DEVELOPMENT OF A CUSTOMIZED ONLINE VIBRATION MONITORING SYSTEM FOR ICG SHIPS

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Maintenance process is undertaken to keep machinery in proper working condition. Maintenance philosophy followed onboard Indian Coast Guard (ICG) Ships is Planned Preventive Maintenance (PPM). The main drawback of PPM is that it doesn't take cognizance of prevailing health condition of machinery and hence, despite undertaking maintenance of machinery at defined intervals, there are still unscheduled machinery breakdowns. This paper discusses that ICG is in the process of developing a customized online vibration monitoring system as a Research and Development pilot project for one of the FPV class of ship. By installing a customized online vibration monitoring system onboard ICG Ships the availability of critical machinery onboard ship can be increased and unscheduled breakdowns can be reduced.

KEY WORDS

Vibration Monitoring; ICG Ships; Health Index; Diagnostics Software

INTRODUCTION

Maintenance in general is performed to increase the reliability, utilization, performance and life-time of the machinery. It is a process that is undertaken to keep machinery in proper working condition. The maintenance philosophy presently followed onboard ICG ship is Planned Preventive Maintenance (PPM). The guiding principle of PPM is to carry out maintenance of machinery/ equipment after a fixed interval of time. In planned maintenance the frequency of maintenance operations are based on recommendations from the equipment manufacturer in combination with internal practices (Myhre, Petersen and R. Ugarelli 2014). The main drawback of PPM is that machinery are not fully exploited and sometimes PPM process may disturb an otherwise healthy machinery, often leading to other faults due to improper re-assembly and similar issues. The PPM is also unable to give advance warning about any impending failure that may occur within the pre-defined periodic inspection interval. PPM doesn't take cognizance of prevailing health condition of the machinery and hence, despite undertaking maintenance of machinery at defined intervals, there are still unscheduled breakdowns. These unscheduled breakdowns at times lead to unavailability of critical machinery onboard, which has direct bearing on the operational capability of the ships.

In the present scenario for preventing unscheduled machinery breakdown / possibly catastrophic failure and increase operational availability of onboard machinery, there is a dire need of taking cognizance of the prevailing health condition of these running machineries. The health condition of these machinery can be ascertained by checking physical parameters viz. vibration, temperature, sound, etc. associated with machinery operation and the same can be analysed for determining machinery integrity. The collection of information from machines and its further analysis aids in making decisions about their health, repair and possible improvements in order to reach maximum availability, before any unscheduled breakdown.

It has been observed that most mechanical systems always give some advanced warning as the condition deteriorates to the onset of failure. Vast majority of failures in mechanical systems pass through a distinct incipient phase, a measurable deteriorated phase, before entering into a damaged state. Thus, analysing the physical parameters associated with the machinery condition (such as temperature, vibration, oil condition, etc.) helps in detecting the onset of defect, diagnose the health condition and trend its progression over time. This in turn aids in avoiding any unscheduled breakdown.

VIBRATION MONITORING

Vibration is simply the oscillation about a reference point. Vibration exists when a system responds to some internal or external excitation. The amplitude of vibration depends on the magnitude of the excitation force, the mass and stiffness of the

system and it's damping. The major factors that lead to machinery vibrations are dynamic forces, wear and tear of moving members, looseness of machine parts, unbalance, misalignment, resonance, etc., to name a few. Every machinery fault generates a unique vibration characteristic signal. Since most rotating machinery problems show themselves as excessive vibration with characteristic frequency composition, we generally use vibration signals as an indication of a machine's mechanical condition.

The dynamic forces in most machinery with rotating components and the forces generated due to the process itself give rise to vibration as an inevitable outcome. The vibrations so generated by machinery have evolved as a well-utilized parameter for assessment in Condition Monitoring. Machinery vibrations are complex, but can be measured, processed and their interpretation simplified in order to ascertain the health condition of machinery.

It is acknowledged that in case of most machines, the deterioration of the health can be detected easily and conveniently using vibration signal, although temperature and acoustic signals may also provide some indication, although not easy and foolproof. Thus, using vibration monitoring systems, one can assess machine vibration and correspondingly if the machine vibration is outside its normal level, it may indicate a potential problem. This is due to the fact that vibration level is directly correlated to the level of fault severity.

Vibration monitoring helps in early detection of component anomalies based on the vibration data acquired from the target machinery. By early detection of anomalies, damage progression can be limited by scheduling and initiating an appropriate maintenance activity (changing of oil/bearing, resetting clearances, etc.) at an opportune time, resulting in increased machine availability and reduction in costs associated with unscheduled breakdown. The operational reliability of the critical mission is ensured.

IMPORTANCE OF MONITORING MACHINERY VIBRATIONS

Machinery vibration is an important parameter of equipment operation includes a variety of useful information and can be used for fault diagnosis (Dongmei, Qing and Zirui 2013). Early fault detection and associated subsequent maintenance action is important because it can lessen the likelihood of more severe and costly machine damage, catastrophic failures, reduce machine unavailability, prevent unnecessary preventative maintenance, reduce occupational hazards and helps in meeting operational commitments. Vibration monitoring can be used to discover a wide range of defects including (Smart Diagnostics 2012) :-

- ✓ Imbalance
- ✓ Mechanical looseness/weakness
- ✓ Eccentric rotors
- ✓ Rotor rub
- ✓ Misalignment
- ✓ Sleeve-bearing problems
- ✓ Resonance problems
- ✓ Rolling element bearing problems
- ✓ Flow-induced vibration problems
- ✓ Gear problems
- ✓ Electrical problems
- ✓ Belt drive problems

ONLINE VIBRATION MONITORING

Traditionally machine vibration monitoring technique utilizes a temporarily mounted sensor and a portable analyzer. The advantage of a portable system is that it costs less to procure and offer an ease of use, while still providing some level of predictive monitoring. However, the period between successive monitoring intervals are not known and are usually set based on experience and history of the machine. As discussed earlier, since the machinery health have unpredictable behaviour for variety of reasons. The machine may show early failure and faster deterioration, leading to failures much before the next inspection interval. Hence, for an effective monitoring of the machinery health, the condition of the running machinery is required to be monitored on a continuous basis. Installation of continuous/online vibration monitoring system onboard involves acquiring and processing the vibration data at a reasonably quick intervals and the same can be achieved by the following :-

- ✓ Installation of vibration sensors (typically, piezoelectric accelerometers) at appropriate locations on machinery.

- ✓ Integration of accelerometers with Data Acquisition Cards.

- ✓ The acquired vibration data to be routed through LAN cables to a centralized data storage system cum processing and monitoring unit placed in the Machinery Control Room (MCR).

- ✓ The centralized data storage system cum processing and monitoring unit to be installed with customized diagnostic software for real time vibration signal analysis

and interpretation of the acquired vibration data and giving meaningful information including trends of the current health of the machinery.

The advantages offered by the above mentioned system is that it is simple to install and offers greater flexibility i.e in that the sensors can be easily installed (either can stick on machinery casing or magnet mounted) or removed as required. No machinery needs to be modified and structural changes are not required. In addition, no additional manpower is exclusively required for carrying out vibration monitoring. The customized online vibration monitoring system once developed will have an excellent scalability and easy possibility of remote monitoring.

RESEARCH AND DEVELOPMENT PILOT PROJECT

ICG is in the process of development of a customized online Vibration Monitoring System for Aadesh class of Fast Patrol Vessel (FPV) as a Research and Development project, through IIT Delhi. The said project will be undertaken as a pilot project on one of the Aadesh class of Fast Patrol Vessel (FPV). The case is presently at RFP stage. Once the system has been developed and based on it's efficacy, installation of the same will be considered for extension on similar and other class of ICG ships.

INSTALLATION OF SENSORS AND DATA ACQUISITION SYSTEM

As brought out earlier, the customized online Vibration Monitoring system will entail mounting of conventional accelerometers, Data Acquisition system and dedicated software system for analysing the acquired vibration data. Accelerometers & Data Acquisition system are commercially available off the shelf. However, for getting superior/error free performance of the monitoring system, a customized diagnostic software solution is required to be developed akin to the class of ship. ICG is presently not having the expertise of developing the customized software. However, professional expertise of R&D institutes viz. Indian Institute of Technology (IIT's) can be utilized for the development of the system.

The vibration data from all the accelerometers shall be acquired through a data acquisition device and routed through LAN cables to a centralized data storage system cum processing and monitoring unit placed in the machinery control room. The transducers (piezoelectric accelerometers) shall be mounted on the equipment and the data acquisition hardware shall be wall mounted/ placed on safe location with marine standard encapsulation. The accelerometers shall be stud/magnetic base mounted on the equipment/ systems.

The sensors chosen shall be Industry grade / MIL standard.

Fig 1 below shows general layout of the proposed customized online vibration monitoring system to be installed onboard ICG ships. The system comprises of accelerometers mounted on machinery and connected to Data Acquisition system. The acquired vibration data is then transferred from Data Acquisition system to the state of art centralized data storage system cum processing and monitoring unit located in the Machinery Control Room (MCR).

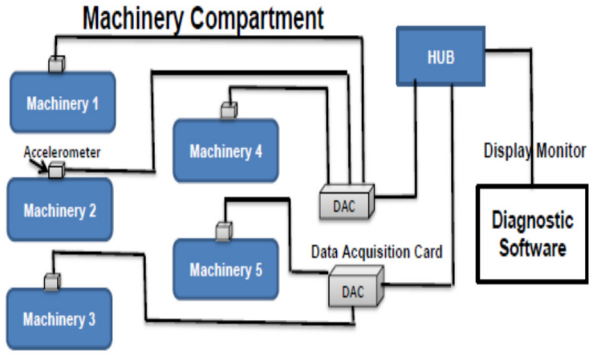

Fig 1. General layout of Customized Online Vibration Monitoring System

MACHINERIES TO BE CONSIDERED FOR VIBRATION MONITORING

It has been observed that onboard ships the unscheduled breakdown of auxiliary machineries is on higher side compared to Main Engines (which are constantly monitored), hence it will be prudent to cover most of the auxiliary machinery as part of the online vibration monitoring system. Some of the critical machineries fitted onboard ship, that are considered for vibration monitoring are as follows:-

- ✓ Blowers
- ✓ Diesel alternators
- ✓ General Service Pumps
- ✓ A/C condensing pump
- ✓ Cooper Roller bearing
- ✓ Motors
- ✓ Pumps
- ✓ Air Compressors
- ✓ A/C Compressors
- ✓ Fuel Oil Transfer pump etc

SMART DIAGNOSTICS SOFTWARE

The smart diagnostics solution installed on a centralized data storage system cum processing and monitoring unit located in

the Machinery Control Room (MCR), will be consisting of a powerful, easy to use software that will enable users to visualize the operating state of vibrating equipment. It will also help in assessing when to perform maintenance activity. The diagnostic and health monitoring software shall give an easy visual and quantified representation of the machinery health condition based on the acquired vibration signal, on a display screen placed in Machinery Control Room.

The diagnostic software will also have the trend monitoring feature. For each machinery or equipment, trend monitoring features shall be formulated and their trend with time shall be shown in the software along with the overall health condition in a simple, user-friendly manner. The software will provide a simple interface to the operator with "warning" and "alarm" thresholds. The system will generate alarms when observed vibration exceeds these thresholds. In addition, the software will also provide easy to read charts that show the trend of peak vibration amplitude with time as well as full vibration spectrum of each sensor sample. The software will also be designed to initiate the vibration signal acquisition at the designed/user-configured interval of time.

The diagnostic software will also display time domain and Health Index (HI) plot. The time domain plot will show the acquired vibration data obtained for a particular component and gives an idea of overall level of vibration. The Health Index (HI) plot will show the trend or variation in component health with time. For the purpose of easy interpretation, the overall health condition of the machinery will be displayed in three distinct colours viz Green, Yellow and Red. The HI value in the green region will indicate that the component is in healthy region, value in yellow region will indicate that the component is no more in healthy condition and needs closer monitoring and plan for early corrective action/inspection, while a value in red region will indicate that the component may need immediate attention and is likely to fail in near future.

The back end of the software that processes the raw time domain data, extracts features that are appropriate to indicate the health degradation of the system being monitored. The front end will have display list of all the components and if clicked on a specific component, the display of the feature values or trend of feature values will be displayed. The overall health condition against a set reference value will also be shown on the screen.

CHALLENGES ENVISAGED

Every machine is typical in terms of its working environment and operating conditions. The vibrations are sensitive to the operating conditions. Hence they are usually not so generalized. Two identical machines may have different vibration levels even if they are new. The system dynamics of the interconnected components play its role in some variations in the baseline vibration signature. Hence, benchmarking of each machine for its baseline vibration signature to enable more accurate diagnosis and monitoring will be required at the initial stage. Moreover, in the instant case the onboard machinery are placed on a moving platform. Hence, the project involves extensive measurements over a period of time to evolve knowledgebase that will help accumulate historical data that can be useful for future prognostic activities on machine health. The activity involving baseline measurement can be challenging and time-consuming. However, initially, one can plan both the usual monitoring activity and benchmarking activity in parallel.

Different type of machinery (such as pumps, compressors, diesel generators, motors, etc.) have their own typical signature that are broadly known. However, for development of precise algorithm (and its fine tuning), it would take reasonable time to acquire vibration signal and correlate with the actual observed anomalies. Although this activity is time-consuming, it will ensure more robust diagnosis and reduced false alarms.

ADVANTAGES OFFERED BY THE SYSTEM

The distinct advantages offered by the installing a customized online machinery vibration monitoring onboard ICG Ships are as follows:-

- ✓ The presence of online vibration monitoring will help in reducing unscheduled machinery breakdown.
- ✓ It will reduce unnecessary / overdoing of maintenance activities.
- ✓ It will help in diagnosing health condition of machinery based on physical parameters, without usage of additional manpower and expertise.
- ✓ It will help in early fault detection, so that timely corrective action will avoid costly untimely breakdown.
- ✓ It will improve availability of critical machineries.
- ✓ It will help in generation of rich repository of data which can be used for predicting the residual useful life of the system / optimum inspection interval for the system.

- ✓ It will also be helpful in providing necessary inputs for gradually migrating from the existing fixed interval based maintenance philosophy to Condition Based Maintenance (CBM) philosophy in near future.

CONCLUSIONS

As brought out in the above mentioned paragraphs, all running machinery vibrates and vibration level generated by each machinery is directly correlated to the level of fault severity. Hence, by continuously monitoring the vibration level of any onboard running machinery the anomalies can be detected at an early stage, damage progression can be limited by scheduling and initiating an appropriate maintenance activity. This in turn will help in increasing machine availability and reduction in costs associated with unscheduled breakdown. Further, operational reliability of the critical mission can also be ensured.

The customized online vibration monitoring system envisages fitment of vibration sensors on ship's machinery and then online collection of vibration data which will be further processed using smart diagnostic software. The diagnostic software containing carefully calibrated algorithms will process the input raw time domain vibration data, extract relevant information, choose appropriate post processing specially designed algorithms and will intimate the real health condition of machinery. It will also generates data for trending the feature/parameter for easy interpretation of the overall health of the system to the operator. Based on the outcome and experience of the programme it can be further fine tuned for its efficacy and in future can be extended to other class of ICG ships. The online health monitoring of machinery would help in assessing and ascertaining the actual health condition of equipment and would ensure minimum unnecessary maintenance, maximum interval between repairs, minimize unscheduled breakdowns and improve the overall availability of onboard machinery.

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REFERENCES

Myhre B., Petersen S., Ugarelli R., " Using Wireless Vibration Monitoring to Enable Condition-Based Maintenance of Rotating Machinery in the Water and Wastewater Industries", 16th Conference on Water Distribution System Analysis, WDSA 2014 Procedia Engineering, 89 (2014), pp 1397 – 1403.

DU Dongmei, HE Qing, HE Zirui, "A Novel Vibration Monitoring System Based on Wireless Sensor Networks", PRZEGLĄD ELEKTROTECHNICZNY,2013, pp 35-37.

Maximizing Uptime and Efficiency with Wireless Vibration Monitoring by M/s Smart Diagnostics, KCF Technologies, 2012.