

CONDITION MONITORING MAINTENANCE

Ensuring that the Defence Dollar is maximised has placed the operating budgets of many of the world's navies under close scrutiny. Maintenance is a critical area of the operating budget for any navy and the optimal use of the maintenance dollar can secure a range of benefits.

Introduction

The current maintenance regime for machinery fitted onboard Royal Australian Navy (RAN) ships, is predominantly in step with the original equipment machinery manufacturer's (OEMs) recommendations. This maintenance is based primarily upon running hours and/or calendar time scheduling. This form of maintenance scheduling typically leads to the over maintenance of machinery and the introduction of faults into machinery which, in all real respects, is perfectly functional. This type of maintenance is expensive in terms of spares, consumables and manpower. Therefore a more reasoned approach is required to identify appropriate maintenance. A maintenance regime structured around Condition Based Maintenance (CBM), utilising Condition Monitoring techniques, is one such approach. Under a CBM regime, regular measurement or assessment of machinery is performed to determine condition. The essential aim of a maintenance regime that incorporates condition monitoring is to ensure that maintenance is performed only when actually required to achieve the necessary levels of safety, reliability and operational availability (as well as protecting the capital investment).

Condition Monitoring

Condition Monitoring (CM) is a type of maintenance inspection where regular measurement or assessment of machinery is performed (facilitating trending) to determine condition. This approach eliminates over maintenance of machinery – as it works on the principle - 'If you know it ain't broke, don't fix it.'¹ This approach reduces maintenance induced faults. CM is an approach that also offers the opportunity for continuous improvement of the maintenance regime. CM based maintenance has been used by many commercial organizations, to good effect, over many years. In recent times, the commercial shipping industry has come to focus upon the benefits that CM techniques can deliver.

Condition Monitoring Techniques

There are a numerous CM techniques applicable to the machinery fitted onboard RAN ships, many of which have been inspired by the demand for low-manned commercial installations, for example;

1. Performance Analysis;
2. Lube Oil Analysis;
3. Vibration Analysis;
4. Remote Visual Inspection;
5. Thermography;
6. Cylinder Pressure Analysis; and
7. Crankcase Oil Mist Detection.

Performance analysis is used to examine the performance characteristics of machinery or specific parts of that machinery. The imperative being the examination of the performance characteristics of each piece of machinery and the monitoring of those parameters will indicate the most likely failure, for example - flow, temperature, pressure etc.³

Lube oil is the lifeblood of any reciprocating machinery and thus oil condition must be closely monitored and remedial action initiated as required. Wear debris analysis is especially useful in that critical wear components can have small quantities of an indicator metal (not present in any other component) incorporated at manufacture to indicate wear in a specific component.

Lube oil analysis generally consists of two techniques, namely spectrographic and ferrographic analysis. Spectrographic analysis enables identification of the element concentration in the sample, for example, copper, tin etc, to be established, whilst ferrographic analysis is used to forecast component failures based upon wear debris analysis. In addition the characteristics of the oil can be identified, such as - viscosity, pH, Total Base Number (TBN) fuel dilution, water content and so on.

Vibration Analysis - Monitoring of overall vibration levels can be used to detect around 70% of machine problems.¹ It is useful as a screening mechanism, on appropriate machinery, whereby any changes in overall vibration levels may indicate that further investigation is required by using spectral analysis. The nature of a defect can be identified by resolving



the measured vibration signal into its constituent frequencies and relating these to known discrete frequencies associated with the component. Changes in the vibration level of these discrete frequencies may indicate changes in condition of the relevant component. For example, rotating component imbalance causes an increase in vibration at a frequency corresponding to rotational speed, first order and misalignment affects frequencies at twice the shaft speed, second order.

Remote Visual Inspection (RVI) enables internal inspections to be performed using a borescope, flexiscope or videoscope. These instruments consist of a rigid or flexible fibre optic scope, light source, CCTV monitor and video module. This technology facilitates the internal inspection of many different types of shipboard machinery, allowing these inspections to be undertaken with ease. The condition of internal components can thereby be determined. This provides a quicker and cheaper alternative to stripping down machinery for survey.

Thermography (thermal imaging) is a type of infrared imaging science. Thermographic cameras detect radiation in the infrared range of the electromagnetic spectrum (roughly 900–14,000 nanometers or 0.9–14 µm) and produce images of that radiation, called thermograms. Thermal image cameras are particularly useful for detecting faults within electrical switchboards, electric motors, converters, transformers and electrical insulation degradation. They can also be used to detect damage to refrigeration insulation, boiler refractories and misaligned couplings.

Cylinder Pressure Analysis is one of the most comprehensive information sources for monitoring diesel-engine health. The correct interpretation of cylinder pressure information can reveal various faults which effect combustion, for example - timing deficiencies, afterburning, defective fuel pumps, leaking fuel injectors, early firing and leaking piston rings. It is vital that these problems can be readily identified and remedied to avoid loss of output power, shock loadings, fuel pipe rupture and blow-past which can lead to crankcase explosions.²

Crankcase oil mist detection monitors, fitted within a diesel engine, indicate hot spots within a crankspace, indicating wear through the friction/heat produced by the rubbing of components, which can lead to a crankcase explosion. Another useful technique is cylinder liner wear. This can be measured by using thin film resistance sensors, the resistance of which increases as wear increases.

Merchant Marine Sector - Ship Classification Societies

The origin of Ship Classification Societies in the early 1800's was based upon the commercial imperative to evaluate the condition of a ship to carry cargo. Surveyors used an open and inspect regime, for all

parts of the ship. This was followed by planned maintenance programmes where the manufacturer provided a maintenance programme based upon the replacement or overhaul of key components at set time intervals, calendar time or running hours. In recent times, Classification Societies have approved the use of appropriate CM techniques as part of a maintenance regime, in order to meet on-going survey requirements of shipboard machinery, such that open-up inspections can be significantly reduced or even negated.

Numerous Ship Classification Societies have developed and introduced Integrated Conditioned Monitoring Systems, which enable ship-owners to utilize CM as part of their on-going machinery survey requirements. The primary purpose of which is to enable the required levels of safety, reliability and operational availability of shipboard machinery to be achieved, whilst reducing the cost to the owner.

ICMS are based upon a modular service designed to optimise machinery maintenance in the following manner:

1. Initial criticality assessment of shipboard machinery;
2. Development of a tailored Condition Monitoring plan;
3. Collection of baseline vibration, lube oil and thermography data;
4. Installation of shipboard portable data collection systems and analysis software;
5. Bi-monthly analysis of data accompanied by detailed reports and recommendations; and
6. Training for shipboard staff in the collection of data required and use of analysis software.

Pre and post docking surveys can also be offered as part of ICMS. The pre-docking survey facilitates the development of a detailed defects list, which may reduce the length of the docking, whilst the post-docking survey can assist in the identification of defects within the warranty period.

The benefits of the ICMS approach include the following:

1. Lowering of the risk of unscheduled unavailability by detecting impending machinery failure;
2. Make the scheduling and utilisation of maintenance resources more efficient;
3. Reduce the time spent in dry-dock;
4. Reduce the likelihood of maintenance induced failures;
5. Ease of access to condition monitoring data via Class Society website; and
6. Independent third party verification of the maintenance of shipboard machinery – required to satisfy the RAN's Technical Regulatory Framework requirements.



Application of Condition Monitoring to a Commercial Shipping Fleet

An ICMS approach towards maintenance has been adopted by Carnival UK, a subsidiary of Carnival Corporation - the world's largest cruise-ship operator.

Carnival UK has deployed a combined monitoring and maintenance software tool across its fleet of nine ships, as it moves to a maintenance regime based upon condition monitoring. With the assistance of Lloyd's Register, machinery performance is monitored and analysed to facilitate maintenance optimisation.

This has been achieved by the development of an interface between James Fisher's 'Mimic' and Spectec's 'AMOS2,' software. Mimic is a Condition Monitoring (CM) system and AMOS2 is a Computerised Maintenance Management System (CMMS).⁵ Data such as - vibration, pressure, temperature and load etc, are collected from numerous machinery sensors, the outputs from which are fed to the Mimic CM system which is fully accessible through Spectec's AMOS2 CMMS.

James Fisher Mimic, provides monthly analysis reports describing specific machinery condition to the Ship Classification Society (LR) the marine engineer superintendents and chief engineer officers of all Carnival UK ships. The reports facilitate trend-analysis of the condition of machinery being monitored and is an integral element used by the Ship Classification Society to meet the on-going survey.

The continued success of such software specialists demonstrates the value that shipowners/operators are placing upon shipboard machinery maintenance and performance, in particular when unscheduled breakdowns and the poor performance of shipboard machinery can result in costly dry-dockings and increased costs due to increased fuel consumption.

Conclusion

All RAN engineering personnel receive basic training in CM during Initial Technical Training (ITT). Thus an understanding of relatively simple CM techniques such as - parameter measurement, lube oil analysis and vibration analysis, currently exists within the RAN. This knowledge could be used as the first step in improving maintenance across Navy.

The adoption of CM across all platforms within the RAN has the potential to optimize the maintenance of shipboard machinery. CM technologies are inexpensive to implement and provide a relatively quick return on investment.

CM may also enable the RAN to reduce the number of shipboard maintainers. This would be welcome, as man-power is the most significant cost contributor to the operational phase of the life cycle of a warship. Thus, lower manning levels are desirable. The quantity of maintenance, however, must not be excessive. It

follows that maintenance must be optimal and only conducted when absolutely necessary.

The adoption of CM aligns with the short term goal of the Australian Department of Defence (DoD) to deliver cost savings of approx \$1billion per year from the Defence Budget.

The long-term benefits to the RAN of reduced breakdown maintenance, optimal use of manpower, improved crew morale, job satisfaction and increased retention rates of quality personnel are immeasurable.

END NOTES

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Published by: The RANR Professional Studies Program, Office of the Director General Reserves (Navy). The views expressed in this publication are entirely those of the author and do not necessarily represent those of the RAN, The Department of Defence or the Australian Government.

