Design of a Predictive Maintenance Program

A.P.Shrotri, S.B.Khandagale

Abstract *-The modern manufacturing plants are generally equipped with complex and continuous running machines and equipment. These are characterized with high speeds heavy working loads high temperatures and pressures etc. The shutdown costs are very large in case of such complex plants. Any breakdown or malfunctioning in such cases is not only a costly affair but it also raises the question of safety of plant itself and persons working there in. This initiates the need for prediction of failure of machines as well in advance so as to initiate the corrective action. The condition monitoring and subsequent condition based maintenance is an effective measure in this regard. However in a factory same maintenance practice is neither desirable nor required for all equipment and machines and a routine practice is to use mixed maintenance scheme. As the predictive maintenance efforts are very expensive hence the design of predictive maintenance scheme itself becomes a task of utmost care. This paper suggests a stepwise procedure for design of predictive maintenance program and also discusses the justification factors, choice of monitoring techniques and various related facts regarding predictive maintenance. The paper also includes a case study of condition monitoring and thereby arranging a predictive maintenance for sugar industry.*

Index Terms *– condition monitoring, Predictive maintainance,VEIN analysis, vibration analysis.*

I. INTRODUCTION

The failure of rotating machines can usually be predicted much earlier before the failure. Long before the failure stage, the condition of machine begins to deteriorate due to wear and tear of the various moving parts. The wear always manifests itself in terms of signals like mechanical vibrations, noise, acoustic, thermal emission, smell, pressure, relative displacement etc. Usually change in vibrations level provides good indication of change in the condition of machine. Abnormal vibrations in machines cause accelerated wear .Evan a small insignificant increase in the level of vibration causes a sharp increase in bearing wear which further reduce the service life of bearing by 50%.Increased vibration levels in a machine will lead to operational difficulties sooner or later. These difficulties can often be foreseen by periodic monitoring and the machine can be considered for maintainance. The fact can be seen easily from classical machine bath tub curve from[Fig.1]. The classical bath tub curve shows the vibration level measured for a machine for the life cycle. At initial installation and run in phase the vibration level is acceptable but on higher side. This is due to initial seat and mechanical fitment phase. The level further decreases as the machine achieves normal operation phase. This phase represents the satisfactory working of the machine. On further operating due to mechanical wear of components the defects start developing.

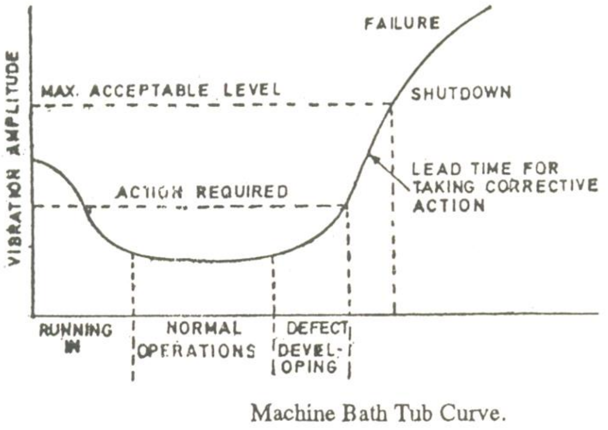

Fig.1

The defect development indicates rise in vibrations amplitude which when crosses a certain predefined level a corrective action is called for and ought to be taken until the vibration level is within acceptable limits. If the exact condition of the machine are monitored regularly and recorded, the fault detection and its diagnosis are very easy by comparison of measured signal and safe operating parameters of machine. This also provides sufficient lead time for taking corrective action. The condition monitoring and subsequent corrective action which is called popularly as condition based maintenance or predictive maintenance are now-a-days becoming the indispensible part of a maintenance system of factory. However the expensive nature of this technique calls for a careful plant wide study and selective approach for critical machines for considerations while designing a predictive maintenance program. The detail procedure of design and other related facts are discussed in details hereafter.

II. STEPS FOR ESTABISHING PREDICTIVE MAITENANCE PROGRAM

As discussed earlier the vibrations amplitude of a machine rises with defect development. Thus vibrations become a signal which indicates variation in condition of machine. Hence a monitoring scheme based on vibration amplitude verification can work satisfactory in case of most

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***** Correspondence Author (s)
A.P.Shrotri*, Associate Professor, PVPIT, Budhgaon, Dist. Sangli, M.S., India, (E-mail: amod_shrotri@rediffmail.com).
S.B.Khandagale, Assistant Professor, PVPIT, Budhgaon Dist. Sangli, M.S., India (E-mail:shashikhandagale@gmail.com).

of the rotating machines. The abnormal vibrations in the machines cause accelerated wear. A vibrating machine represents a troublesome problem in a factory. The common causes of vibrations can be listed as under;

Common causes of vibration

- Imbalance
- Resonances
- Misalignment
- Mechanical and electrical asymmetry
- Worn bearings
- Slippage
- Oil whirl and oil whip

[Fig.2] indicate the flow diagram of predictive maintenance program.

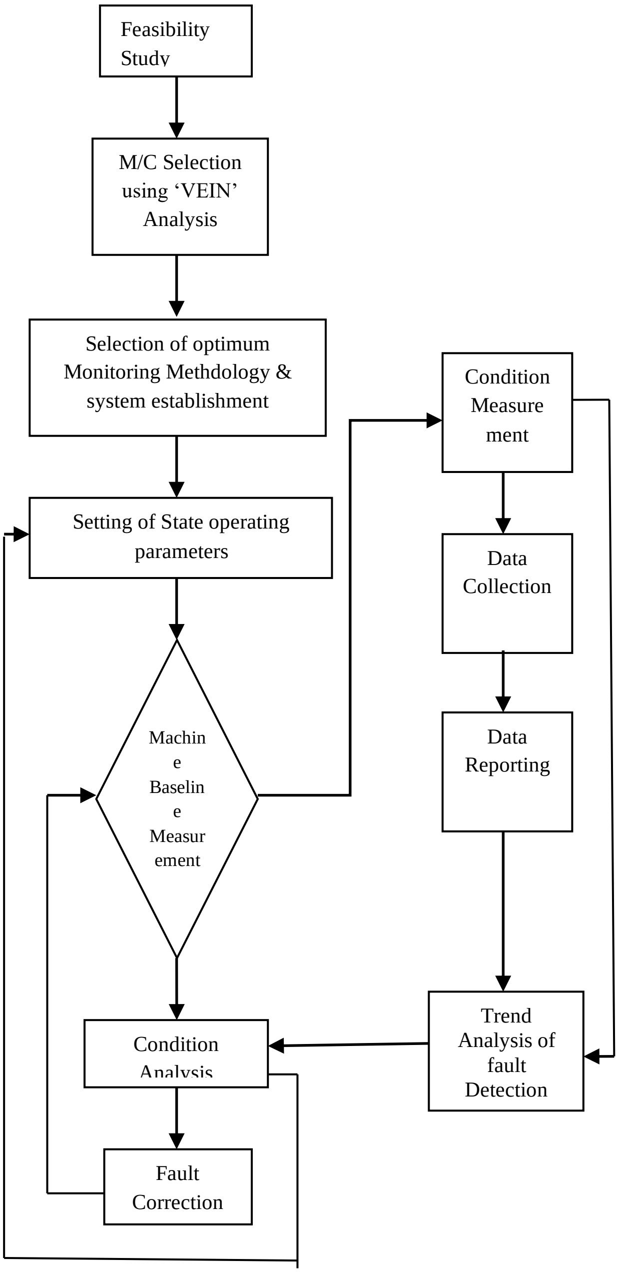

Fig.2

A vibration based condition monitoring program involves detection analysis which highlights the causes of vibrations and the remedial correction. The detection phase is related with diagnosis activities and the correction is fault repairing activities. It is true that in factory or plant same maintenance practice is neither desirable nor required for all equipment and machines. Hence we have to go for a generic stepwise procedure which involves determination phase which decide the scope of predictive maintenance based on criticality to some vital machines and design and implementation phases which involve designing for monitoring scheme and actual monitoring and subsequent corrective actions, irrespective of the size, nature and type of factory or plant.

The generalized steps for establishing predictive maintenance program can be listed as

1) Feasibility study
2) Machine selection using 'VEIN' Analysis
3) Selection of optimum monitoring technique & system establishment
4) Setting of safe operating parameters
5) Machine baseline measurement
6) Routine monitoring program
7) Condition analysis
8) Fault correction

a. *FEASIBILITY SURVEY:*

The predictive maintenance efforts are very expensive hence a careful study or plant-wise feasibility survey for deciding the machines to which the predictive maintenance technique is to be applied is carried out, so that those equipment and machines which do not require. So much maintenance and care will not get mixed into predictive maintenance system.

For selecting the machines which need predictive maintenance following points are to be carefully studied.

1) Criticality of the machine
2) Downtime costs
3) Downstream effects
4) Age of machine
5) Severity of utilization
6) Stand by availability
7) Hazards involved in the event of failure
8) Skill availability
9) Maintenance support facility and infrastructure
10) Use skill and operating environment
11) Condition of usage

After studying the feasibility and collecting the list of probable members of predictive maintenance scheme, we have to select the most prominent or front liner members to be included in the program by using VEIN analysis.

b. *VEIN ANALYSIS:*

The decision to go for a particular maintenance method is not a static concept but it changes with time. The weightage is given to various machines under consideration on the basis of various factors discussed earlier in feasibility study and critically indices for various machines are found out factory wide.

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On the basis of these indices, the OEM recommendations and reliability analysis of each machine, the monitoring technique selection depends on,

Criticality
Availability of standby
Hazards involved in case of failure
Downstream effects

1) Cost of down times
2) Cost of condition monitoring equipment

The various monitoring equip can be listed

A) Equipment for mechanical failure

1) Shock pulse meter
2) Vibration meter
3) Vibration analysis
4) Ultrasonic flow meter
5) Mechanical or electrical strain gauges

B) Equipment for thermal failure

1) Infrared thermometer
2) Thermovision

The optimum monitoring technique and relevant equipment are selected by making a cost-benefit analysis on the basis of cost complexity sophistication and versatility. However in the most of the cases the online vibration monitoring is preferred.

c. SETTING THE SAFE OPERATING PARAMETERS AND SYSTEM ESTABLISHMENT:

For efficient and effective working of condition monitoring system it is required to study and set the safe operating parameters for the machine under considerations and the parameters under observations.

This is normally based on the operating characteristics curves or machine service charts supplied by the original equipment manufacturer (OEM) the entire plant, equipment and machines can be divided into four categories as

1. Vital (V)
2. Essential (E)
3. Important (I)
4. Normal (N)

This is known as 'VEIN' analysis which enables us to plot criticality Vs type of maintenance curve. One such typical plot is as shown in [Fig.3]

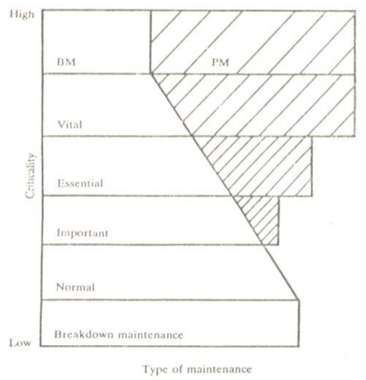

Fig.3

It suggests distributing the equipment /machine into mix of breakdown and planned maintenance. The planned maintenance can be referred as predictive maintenance after confirming criticality complexity, need & cost of maintenance.

Selection of optimum condition monitoring technique:

The condition monitoring can be applied in following three ways

based on look Qualitative checks, sound and feel through simple inspection

Condition checking by measuring some parameters regularly

Trend monitoring by making measurements and plotting them in order to detect gradual department from safe operating parameters. The above methods can be applied on-line i.e. when the machine is in operation or when off lined are speed temperature, vibration and pressure. However off-line monitoring is carried out when the machine is not in operation and the monitoring would include crack detection a through check of alignment state of balancing and corrosion and pitting etc. the service charts OEM specifications and initial parameter recordings for machine after installation are to be considered for setting the safe operating parameters for the machine under considerations. If such data is not available the several readings taken at random during satisfactory working of machine are studied and the safe limits are established by this experience.

d. Machine Baseline Measurement:

After setting of the operating parameters prior to introduction of predictive maintenance program a base line of the machine condition must be established.

The recording of baseline reading act as a comparison standard with set safe working limits. There are chances that due to corrective action taken at any instance that due to corrective action at any instance after applying the predictive maintenance

scheme; there exist some chances in baseline readings. Hence after every corrective action new machine baseline should be taken and recorded as amendments in the base lines.

e. Routine monitoring program:

After setting the standards for safe operations and current condition of machine the installation of various pickups, transducers and sensors is done for continuous monitoring. In case of periodic checking system the various check points are enlisted and marked on machine clearly. The routine monitoring program for the parameters decided earlier is carried out. The significant variations are observed and recorded regular intervals or on continuous basis as per set standards.

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f. Condition analysis

The routine monitoring program continuously monitor the machine and records the variations in the form of mechanical vibrations, noise,acoustic,thermal emissions,smell,pressure,relative displacement etc. about the existing status of the machine which provide the significant information which help to diagnose the likely faults and failures. The analysis made on the basis of these records helps in

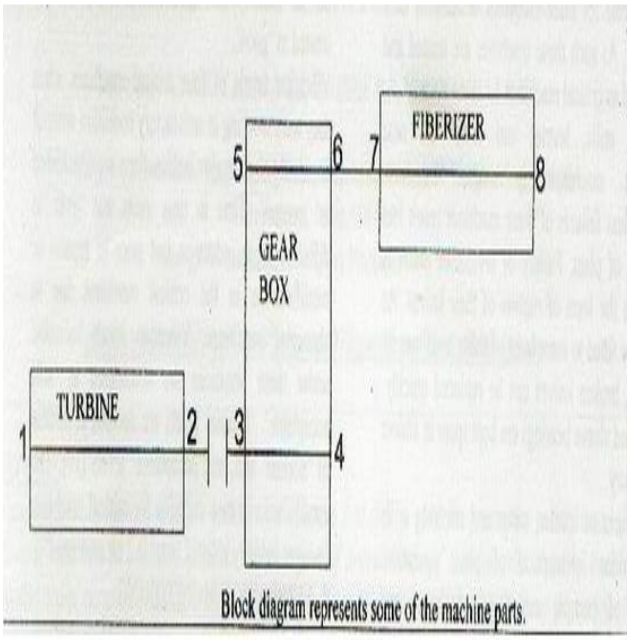
- Preventing defects
- Knowing the machine's reliability
- Deciding life of the machine
- Forecasting defects and failures
- Planning for rectification
- Deciding frequency of inspection and check-ups

g. Fault correction

Fault correction work is the outcome of the analysis phase of the condition monitoring based maintenance program. On the basis of the expert's opinion who has analyzed the condition data the fault diagnosis has been drawn. With respect to this diagnosed causes the remedial actions of repairs, programmed replacements, modifications, reinforcements or overhauling are decided and executed.

III. CASE STUDY

To summarize on the importance of predictive maintenance program a case study based on condition monitoring and diagnostic analysis after selecting the vital machine (Fiberizer) in a sugar factory is added here which explains periodic analysis and monitoring of fiberizer of Sugar factory. In the predictive maintenance program in this case study the measurement of vibrations provides valuable information about the operating conditions of the Fiberizer. For the Fiberizer the measurements are taken in different directions and at relevant points along the machine. Periodic checking is done within an interval of 15 days; fig[4] shows machine unit and the points where the vibration level is checked. The data table for 8 points is shown bellow. The horizontal, vertical & axial directions are taken into consideration & vibration velocity is measurement parameter as fiberizer is high frequency machine. Here velocity goes on increasing to a particular day, as indicated in the table readings. The results obtained provide the basis for the diagnosis which in turn, determines the remedial measures to be taken. The corrective actions are taken, and the vibration velocity is reduced to usable range & reduction is seen on next interval. It can be stated that, the reliability and availability of running equipments vital to production can be increased to higher level by applying this technique to machines in process industries. Experiences have revealed that there has been immediate and obvious improvement in engineering standard of industries where the design of a predictive maintenance program is done. Indian sugar industry, being second largest sugar producer in the world, playing vital role in the Indian economy. For the success of this industry in today's competitive technological environment design of such predictive and diagnostic maintenance system have become increasingly important.



Block diagram represents some of the machine parts.

Fig.4unit:SugarFactory

Section: Mill House Machine: Fiberizer

Table : Vibration Parameter Measurement Data Sheet

(Readings at full load condition)

Pick-up position		Vel. mm/s	Vel. mm/s	Vel. mm/s	Vel. mm/s	Vel. mm/s	Vel. mm/s
1	H	4.8	3.4	4.5	5.5	8.0	5.2
	V	2.6	3.0	3.0	3.0	5.5	4.0
	A	4.0	3.6	2.8	4.0	5.5	4.0
2	H	4.2	3.0	3.6	3.7	4.0	4.2
	V	3.0	3.0	3.0	1.8	2.5	3.0
	A	3.8	3.6	3.8	3.6	4.0	3.9
3	H	2.7	3.3	2.8	2.8	3.0	2.8
	V	3.0	3.0	1.8	2.4	3.2	2.2
	A	2.5	2.5	2.1	3.6	2.6	2.6
4	H	2.2	3.8	3.0	2.6	2.7	2.4
	V	2.4	3.2	2.3	2.0	2.0	2.0
	A	2.8	2.5	2.4	2.5	2.5	2.4
5	H	2.8	3.2	2.5	2.9	3.0	3.0
	V	3.7	2.5	2.2	2.0	1.8	1.8
	A	3.8	2.5	2.4	2.3	2.8	2.4
6	H	5.0	3.0	2.0	2.8	2.8	3.0
	V	2.2	2.2	2.2	2.2	1.8	1.8
	A	3.2	2.0	2.4	3.2	2.2	2.4
7	H	3.0	5.0	5.0	5.5	5.2	5.2
	V	2.4	3.0	2.5	2.2	2.0	2.2
	A	3.1	5.0	5.5	4.8	5.0	4.5
8	H	3.6	5.0	5.5	5.0	7.5	4.5
	V	5.0	4.4	3.0	2.8	2.0	2.0
	A	5.0	4.4	3.2	5.5	4.0	4.8

IV. CONCLUSION

The predictive maintenance or condition monitoring based maintenance is a very cost effective in those areas where the cost of

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unplanned break down is very high. Predictive maintenance provides the ways and means by which likely failures can be detected in time and remedial actions can be planned for and thus improving overall efficiency of the plant. It also makes it possible to increase the useful life of certain components beyond their recommendation life span. Also, it can be concluded that if condition monitoring is applied within regular intervals using suitable instrumentation and analyzed by experts, the impending failures can be easily predicted and will be taken care of. However it should be remembered that the effectiveness of condition monitoring depends upon the availability of specialists and highly skilled back up staff trained in the analysis and diagnosis of monitored parameters.

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AUTHOR PROFILE

Prof. A.P.SHROTRI is working as an Associate professor in P.V.P.I.T.BUDHAON, Dist. Sangli, Maharashtra, INDIA since 1986 .He is a graduate in mechanical engineering and a post graduate in mechanical Engg. with specialization in production engineering. He has a remarkable teaching experience of 25 years .He has worked as an expert for curriculum development of Shivaji University Kolhapur, for UG and PG courses in mechanical and production Engg. He has published seven papers at national level workshops and one paper in international journal. He is conducting a national level technical symposium for UG students of India since 2009.

Prof. S.B.KHANDAGALE is working as an Assistant professor in P.V.P.I.T.BUDHAON, Dist. Sangli, Maharashtra, INDIA since 2010 .He is a graduate in mechanical engineering and appearing for post graduate in mechanical Engg. with specialization in product design and development.

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