Mansoura University
Faculty of Engineering
Mansoura Engineering Journal

Vibration and Faults Prediction for Air Blowers – Case Study

الإهتزازات والتنبؤ بالعيوب لنافخات الهواء– دراسة حالة

Hassan El-Rammal, *Samy El-Gayyar* and Salah H. El-Emam

KEYWORDS:
Predictive Maintenance; Condition Monitoring; Vibration Analysis; Air Blower

الملخص العربي:- في أي عملية إنتاجية يتم إنفاق جزء ملحوظ من التكاليف الكلية على أعمال الصيانة الخاصة بالمعدات وللتحكم في هذا القدر من الإنفاق فإن اختيار سياسة الصيانة الفعالة يمثل خطوة أساسية وضرورية لتحقيق معدلات عالية من الإنتاجية مع تقليل التكاليف وضمان اعتمادية المنشأة الصناعية وتحسين الإتاحية للمعدات. وحيث أن سياسة الصيانة التنبؤية للماكينات الدوارة تعتمد على تشخيص أسباب أعطال الماكينات قبل حدوثها، فإن هذا البحث يقدم عرضا تفصيلياً لتطبيق هذه المنهجية (كحالة دراسية) على نافخ هواء موجود بمصنع إنتاج سماد اليوريا بالعين السخنة بجمهورية مصر العربية للإمداد بالهواء اللازم لتذرير وتشكيل حبيبات اليوريا، ويعتبر الوحدة الرئيسية والأكثر أهمية في خط الإنتاج كما أن توقفه يؤدي إلى توقف العملية الإنتاجية بالكامل. في هذا البحث تم العمل من خلال عدة مراحل أساسية بدأت بإعداد جهاز القياس لجمع البيانات وفقا لمتطلبات القياس المطلوبة. تم الحصول على بيانات الاهتزاز عند عدة نقاط مختلفة بكراسي التحميل لنافخ الهواء والموتور الكهربي في اتجاهات مختلفة مع مراقبة حالة الماكينة بمتابعة القراءات دوريا. بعد ذلك تم تغذية القراءات التي تم الحصول عليها لبرنامج تحليل قاعدة بيانات الاهتزاز باستخدام جهاز حاسب آلي مع متابعة نتيجة التحليل حتى يتم رصد ارتفاع ملحوظ بالقراءات. بعد ذلك تم إجراء تحديد خصائص الاهتزاز على أساس التحليل الطيفي، وعليه أمكن تحديد واكتشاف عيوب النافخ والتنبؤ بدرجة خطورتها ومعدل تزايدها لتحديد الوقت المناسب لإيقاف الماكينة وإجراء الصيانة المطلوبة قبل حدوث الانهيار. تمت مقارنة القيم الإجمالية للاهتزاز وأطيافه وذلك في كلاً من ظروف التشغيل المبدئية، وخلال وقوع الخلل والعطل، وأيضاً بعد عملية التصحيح للعيوب، ومراجعة كلا منها بخارطة درجة خطورة الاهتزازات وفقاً للمعيار الدولي (ISO 10816-1). ومن هذه الدراسة أمكن التحقق من فاعلية كلاً من منهجية الاجراءات التشخيصية والتنبؤية وإمكانية تطبيقها لمعدات دوارة أخري.

Abstract— **At any production process, a significant part of the total cost has been expended during the maintenance of the operated equipment. To control this maintenance cost; choosing certain, clear, and effective policy is an essential for increasing industrial productivities, minimize related costs, and to ensure plant reliability and equipment availability. Predictive maintenance policy for rotating equipment had been used in the machinery fault diagnosis. This research introduces detailed elucidation for this methodology as a case study of an industrial air blower located in urea fertilizer production plant at Ain-Sokhna, Egypt, acting as an air atomization source required for the formation process of urea granules. It is considered as the main and more critical equipment in the production facilities and its breakdown leads to complete stoppage of the production process. The proposed methodology has been organized in certain phases; starting with the preparation of measuring instrumentation for data acquisition. Data gathering from various determined locations at the blower and drive electric motor bearings in different directions was performed. After that, feeding acquired data to the supporting vibration database analysis software on PC and followed it up periodically till high values were detected. Vibration data analysis performed on the basis of spectral plot, frequencies against amplitude. The spectral analysis was used to analyze blower faults and predict their causes and consequences to determine the time of machine shutdown and maintenance. Vibration overall values and spectrum compared on initial conditions, troubleshooting, and after carrying-out corrective action; also referred to vibrations severity standard according to the international standard (ISO-10816-1). From this study; effectiveness of diagnostic and prognostic methodology was verified to be applied for other rotating equipment.**

Received: 22 May, 2016 - accepted: 9 August, 2016

Hassan El-Rammal, Department of Mechanical Power Engineering, Mansoura University, Mansoura 35516, Egypt

Samy El-Gayyar, Department of Production Engineering and Mechanical Design, Faculty of Engineering, Mansoura University, Mansoura 35516, Egypt

Salah H. El-Emam, Department of Mechanical Power Engineering, Mansoura University, Mansoura 35516, Egypt

I. INTRODUCTION

CONDITION monitoring (CM) is the process used to analyze the operating condition of machines. It considered as an aspect of predictive maintenance. CM techniques, diagnostic systems are mainly applied to technologically critical, expensive machines and based on technological parameters measurements. The CM techniques has long been practiced by maintenance personnel who relied on their innate senses of hearing, touch, and sight, but the judgment and conclusions were often not reliable. For instance, it may involve vibration measurements, infrared thermography, oil analyses, etc. Vibration analysis is the most commonly used technique; that provides an early warning of impending failures.

The generated vibrations by machinery have become a well-utilized parameter for assessment in CM. It is one of the most versatile techniques, which is capable of detecting about 70% of common mechanical faults associated with rotating machinery.

Machinery vibrations are complex, but can be measured, processed, and their interpretation simplified in order to facilitate the implementation of recommended action. Rotating machinery produces vibration patterns, which have been repeated periodically and have been found to be amenable to analysis. Kirankumar et al., (2012) studied vibrations analysis to investigate the unbalance, misalignments, and imperfect bearings on rotating systems. Dabiri et al., (2009) used vibration analysis to analyze the unbalance effect on blower. Amarnath et al., (2004) used different vibration monitoring and analysis techniques such as time domain analysis and frequency domain analysis for suitability in identifying different defects in bearings. Barzdaitis et al., (2003) discussed the reasons of the amplitude growth of the synchronous frequency vibration of the electric motor rotor under the load of blower; results have been verified through an actual industrial plant. Edwards et al., (1998) introduced a general review of the broader issues of fault diagnosis. Also, detailed review of the subject of fault diagnosis in rotating machinery has been presented and special focus has been given to the areas of mass unbalance, bowed shafts and cracked shafts.

Vibration response measurements yield a great deal of information concerning any faults within a rotating machine, and many of the methods utilizing that technique are reviewed. Vasylius et al., (2008), determined the main reason of the journal bearings failure. Some other authors use vibration analysis tool to study the energy loss during mechanical fault phenomena. Gaberson and Cappillino, (1996) established an experimental program to conduct accurate measurements of the energy lost due to misalignment and unbalance of rotating machinery. Estupiflan et al., (2008) finding a correlation between vibration levels and energy consumptions for different degrees of misalignment.

Monitoring and analysis the vibration characteristics of an air blower give us as understanding of the health condition of it. That has been utilized in this study to detect problems that might be occurred, and enable us to have suitable fast response to any problems. Dileep et al., (2009) explained that the vibration predictive maintenance program has four steps;

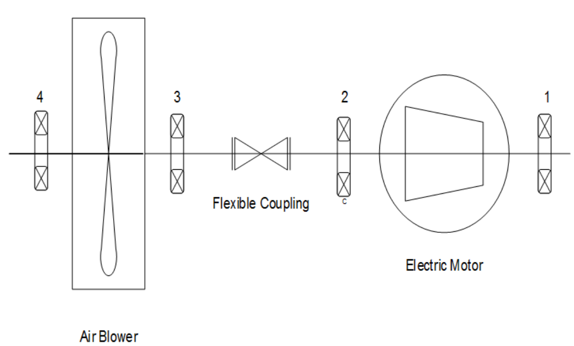
- Detection,
- Analysis,
- Correction,
- Confirmation.

This is also similar to the sequence of the proposed methodology. This methodology was set for an air blower which operating in continuous long term running mode in the facilities of urea fertilizers production plant. That is used for air atomization. This type of blowers was selected because of; its criticality in the fertilizer plants, its failure or the unexpected stoppage damages the technological process, and it's one of the repeated common problems in this industry. The conditions of this air blower and its driving motor were monitored and experimentally tested to study the involved mechanical problems. Failure diagnostic was done via vibration signal monitoring, processing and analysis based on frequency domain only.

II. CASE STUDY AND MEASURING INSTRUMENT

The case study considered was conducted on industrial air blower located in urea fertilizer production plant at Ain-Sokhna, Egypt. The plant produces urea granules with a full production capacity of 2000 ton/day. It's employed as the atomization air source required for the formation process of urea granules. It's derived via medium voltage electric motor. Table 1 tabulates both design and normal operating specifications of the blower. Fig. 1 shows a schematic diagram of the blower arrangement and Fig. 2 shows a photographic image for the air blower at its location.

For vibration data monitoring and analysis, Vibration Analysis System: Brüel&Kjær (B&K) from (Schenck, Germany), Vibro60 vibration data collector device, shown in Fig. 3, is used as measuring instrument for carrying-out required tests. It was supported via the vibration database analysis software XMS on PC and using velocity transducer type AS-065. Sensitivity of a piezoelectric transducer is 10.2 mV/m/s2 ± 5% and frequency range from 3 Hz to 10 kHz (± 0.5 dB) and 1 Hz to 15 kHz (± 3 dB).



1: motor outboard bearing, 2: motor inboard bearing
3: blower inboard bearing 4: blower outboard bearing

Fig. 1 Schematic diagram of atomization air blower

Fig. 2 Photographic image for atomization air blower

Fig. 3 Vibration data collector (B&K VIBRO 60)

TABLE 1
DESIGN AND NORMAL OPERATING SPECIFICATIONS OF THE AIR BLOWER

	Design	**Normal**
Medium	Atmospheric air containing salt and urea traces	
Density at suction cond.,(kg/m3)	1.135	1.136
Suction pressure stat., (mbar)	998	1000.12
Suction temperature, (°C)	32	32
Pressure increase, stat. required, (mbar)	622.2	569
Running speed, (rpm)	3000	2984
Rated power, (kWatt)	1250	

III. EXPERIMENTAL PROCEDURE

Measurements are taken on regular basis for all bearing pedestal supports along horizontal (H), vertical (V), and axial (A) directions for both air blower and electric motor. Bearings are considered as the reading verification was set according to manufacturer recommend-actions and all measurements are for parameter of velocity in (mm/sec.) with statistical parameter of root mean square (rms), and vibration data collector was set to collect such parameters. Vibration measurements are carried-out under approximately 90% of the full load (40849 m3/h). The vibration transducer was mounted via magnetic base at each measuring position. Monitoring was scheduled to be weekly and it was performed during 13 months till high readings was detected and became at the alert and danger zones as per (ISO 10816:1995) as shown in figures 4 and 5 in next part which illustrates a sample of vibration overall values for both blower and motor.

IV. RESULTS AND DISCUSSION

Vibration overall values were trended during the examination time. One week readings each month were selected as a sample reading for this month. Figures below show a sample of the resulted trends of vibration overall values of both air

Blower and electric motor. These trends are a correlation between vibration amplitude on Y-axis which indicates the vibration severity degree versus time on X-axis. Fig.4 shows the trend of vibration overall values of the air blower outboard housing-type bearing in the axial direction as readings started from initial condition till it became at alert and danger zones while Figure 5 shows the same range of vibration overall values trend but for the electric motor inboard bearing in axial direction. Data transform was performed for all resulted readings via Fast Fourier Transform (FFT). This signal processing task was done to get spectrum diagrams which are a correlation between frequency in Hz. versus amplitude in mm/s. to illustrate the various existed frequencies and their amplitudes as shown in figures 6, 7, 8 and 9.

V. VIBRATION SPECTRUM ANALYSIS AND FAULT POSSIBILITIES

Vibration levels are showing general increase at most locations especially in both axial and vertical directions. It shows significant increase compared to initial running readings. Technical condition of the air blower is critical since housing-type outboard bearing vibration value in axial direction reached (10.413 mm/s) as shown in Fig. 4.

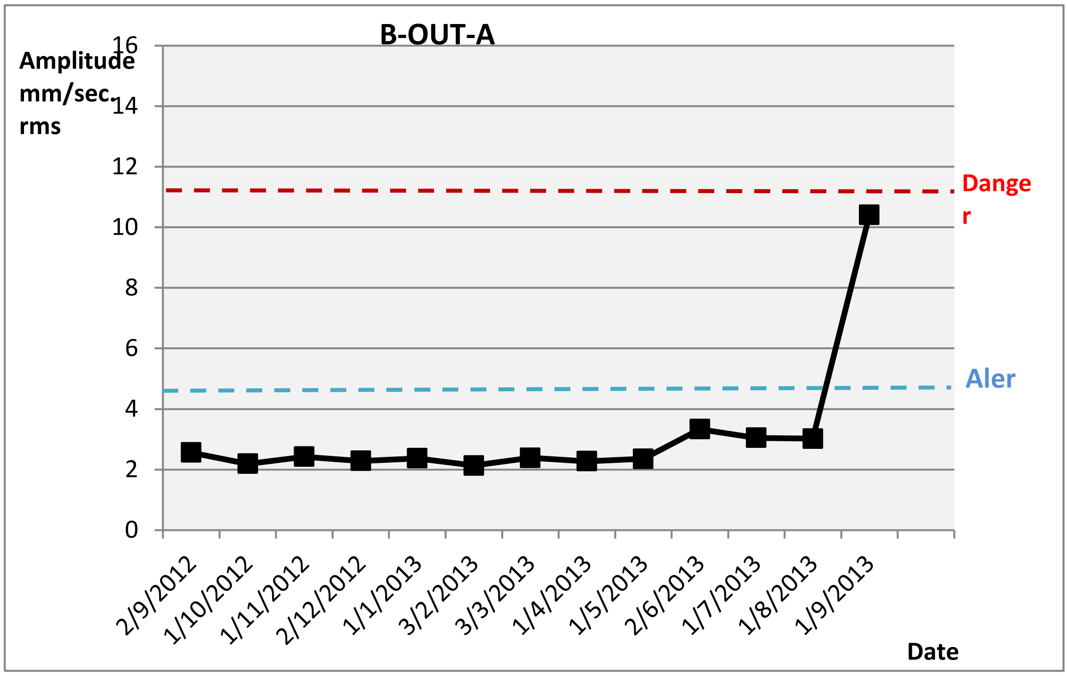


Fig. 4 Blower inboard bearing overall values in axial direction

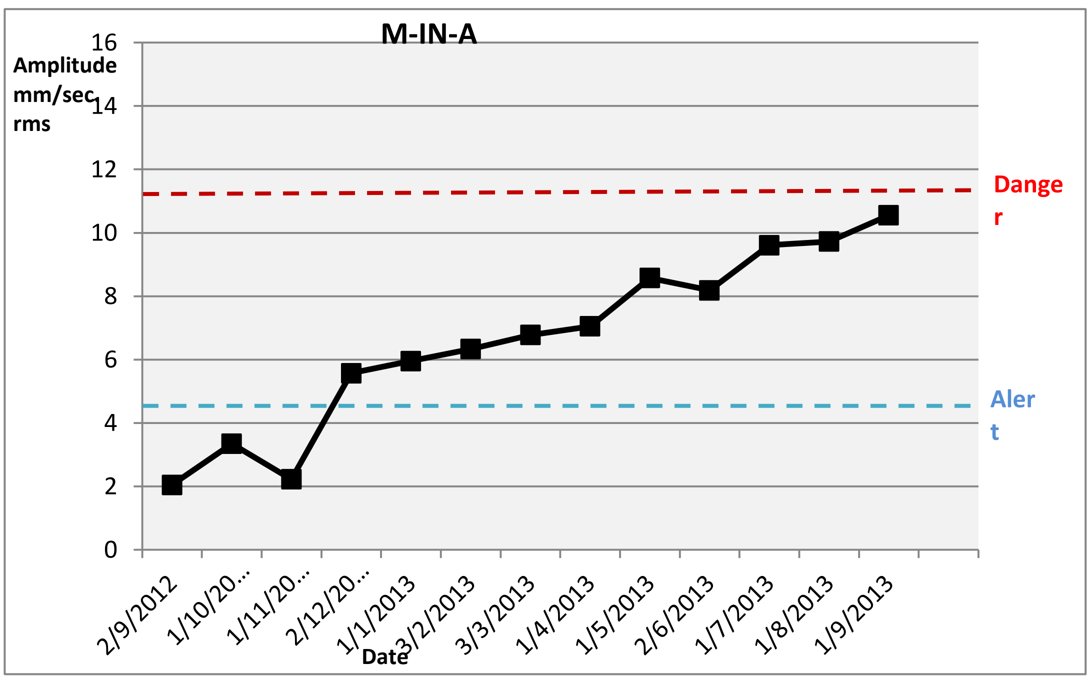


Fig. 5 Motor inboard bearing overall values in axial direction

It was observed that a significant increase in vibration values at this point and referring to vibration severity chart of the standard (ISO 10816-1:1995) which is appropriately color coded according to defined mechanical faults it became at the not permissible zone. Gradient increase was observed also at the electric motor inboard bearing in the axial direction as shown in Fig. 5 during the regular measurement basis till it became at the not permissible zone as per vibration severity chart of the standard (ISO 10816-1:1995). Norton and Karczub, (2003) explain and clarify that at the phase of vibration analysis the most dominant vibration frequency is the machine running speed component. In this study the first order of machine running speed component 1X=49.688 Hz is dominant in the vibration velocity spectrum of both blower and electric motor bearings as shown in the spectrum diagram of air blower outboard bearing in axial direction, Figure7 is comparing it with spectrum of the same point at initial running, as shown in figure6. Appearance of several harmonics for the running speed component at multiple orders as in the motor inboard bearing in axial direction Fig.9 and comparing it with spectrum of the same point at baseline verification Figure8 indicates looseness problem. The relative magnification 2X=99.376 Hz existence may indicate slight misalignment problem between the blower and motor as 1X is the main response frequency when there is no misalignment; while 2X-rotating speed appears when misalignment is present Guang et al., (2008) and the 2X and 3X vibration amplitude components are predominant frequencies and increase as the misalignment and shaft rotational speed increases, Rameshkumar et al., (2012). Based on the previous analysis of the blower vibration signature analysis, the following are recommended corrective actions that should be taken at both blower and motor which could be lead to solve the machine problem;

- Bearing clearances and temperatures should be measured and checked.

- Thrust bearing should be checked for any defects and if any one exist; bearing replacement should be took-place.

- Check for the alignment between shafts of air blower and electric motor; adjust if required.

- Cleaning for the air blower impeller and for the air inlet passage to avoid any turbulent air flow or impeller unbalance as a result from dust accumulation.

VI. Corrective Action and Repairs

The machine was stopped for check and maintenance during 1 month as per recommendations based on vibration analysis that previously explained.

During machine shutdown the following activities were carried-out according to previous considerations;

- Housings of both inboard and outboard bearings were dismantled for bearing inspection; and defects were detected at the inboard (thrust) bearing at the inner angular race and at thrust pads also (Figs. 10, 11, & 12).
- Replacement was done for the defected inboard (thrust) bearing of air blower.
- Replacement was done for labyrinth seal of the defected bearing also.
- Clearance of journal bearing was measured and checked, found it in recommended range.
- Axial displacement of thrust bearing was measured and checked found, it in recommended range.
- Alignment between both blower and motor was checked, and found out of tolerance, so it was adjusted.
- Cleaning was done for the blower impeller and air inlet duct.

After corrective action taken for the machine and repairs were finished, it was operated again.

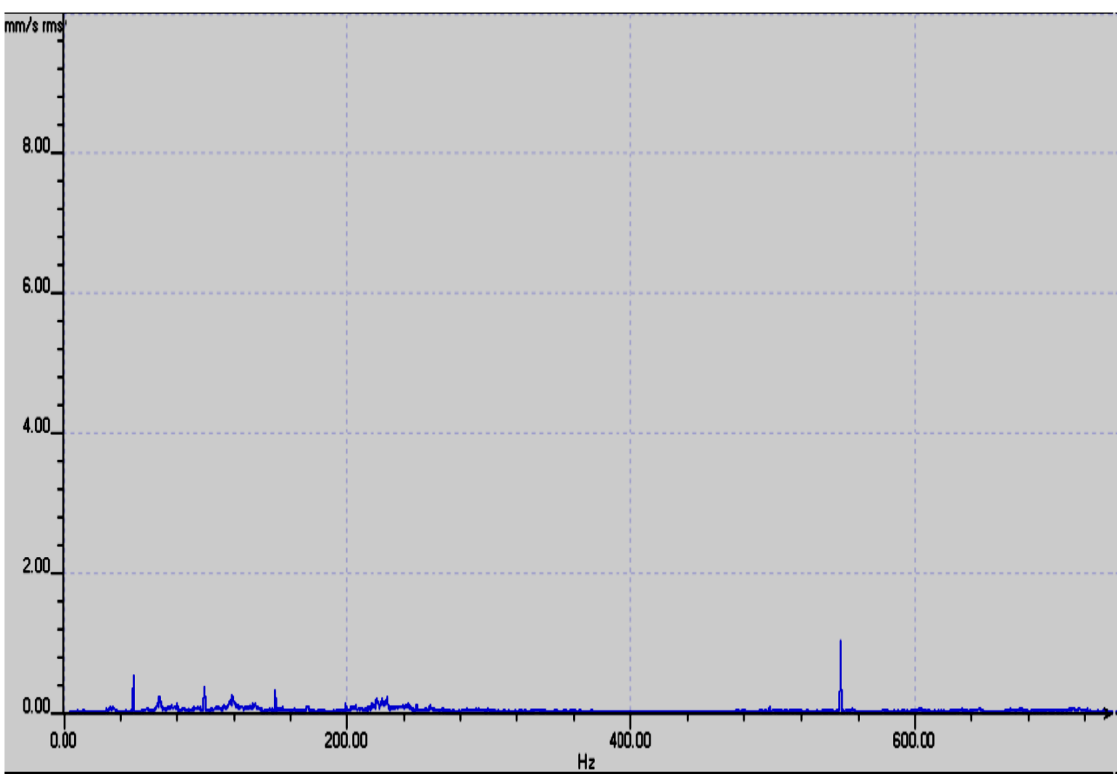


Fig. 6 Blower outboard bearing spectra diagram in axial direction, initial running

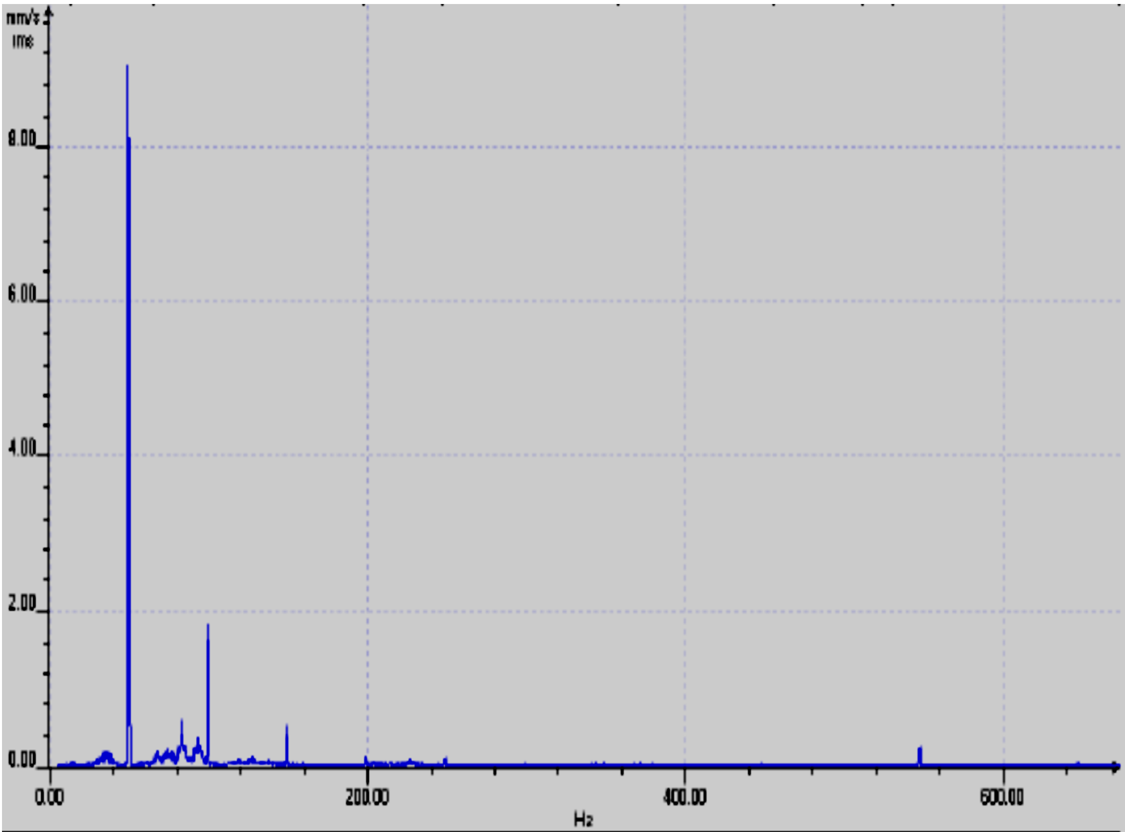


Fig. 7 Blower outboard bearing spectra diagram in axial direction, within fault occurrence

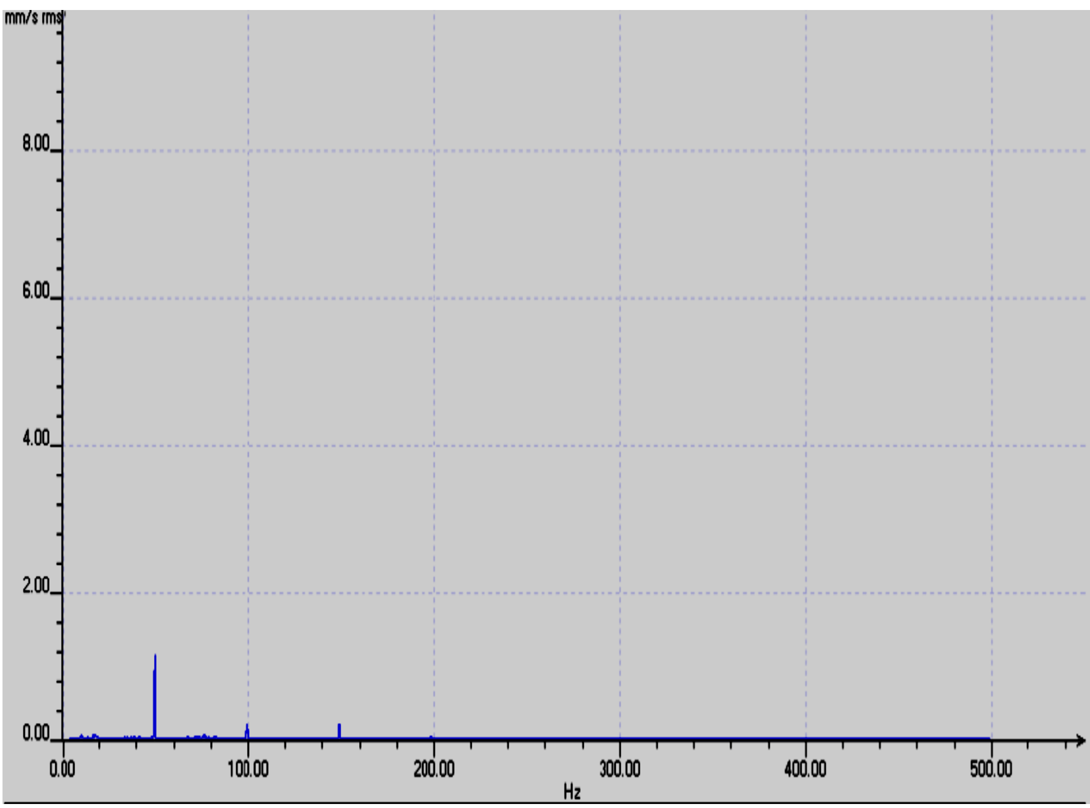


Fig. 8 Motor inboard bearing spectra diagram in axial direction, initial running

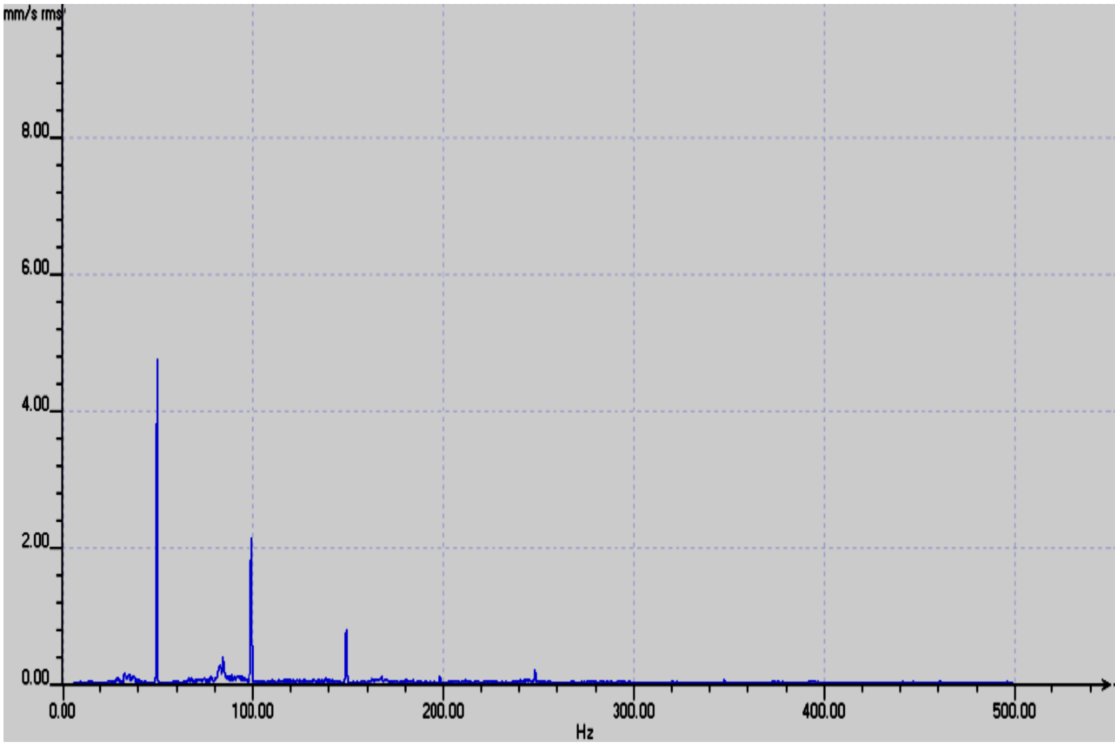


Fig. 9 Motor inboard bearing spectra diagram in axial direction, within fault occurrence

Fig.10. Defects at thrust bearing 2nd half inner angular race

Fig.12. Defects at thrust bearing inner angular race

Fig.11. Defects at the thrust bearing pads

Vibration monitoring process took-place again for another six months to determine machine new condition after maintenance throughout vibration monitoring and analysis technique as per the same sequence mentioned in part 3.

Fig.13 and 14 show a sample of vibration overall values for equipment after maintenance which could be compared with results showed in figures 4 and 5, noted that all measurements are for (mm/sec) velocity root mean square (rms) and data acquired from the same points.

From the obtained results, the following conclusions are identified:

Irregular harmonics are observed in the axial direction at both blower and motor which indicates a problem at thrust bearing.

Indication for such other problems was detected via this technique such as looseness and misalignment.

With this indications, corrective action was initiated to avoid further development of these faults and ultimately to reduce machine breakdown.

Replacement of bearing requires a temporary shutdown of the blower (about 1 month working time) as it couldn't be waiting for a planned shutdown based on the vibration severity.

After replacement of bearing, the previously occurred irregular harmonics were vanished in axial and vertical direction.

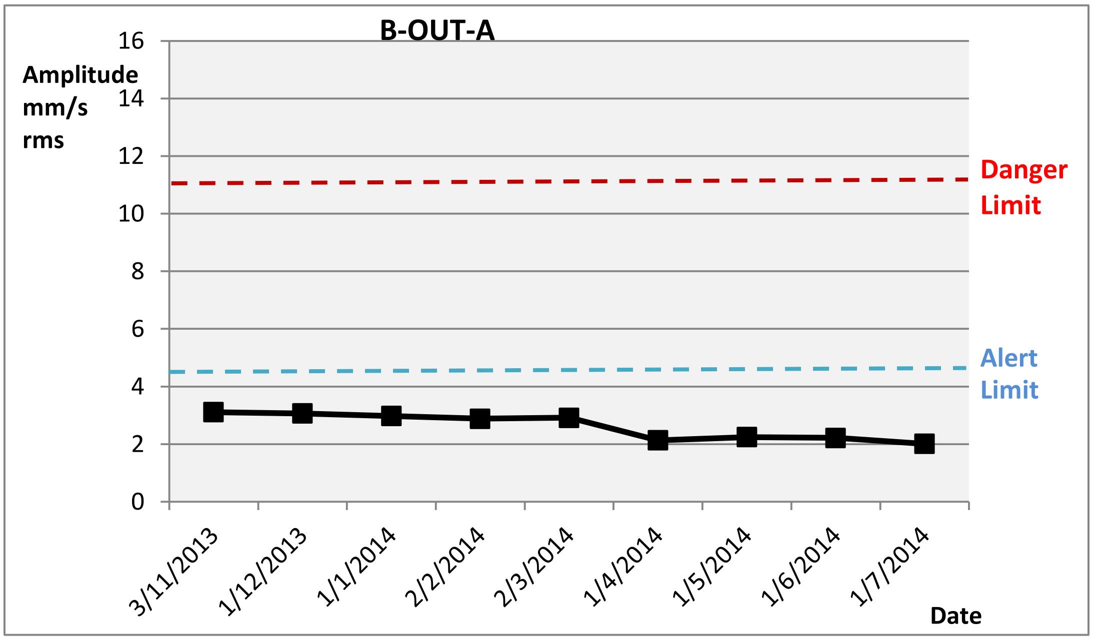


Fig. 13 Blower outboard bearing overall values in axial direction after machine rectification

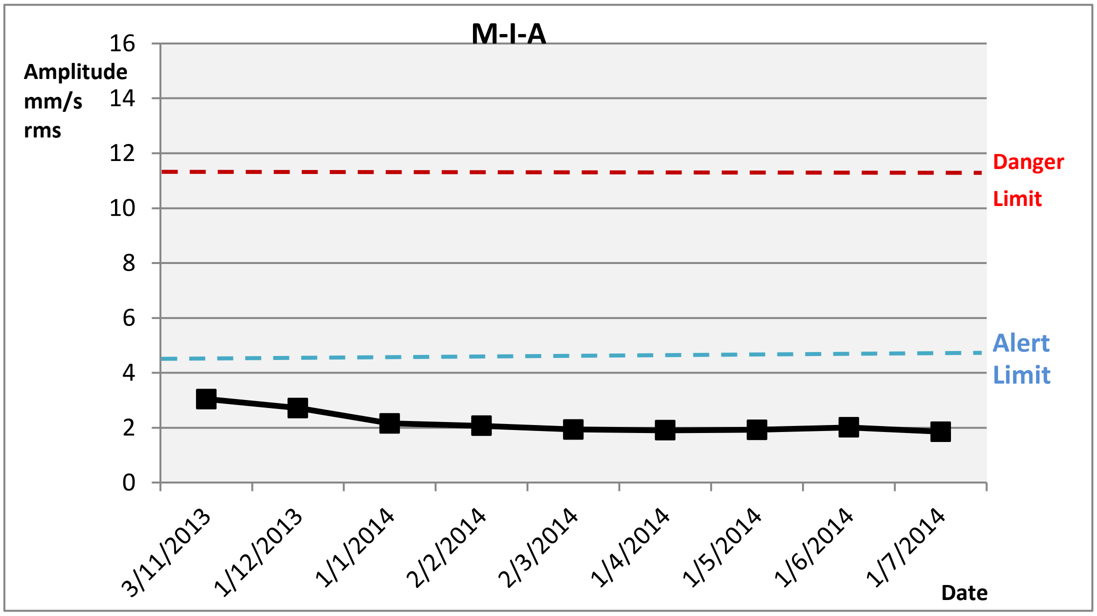


Fig. 14 Motor inboard bearing overall values in axial direction after machine rectification

VII. Conclusion

Vibration analysis considered to be powerful technique adopted in condition monitoring process.

- A diagnostic condition-based technique that could be used for the predictive maintenance of rotary equipment had evolved from this study.
- In this study, vibration analysis is used to examine various mechanical and aerodynamic faults in an air blower.
- Abnormal vibration evolution, which could be used to detect faults and defects.
- The entire case study is a practical application of vibration monitoring and analysis in the machine condition monitoring and fault diagnosis area.
- Spectral based analysis had been used in this procedure.
- Faults of the rotating air blower and its driving motor in fertilizers industry identified through analysis of its vibration characteristics which displayed based on numerate and graphical basis.
- This diagnostic and prognostic methodology is applicable to use for other rotating equipment after determined each machine class at the vibrations severity chart.
- To apply this methodology; it is important to determine the power consumption and running speed of the machine.
- This proposed methodology was significantly save time and money.

References

[1] Amarnath,M., Srinidhi,R., Ramachan-dra, A. and Kanadagal, S.B., 2004, *Prediction of Defects in Antifriction Bearing Using Vibration Signal Analysis*, Institution of engineers (India) Mech. J, vol. 85, pp. 88-92.

[2] Barzdaitis,V., Bogdevičius,M., Gečys, S., 2003, *Vibration Problems of High Power Air Blower Machine*, ISCORMA-2, Gdańsk, Poland.

[3] Dabiri,H., Houshmandan,P., Mousavi, A. and Abbasi, K., 2009, *Overhung Blower Fault Diagnosis by Vibration Analysis and Using of Field Balancing Method for Correction in Shahid Tondgooyan Petrochemical Company*, 22nd International Congress, COMADEM 2009, San Sebastian, Spain, pp. 101-104.

[4] Dileep, N.,Anusha, K., Satyaprathik, C., Kartheek, B., and K. Ravikumar, 2013,*Condition Monitoring of FD-FAN Using Vibration Analysis*, International Journal of Emerging Technology and Advanced Engineering, vol. 3, no.1, pp. 170-176.

[5] Edwards, S., Lees, A.W. and Friswell, M.I., 1998, *Fault Diagnosis of Rotating Machinery*, Shock and Vibration Digest, Vol. 30, No. 1, pp. 4-13.

[6] Estupiflan, E.,Espinoza, D. and Fuentes, A., 2008,*Energy Losses Caused by Misalignment in Rotating Machinery: A theoretical, Experimental and Industrial Approach*, International Journal of COMADEM, vol. 11, no. 2, pp. 12-18.

[7] Gaberson, H. A., and Cappillino, R., 1996, *Energy Losses Caused by Machinery Misalignment and Unbalance*, Energy Conversion Engineering Conference, proceeding of the 31st Intersociety (Volume: 3), ISSN 1089-3547, Print ISBN 0-7803-3547, DOI: 10.1109/IECEC. 1996. 553377, IEEE, Washington, DC.

[8] Guang, Z., Liu, Z. and Chen, F., 2008, *Meshing Force of Misaligned Spline Coupling and the Influence on Rotor System*, International Journal of Rotating Machinery, vol. 2008, article ID 321308, 8 pages, doc:10.1155/ 2008/321308.

[9] International Standard, ISO 10816-1:1995.

[10] Kirankumar, B., Diwakar, G. and Satynarayana, 2012, *Determination of Unbalance in Rotating Machine Using Vibration Signature Analysis*, International Journal of Modern Engineering Research (IJMER), vol. 2. no.5, pp. 3415-3421.

[11] Norton, M.P. and Karczub, D., 2003, *Fundamentals of Noise and Vibration Analysis for Engineers*, 2nd edition, Cambridge University Press, The Edinburgh Building, Cambridge CB2 2RU, UK.

[12] Rameshkumar, G.R., Rao, B.V.A. and Ramachandran, K.P., 2012, *Coast Down Time Analysis to Analyze the Effect of Misalignment in Rotating Machinery*, International Journal of Engineering and Advanced Tech. (IJEAT), vol. 1, no.1, pp. 149-156.

Vasylius, M., Didžiokas, R., Mažeika, P. and Barzdaitis, V., 2008, *the Rotating System Vibration and Diagnostics*, ISSN 1392 - 1207. MECHANIKA. Nr.4 (72).