

# Evaluation of Design Using Condition Monitoring of Machinery in an Automotive Industry

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**ABSTRACT:** This paper gives a novel approach regarding the study of implementation of an advanced maintenance system in an automotive industry. The contents are also focused in the inclusion of a comprehensive review of different types of faults that occur in different rotating parts of the machinery and also points out the latest trends in the condition monitoring. Step by Step approach is used for better results and understanding of the current situation of the machinery. Understanding the problem is also divided into multiple stages; this helps in a clear understanding of the actual issue and helps in the reduction of the percentage of virtual space in the problem definition. All the stake holders were involved to analyse the problem and to have a faster establishment of the counter measure Efforts have also been made to understand the reasons for the failure, by carrying out various tests on the failed specimen.

**KEYWORDS:** FTIR, TMF

## I. LITERATURE REVIEW

Various studies have been carried out for the effective development of 'Predictive Maintenance techniques' in order to reduce the number of unplanned stops, since unplanned stops due to failures have a very high economic impact for an industry.

There are different methods and techniques that are being used for condition monitoring such as:

- Air gap torque monitoring and thermal monitoring.
- Noise monitoring.
- Motor current signature analysis.
- Vibration Monitoring.
- Partial Discharge.
- Wavelet analysis.
- Expert systems.
- Fuzzy logic systems.
- Artificial neural network and neural
- fuzzy systems.
- Hidden Markov Modelling

In case of diagnosis of bearings, stator current analysis or park's vector approach is used rather than vibration based approach. Here, the signals are first decomposed and analysed using different approaches such as Fourier analysis, neural networks, statistical analysis etc.

Also different types of studies have been carried out to understand the types of failures in the induction motor. The most commonly seen faults are: bearing related faults (40%), stator Winding faults (38%), rotor related faults (10%) and other faults (12%). Also the main reasons for the failures can be attributed to the presence of thermal stresses, magnetic stress, residual stresses, dynamic stresses, environmental stresses and mechanical stresses.

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Also there are some more advance methods which uses hybrid algorithm that combines both time and frequency domain analysis of the signal. This is basically a combination of Independent Component Analysis (ICA) and FFT.

## II. INTRODUCTION

Condition Monitoring is a maintenance technique that helps to determine the current condition of the machine and its ability to perform the duty with respect to its efficiency. Different parameters are available to accomplish this task, namely visual, Aural; duty based monitoring, corrosion, wear debris monitoring, oil pressure and vibration. All the above parameter helps to determine the present condition of the machine. If the machine is not performing up to the mark or it is in the bad condition, then the condition monitoring can be used to determine the cause of the problem (root cause) and hence solve the issue. Condition monitoring has got large number of advantages such as better maintenance of machines (critical), to avoid catastrophic failure, reduction in the delays and downtime, Increasing the efficiency of the production system, just in time maintenance etc.

This project is based on the vibration measurements that are obtained from the machines and hence determine the faults and take corrective action.

There are two types of condition monitoring systems: periodic systems and permanent systems. In periodic systems (off-line monitoring systems) vibration measurements from the machines are taken at a specific time interval. This time interval is based on the characteristics of the machines. For On-line measurements the probes or vibration measuring device is permanently mounted on to machine of concern. The trends for every hour are obtained and this is closely analysed. If any irregularity or deviation is found, then the corrective action is initiated immediately so as to avoid any serious issues. This type of analysis is usually used when the machines are complex and critical in terms of operation of the plant.

However, in this paper I am going to use periodic monitoring system on various machines. Advance concepts such as condition monitoring of slow rotating machines, sub-synchronous frequency range analysis, relationship between sprocket and chain by using vibration analysis, effect of misalignment of motor on the assembly/other part of the machine, effect of lubrication on the system etc. have been discussed.

## III. FAULTS IN THE ROTARY MACHINE

There are different types of faults, there might be faults when the machine is running at a very low speed and when the speed is very high. The faults that are seen in low speed and low frequency domain are known as Sub-synchronous range faults and the common faults that are seen in high frequency domain are TMF (Tooth meshing frequency), BPF (blade pass frequency) etc.

It is necessary to first determine the spectrum when the body is in the good condition. This spectrum is then considered as a reference system for the subsequent reading. Any deviation that is seen from the original reference spectrum is considered to be some kind of fault. Hence it is possible to determine the fault, before it turns out be a big issue. The spectrum that is obtained depends on number of parameters such as temperature, pressure, load, speed etc. Any deviation which is less than  $\pm 10\%$  its original value will not have a large impact on the results. However, if the reading obtained has a very high variation then this will lead to transient state of vibration, which requires different approach in terms of interpretation. If the harmonics generated by the rotating machines are low, then they can be directly related to misalignment, eccentricity, shaft unbalance, cracks in the shafts and bent shafts.

Difference in phases also provides vital information in the determination of the fault. e.g.: If there is an unbalance in the rotating force then there will be an identical phase relationship between horizontal and vertical component. However, if there is mass unbalance then the phase difference will be 90 degrees. Another type of fault that can be come across is Local fault. In Local fault we get a set of harmonics that is separated by an impact frequency, and there will be 3 or 4 set of harmonics.

Higher harmonics of the fault are basically related to tooth mesh frequency, blade pass frequency etc. any increase in this component can be directly attributed to wear of the machine. Also in case of gears we also find what is known as ghost component. This is basically a fault that has been transmitted to the gear by the parent gear that was used to manufacture this gear. This can be considered as a fault in geometry of the gear; hence they will reduce over a period of time as gear wears.

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## IV. SELECTION OF MACHINES

Selection of machine plays a vital role in Condition monitoring. The machines were selected based on the delays that were caused due to deviation from its intended duty of Work. For the month of June, it was seen that majority of delays were caused due to the breakdown of the m-jig Innova. However, there were other equipment's which were having breakdowns and decrease in the efficiency. These machines were dash oven; re-spot conveyor motor, and roller conveyor of the frame line. In this paper we have taken two critical equipment's M-jig and dash oven as the equipment's that were put to the condition monitoring program.

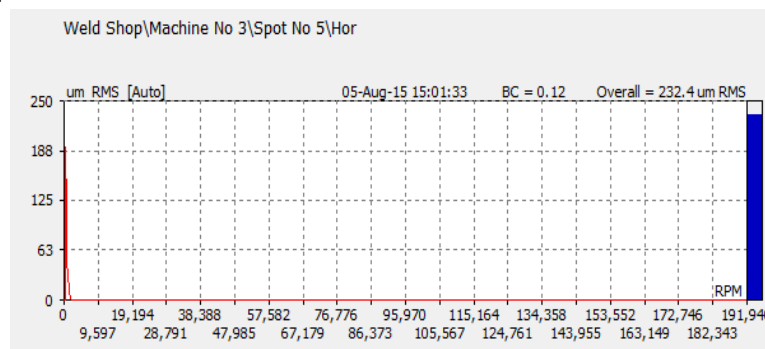
## V. M-JIG INNOVA CONDITION MONITORING

M-jig condition monitoring had been carried out from June to October of 2015. During the first two months the frequency of measurement was every day. For rest three months the frequency being reduced to monthly thrice or as per requirements.

The readings were taken from the bearings, sprockets, motor and gear box. The m-jig is primarily used for holding the side member and under body rigidly and in the right position so as to carry out the welding (spot) with better accuracy and in a faster way. Being a major machine in the shop any delay can lead to subsequent delays in the next shops. Hence it was very much necessary to identify and rectify the problem before it is too late.

The reading was taken in horizontal, vertical and axial direction from 3 sprockets, 1 motor, and 1 gear box. (Note: direction of the reading was subject to accessibility of the part).

The current findings indicated that there was excessive shift of the motor and wearing out of the chain due to faulty bearings and sprockets.



**Figure 1: Displacement Analysis of M-Jig Motor**

Figure 1 shows the displacement of 190 $\mu$ m in the motor of the m-jig. This displacement was prominent in the horizontal direction of the non-drive end of the motor.

The impact of this on the machine was Imbalance of motor structure resulting in the failure of rotors and decrease in the coupling accuracy between M-jig motor and gear box. The counter measure for this problem was:

- Better Usage of Standard Bolt Tensioning Method of Motor with Base.
- Frequent Checking of the Bolt TENSION.
- Checking the Shift in The Motor.
- Never weld any part of equipment.

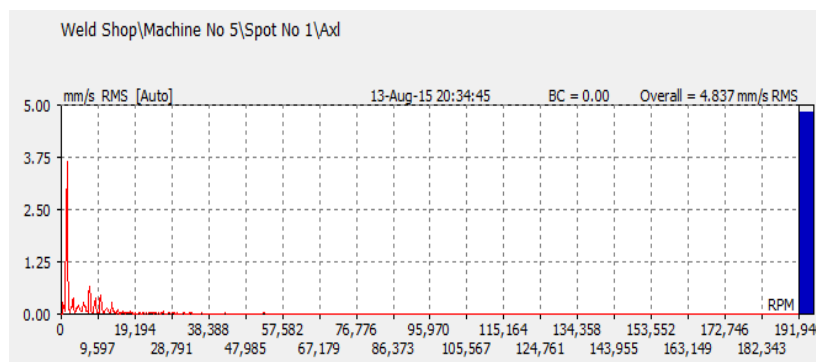
Any problem in the balancing of machine can lead to uneven loads on the rotor of the motor. If not addressed, then it can lead to heavy stresses and strains on the rotor and motor parts. This will ultimately lead to failure of the motor or decrease in the efficiency of the motor. Some advance techniques include the placement of the sensors near the rotor cavity to detect any deviation in the balance.

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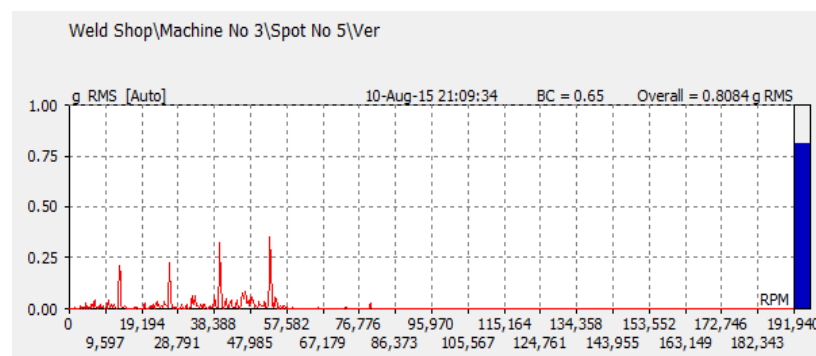
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Misalignment is a problem in the equipment which is generated when the centrelines of the driven and driver machine are not collinear. The major reason for this problem is due to mounting of the motor and the gear box. Care must be taken that mounting surface are clean and plane surfaces, with no unevenness.



**Figure 2: Velocity Analysis showing Misalignment**

The Figure 2 shows the presence of a dominant peak at 1 x rpm. This 1x rpm peak is a clear indication of presence of miss-alignment as per the standard rules of condition monitoring. The counter measure for this problem was cleaning of the rotor. Placing the rubber pads under the motor and gear box. Care must be taken that the rubber pads have same dimensions.



**Figure 3: Acceleration analysis showing sprocket wear**

The figure 3 shows the presence of wear in sprocket tooth. We can observe that a peak appears after a certain interval of time. The best possible counter measure that was implemented was, the replacement of both sprocket and chain to avoid the backlash effect.

- Continuous monitoring of the Slackness of Chain.
- Better follow up of PM.
- Better Lubrication Practices.

### VI. NON REPETITIVE CONDITION

It is very important that the above mentioned problems do not repeat again and again. Hence the effective measures were taken to identify the cause of the problem. The life span of the chain is largely affected by the style of the usage, choice of the gears, lubricants, lubrication techniques, size and condition of sprockets and rollers. A roller chain can be defined as a connection of series of journal bearing, with resulting articulation being the prime cause of the wear and failure. Elongation of 3% is the maximum limit for the wear elongation; however, it is also dependent on the design of the sprocket.

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The specimens of chains were tested in the both macroscopic and microscopic scale. Tests were carried out in the UTM and the failed specimen was tested in the microscope. It was found that when the specimen was lubricated very little or lubricated excessively, the specimen failed with much shorter stress rate. Hence the life of the chain reduced as the lubrication is increased to a high level or decreased to a very low level. Hence optimum level of the lubrication is necessary. Also FTIR (Fourier transforms infrared spectroscopy) was carried out on the lubricant that was used on the chain and sprockets.

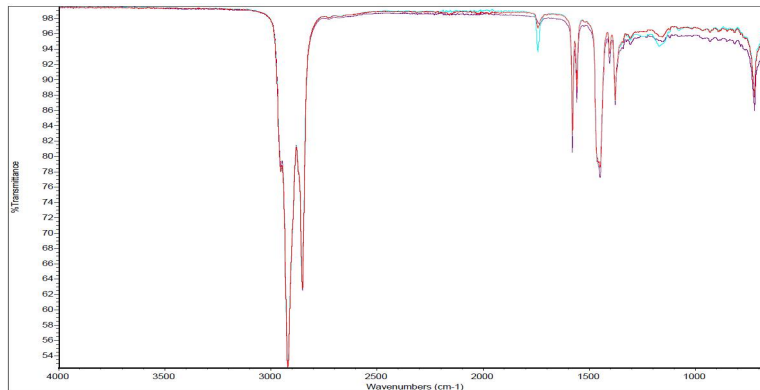


Figure 4: FTIR of 640-A grease

From the above figure 4, we can see that the obtained spectrum (in red colour) deviated from the standard spectrum (Blue colour). This deviation was due to the presence of the contaminants like dust, water and other liquids. Hence to have a better life for chain and sprockets it is necessary to use a good quality uncontaminated lubricant.

## VII. THERMAL MONITORING OF DASH OVEN

The vibrations were taken from the motor and temperature was measured at three different locations. The equipment being an old one had problems related to its operation. (i.e. productivity was decreasing daily due to repetitive issues).

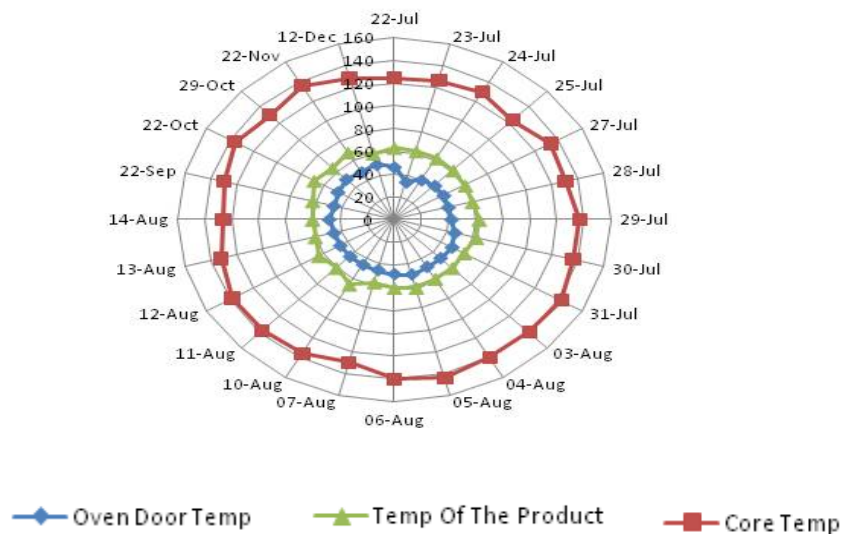


Figure 5: Temperature Chart of Dash Oven

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From the above figure 5 we can also see clearly that the Oven Core Temperature has a variation of  $\pm 5\%$  with average being  $134.83^\circ$ , and the prescribed average temperature being  $136.00$  for a count of 24 measurements. Hence it is within the safe limits. From the given chart we can see clearly that Oven Door Temperature has a variation of  $\pm 3\%$  with average being  $45.667^\circ$ , and the prescribed average temperature being  $48$  for a count of 24 measurements. Hence it is within the safe limits. Also the Temperature of the Product has a variation of  $\pm 1.2\%$  with average being  $61.70$ , and the prescribed average temperature being  $60$  for a count of 24 measurements. Hence it is within the safe limits. The results from the trends also show that the vibration from the equipment is in satisfactory condition. This was possible after the coils were changed and chain that connected the motor and the door were properly lubricated.

### VIII. CONCLUSION

Vibration readings were taken from the selected machine and the results were obtained in a record time. This was ensured so that there is a very little delay in the system due to the mechanical failures. Once the cause of the delay was obtained the counter measures were taken, to have a healthy system. The overall shop delay analysis (machine failure) showed that reduction was 46% to 13% in case of M-jig.

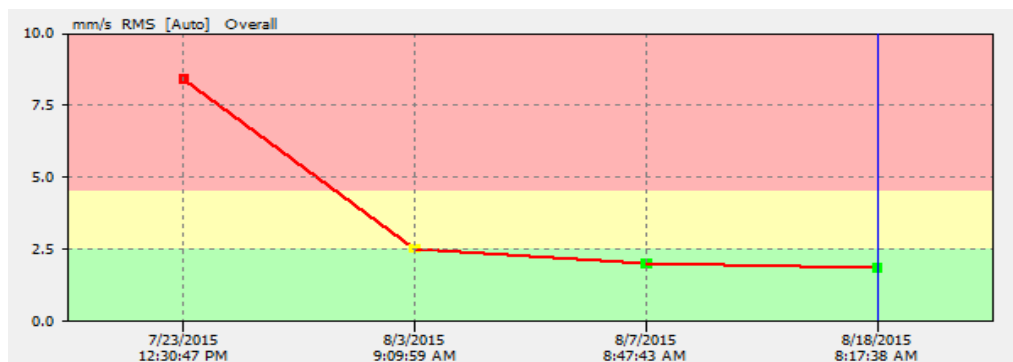


Figure 6: Results of vibration measurement from M-Jig

The above figure 6 shows that the vibration level decreased from  $8.2\text{mm/s}$  to  $2.1\text{mm/s}$ . Hence at the end of the condition monitoring program the vibration levels decreased by 78%. Other equipment's (Dash oven) were the vibration monitoring was implemented saw a delay reduction of 68 %.

Other techniques such as wear debris monitoring, FTIR, thermal monitoring also helped to reduce the future delays (machine failure) by understanding the root cause of the problem. Hence it was observed that all the above techniques helped to achieve a System which was very less prone to failures.

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