

# Condition Monitoring Of Surface Grinding Machine Using Raw Acoustic Emission Technique To Determine Bearing Failure

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## ABSTRACT

Equipment efficiency is a term related to the overall effectiveness of the equipment or machine. The overall equipment efficiency is characterized by three different aspects viz. - availability, performance and output quality. There are many methods being used for improving the efficiency of equipment. The strategy of predictive maintenance has led to the development of monitoring systems which monitor the health of machines/equipments. These techniques include use of AE, VA, OA, IRT techniques. Acoustic emission (AE) is the sound waves produced when a material undergoes stress as a result of an external force. Analysis of sound and acoustics plays a vital role in engineering tasks. In this work the use of raw acoustic waves to determine bearing failure in surface grinding machine spindle to control surface finish of the product is discussed.

**Keywords – Acoustic Emission, Bearing, Condition Monitoring, Surface Grinder**

## INTRODUCTION

Industries invest money heavily in machines for obtaining higher production levels; hence a machine should be utilized to its fullest extent. The major threat to the level of production is imposed by the breakdown of the equipment. The overall equipment efficiency is reduced due to the stoppage of production. Maintenance as defined by British standard glossary of terms [1] is “the combination of all technical and administrative actions, including supervision actions, intended to retain in, or restore equipment to, a state in which it can perform a required function”. Maintenance is a set of organised activities that are carried out in order to keep equipment in its best operational condition with minimum expenditure. The different maintenance strategies employed by industries can be categorized as follows-

- Run to Failure Maintenance (RTF)
- Preventive Maintenance (PM)
- Corrective Maintenance (CM)
- Improvement Maintenance (IM)
- Predictive Maintenance (PDM)

Condition-based predictive maintenance depends on continuous or periodic condition monitoring equipment to detect the signs of failure. In case when a machine breaks down it results in sudden failure, For which early

identification and rectification of machine related problems is critical to to insure continuous, safe, reliable and productive operation. [2] Condition based maintenance can be seen as an integral process of the seamless transformation of raw data related to equipment health and performance into information about process and system health that is essential in decision making regarding production operations [1, 3].

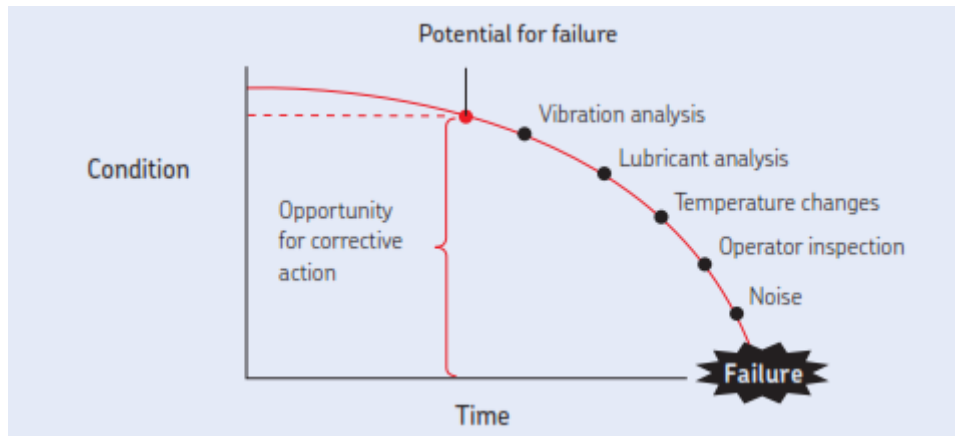


Fig. 1 graph of Time to failure Vs Prediction method used [4]

Condition monitoring techniques commonly used involve –

- 1) Vibration analysis (VA)
- 2) Oil debris analysis (OA)
- 3) Acoustic emission (AE)
- 4) Infrared thermography (IRT)
- 5) Temperature monitoring

## II. LITERATURE REVIEW

Acoustic emission (AE) is the sound waves produced when a material undergoes stress as a result of an external force. Analysis of sound and acoustics plays a vital role in engineering tasks such as product design, production test, machine performance evaluation, and process control. Acoustic emission signals generated by the sensor can be directly used for condition monitoring. These signals are called raw acoustic signals and contains a lot of information which can be processed and utilized successfully. [5] Dressing operation in grinding wheels can also be monitored by acoustic emission (AE) method of monitoring. This method helps in identification of out-of-round wheel and wheel contour errors. Dressing lead is the critical parameter in ensuring workpiece roughness.[6] Artificial Neural network technique (ANN) can also be used for grinding wheel sound discrimination. A three layer ANN gives 70% correct classification rate and an overall classification accuracy of 85%. [7] digital signal processing techniques are useful in deriving necessary information from the signals generated by sensors. Various statistical analyses tools such as RMS, correlation of AE, constant false alarm rate (CFAR), ratio of power (ROP), mean-value deviance (MVD) can be used to detect defects such as the grinding burns in grinding operation. [8] feature extraction and selection tools are also helpful in detecting grinding wheel defects. Autoregressive model, discrete wavelet transforms have been successively appliede in feature

extraction and tools such as artificial neural network (ANN), ant colony algorithm (ACO) etc are used for feature selection process. [9] The current research is done by analyzing raw acoustic signals generated by the grinding wheel in a surface grinder.

### **III. EXPERIMENTAL SETUP**

The usual practice followed in small scale industry is to perform breakdown maintenance. The small scale industries highly depend on skilled workers to decide and execute the maintenance schedules. The machine history data was collected and analyzed to understand stand alone characteristics of the grinding machine under study.[10] Experiments with using acoustic emission (AE) technique includes a surface grinding machine (vertical spindle), acoustic emission sensor to record the noise signals generated by the machine and spectral analysis software. The experimental setup includes a surface grinder, a sensor, DAQ (built in a computer recorder software), and signal analysis module. The sensor used for experimentation was a simple an omnidirectional microphone having Frequency Response: 20 ~ 16 KHz, Impedance: 32 ohms 1 KHz, Sensitivity: 58 dB /mW + 2dB. omnidirectional microphone is the one which captures the acoustic signals generated by different machine components from all sides. Acoustic emission monitoring uses sound waves generated when a material gets stressed due to the external force. These sound waves are used as a tool for grinding machine condition monitoring using a microphone (20-16kHz) to acquire the noise signals. Experimentation with acoustic emission technique is divided in two parts one is machine condition monitoring involving monitoring condition of machine bearings and other is grinding wheel (tool) condition monitoring.

Machine condition monitoring includes detecting occurrence of bearing defect. The acoustic signals for the healthy machine with new set of bearings is recorded and analyzed in frequency domain (FFT plot). Acoustic emission method indicates presence of an incipient defect three - four weeks before the actual failure of the part. As the machine runs its life; bearings start to wear. This results in generation of high amplitude noise by the machine bearings; according to OSHA a noise level over 60dB for a period of 5-6 hours is considered unsafe. The machine history data suggests that bearings fail with machining of 4000-6000 components (a time span of 3-5 months). The acoustic signals from the machine bearings are recorded periodically with 2-3 weeks span between two signal acquisitions. These noise signals emitted by the bearings are analyzed to find out changes occurring in the amplitude levels of certain frequencies. The amplitude of frequencies corresponding to the bearing characteristic frequency rises significantly when defect(s) are present in the bearing element.

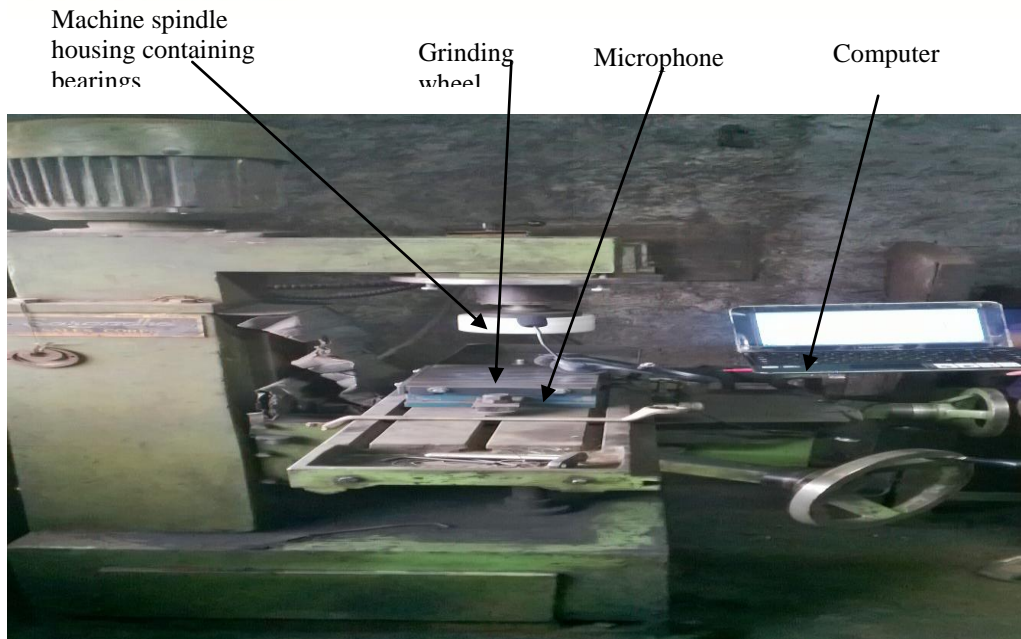
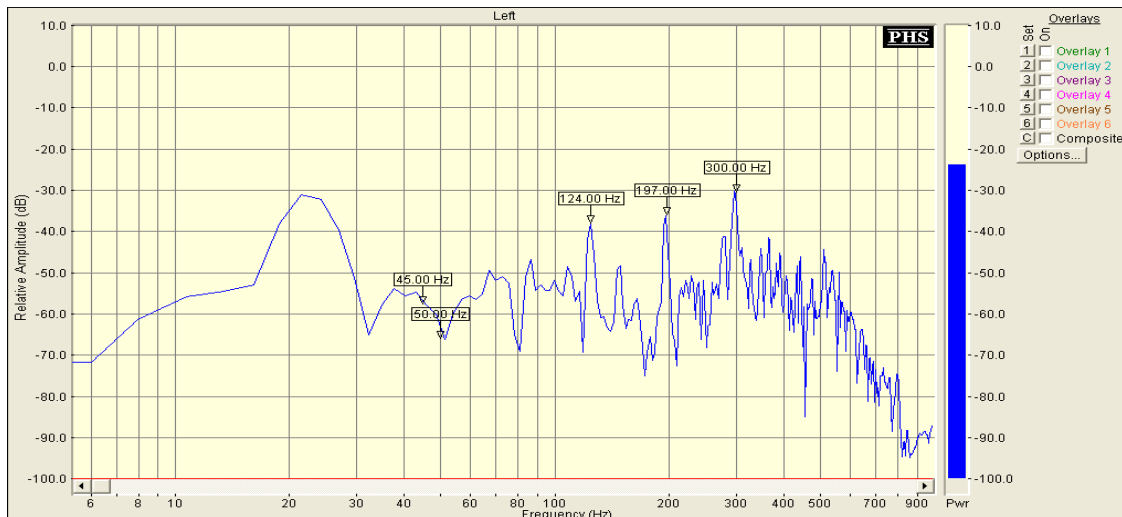


Fig. 2 experimental setup for AE condition monitoring of surface grinding machine

The experimental setup consists of a vertical spindle surface grinding machine. The speed of rotation of drive motor is 3000rpm and that of grinding wheel is 2700rpm, feed is kept constant at 0.02mm/min. The machine spindle housing contains three bearings (fig. 3.5) out of which two are ball bearings (6206) and one is taper roller bearing (30305) of SKF make. The taper roller bearing mounted on the spindle supports pulley connecting machine spindle to electric motor. The ball bearings are situated close to the grinding wheel to support the machine spindle. A microphone with frequency response of 20-16kHz is used for acquiring the acoustical signals. The acoustical signals from different machine components are acquired by placing microphone close to the machine component. A computer is used for recording and analyzing the data (online as well as offline). The data is sampled at a rate of 4MHz. The acoustical data is analyzed in time and frequency domain by using spectral analysis software such as spectraplus. The noise signals generated by the bearings are in low frequency range of 500Hz, so a low-pass filter is used to eliminate unwanted high frequency components.

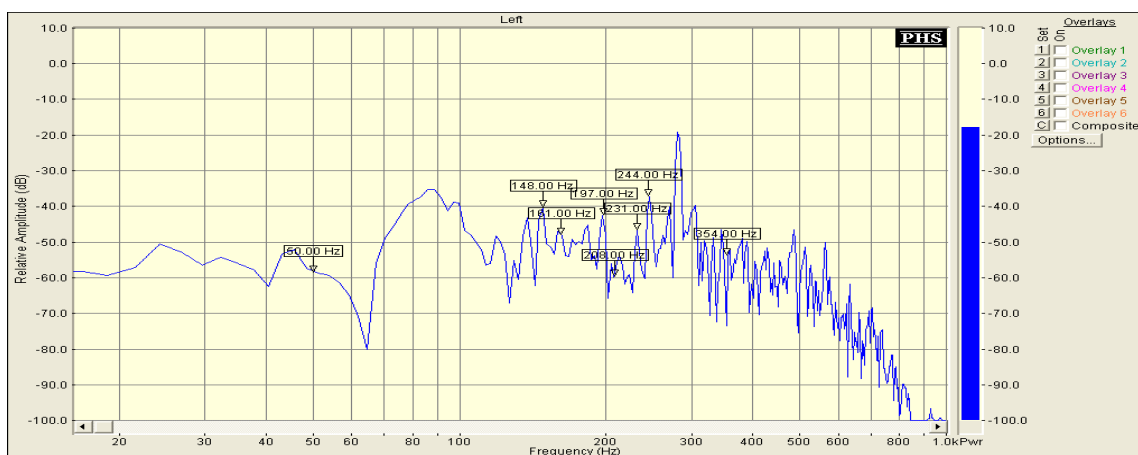
#### IV. RESULTS

For the surface grinding machine, healthy machine condition corresponds to machine without any defect such as bearing defect, misalignment, looseness, etc. Defective machine condition shows presence of one or more defects mentioned above. The results for healthy bearing condition is shown in following graph.



Graph 1 healthy machine condition

The defective machine condition is characterized by the continuous noise produced by the machine spindle bearings during running. The defects observed in bearings in machine under study are - defective ball/roller, inner race, and outer race. Following graph shows the defective machine bearing condition called defective machine condition.



Graph 2 defective machine condition

The results obtained show that ball bearing and taper roller bearing used in the machine spindle generated inner race, outer race, and ball defects over a period of time and contribute to the noise generated during the grinding process and reduce the surface finish obtained during the machining. Table below gives a summary of defects identified in this study.

Table 1 summary of results

Frequency Hz	% rise in dB level from healthy condition	Interpretation
104	-	ball defect - ball bearing.
244	26	BPFI - ball bearing.
161	17	BPFO - ball bearing.
100	12	Roller defect -TRB
200	32	outer race defect - taper roller bearing.

## V.CONCLUSION

Conventionally, in the industry the maintenance problems regarding the surface grinder are solved by a skilled operator based on his experience and judgment about the machine and the process. If the operator miscalculates the maintenance schedule it is likely that the maintenance could be productive or breakdown. To overcome this situation condition monitoring system is implemented. This system works with very little human intervention and hence is reliable. The acoustic emission signals for healthy machine show the presence of frequency of 45Hz (Xs) representing spindle speed and frequency of 50Hz (Xm) showing motor speed. The defective bearings show increased amplitude levels of frequencies corresponding to BPF, BPFI, and BPFO. The defects in a ball bearing are inner race, outer race, and ball defect. The taper roller bearing contains roller, outer race and defects. The amplitude of frequencies representing BSF, BPFI, BPFO of ball bearing along with BSF, BPFO for taper roller bearing must be periodically monitored. Increase in amplitude of these frequencies will point toward a race defect or ball defect and will ensure that the bearing healthy is properly monitored.

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