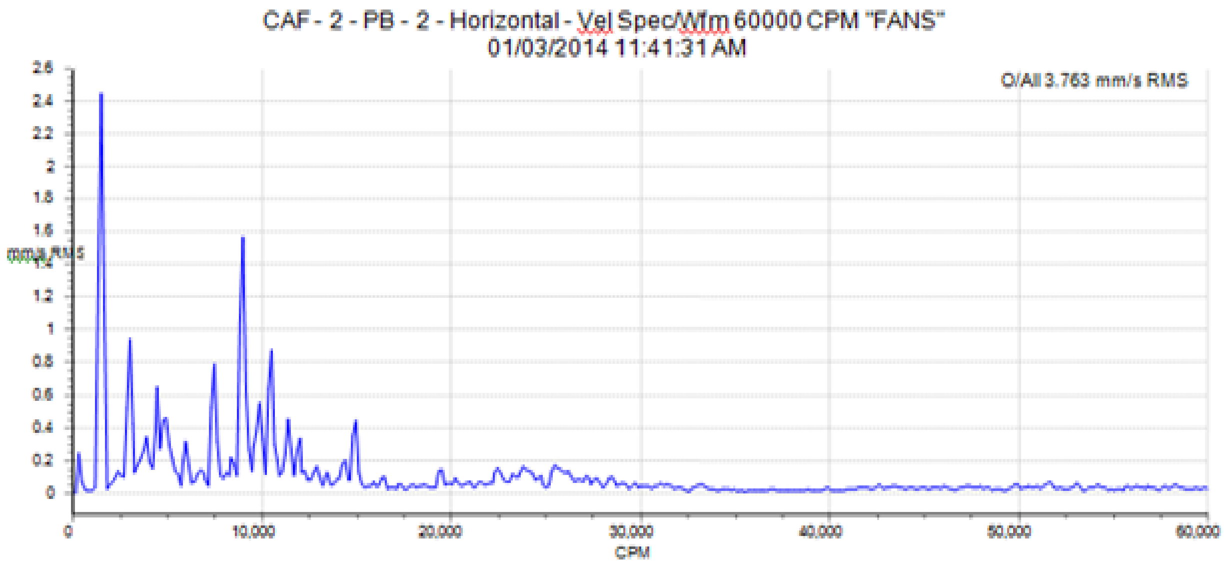

Figure 7. Velocity Spectrum in Horizontal Direction of CAF Bearing in Balanced Condition

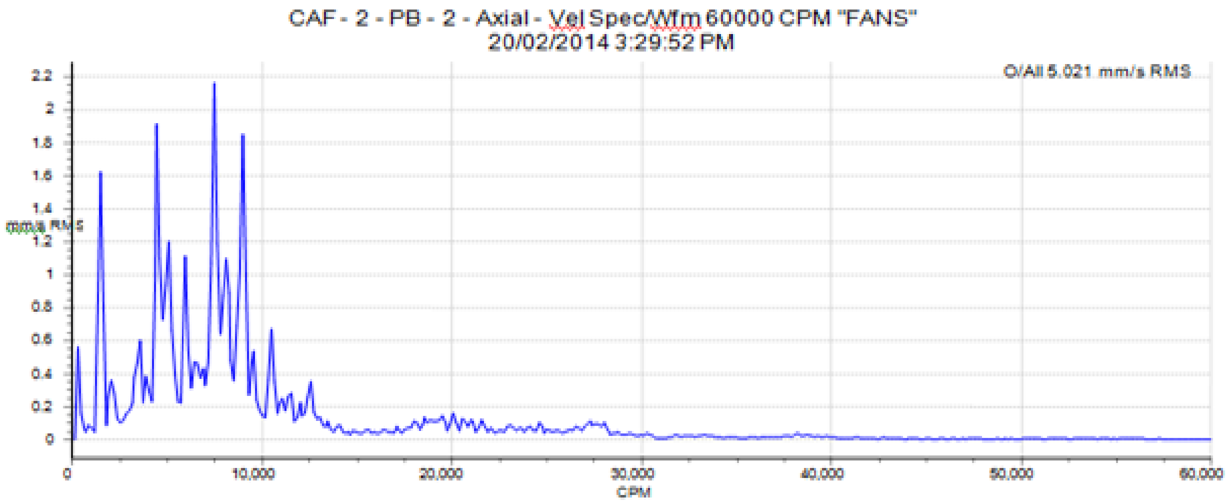

Figure 6. Velocity Spectrum in Axial Direction of CAF Bearing in Unbalanced Condition

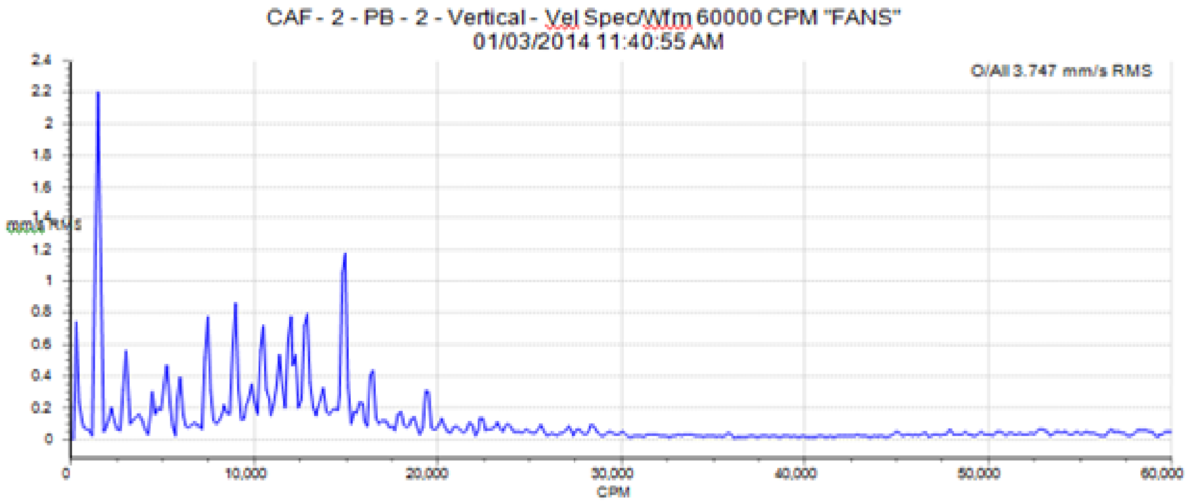

Figure 8. Velocity Spectrum in Vertical Direction of CAF Bearing in Balanced Condition

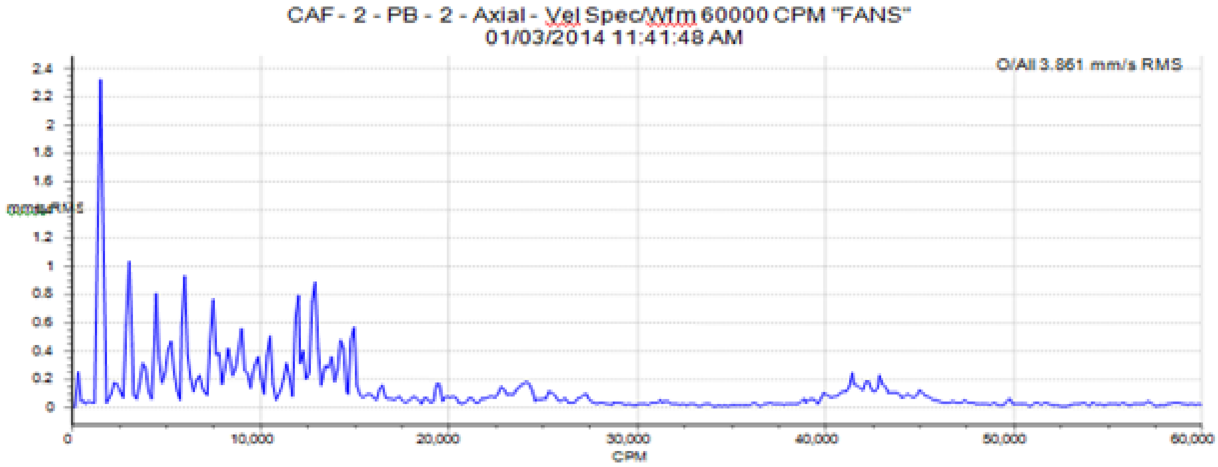

Figure 9. Velocity Spectrum in Axial Direction of CAF Bearing in Balanced Condition

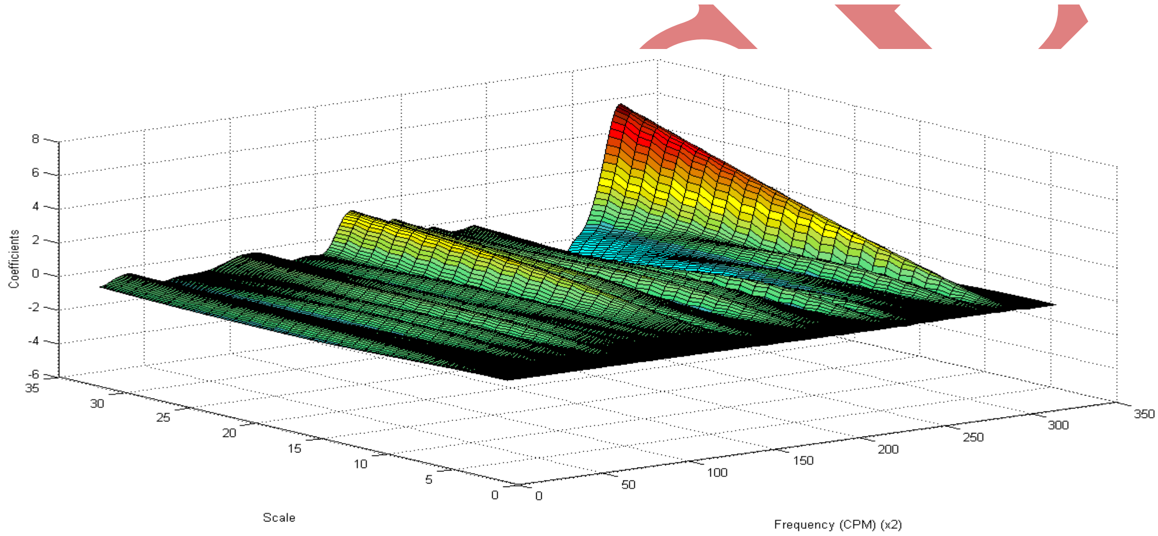

Figure10. Wavelet Coefficients of CAF vibration spectrum in Axial direction for Unbalanced Condition

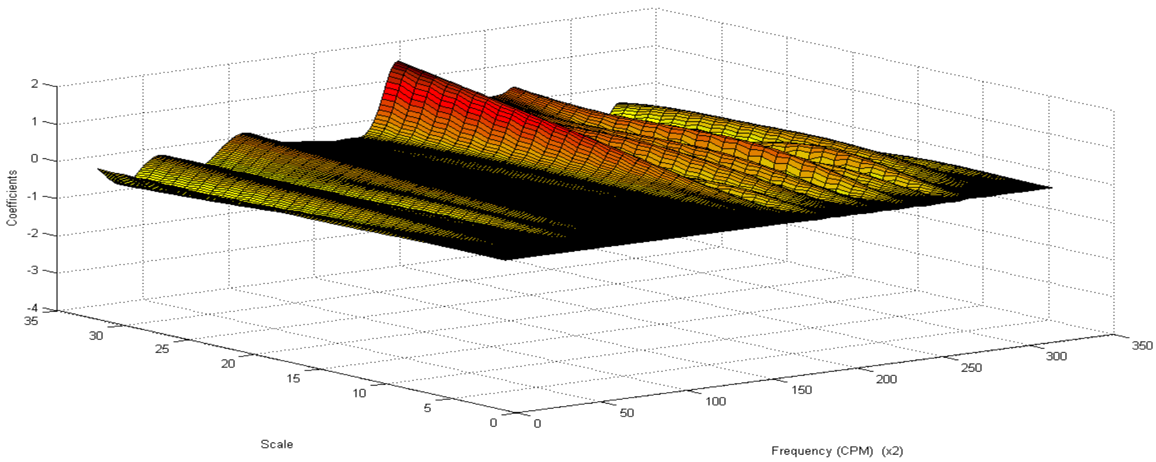

Figure11. Wavelet Coefficients of CAF vibration spectrum in Axial direction for Balanced Condition

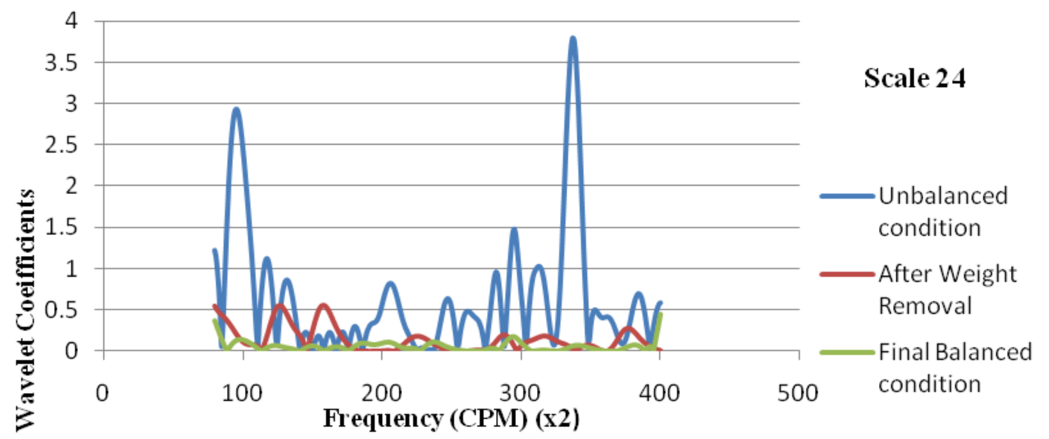

Figure 12. Frequency Vs Wavelet Coeifficients of Vibration spectrum in Horizontal direction

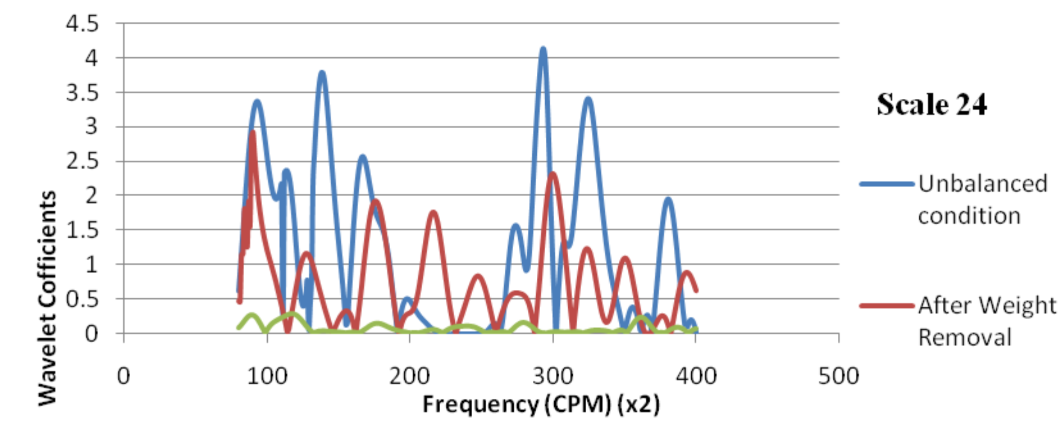

Figure 13. Frequency Vs Wavelet Coeifficients of Vibration spectrum in Vertical direction

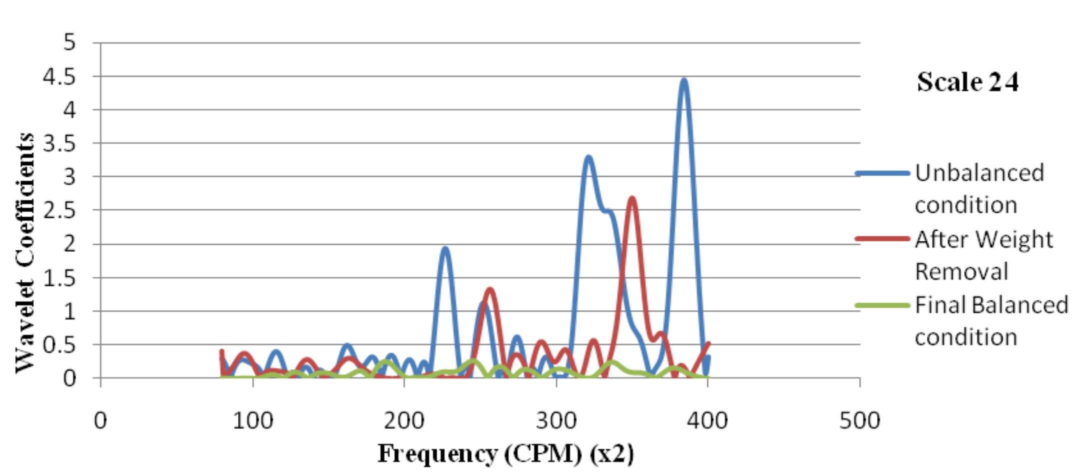

Figure 14. Frequency Vs Wavelet Coeifficients of Vibration spectrum in Axial direction

V CONCLUSION

It is obvious from the above investigation the unbalance may direct to breaking of the base, pedestals during the system's coasting up or down, even though the system is mounted on vibration isolators. Distortion of shaft centerlines, eccentric running of bearings and raise of bearing temperature are the possible actions of higher unbalance. The centrifugal force causes more radial displacement of shaft centerline and increase the bearing wear and leads to the breakdown of cages due to imprecise operation. It is healthier practice to balance the rotors at different stages at operating speed in – situ to exterminate all existing factors which will induce stress to rotating as well as stationary supports.

VI ACKNOWLEDGEMENTS

The authors are grateful to acknowledge the support extended from Dr. Edwin Vijay Kumar, AGM Technical Services Department, and Visakhapatnam Steel Plant. The authors are also thankful to Department of Technical Services, Visakhapatnam Steel Plant for providing the necessary testing facilities.

REFERENCES

[1] Eshleman, R and A. Eubank, Critical speeds of a continuous rotor, *Journal* of Engineering *for Industry, 91, 1969, 1180-1188*.

[2] D.E. Bently, *Fundamentals of Rotating Machinery Diagnostics* (Bently Pressurized Bearing Press, Minden, La, USA, 2002).

[3] Gupta, K.D. Gupta and K Athre, Unbalance response of a dual rotor system theory and experiment, Transactions *Journal of Vibration a Acoustics, 115, 1993, 427-435.*

[4] K.P.Ramachandran , Vibration signature analysis for machine health monitoring and fault diagnosis, *Caledonian Journal of Engineering 2004 , 26-39,*

[5] Ronald l. Eshlemen, *Basic machinery vibrations An introduction to machine testing, analysis and monitoring* (Clarendon Hills, Illinois, 1999).

[6] MATLAB 7.0.1 the math works of Imc

[7] Mladen Victor Wickerhauser, *Adapted Wavelet Analysis from Theory to Software* (AK Peters Ltd, 1994).