The Royal Navy and a modern approach to condition-based monitoring in remote locations

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Synopsis

At 367,850 tonnes the Royal Navy is the fifth largest navy in the world, with this set to increase in the near future as the Type 26 and Type 31 enter the fleet. As one would imagine this presents a large logistical challenge when managing the maintenance of a fleet this size. Since its introduction to the commercial world as a concept in the early 20th century, condition-based monitoring has been used in the Royal Navy. Currently the Navy is looking into 'Big Data' as a concept and as such has an appetite for adopting a predictive approach to platform management. With the introduction of integrated platform management systems as seen in the Type 45 destroyer and the Queen Elizabeth Class aircraft carrier the RN has begun to adopt a lean manning approach to crewing its vessels. This has huge benefits in terms of both quality of living for the embarked ships company as well as a significant reduction in running costs. However, in terms of platform management there are fewer Technicians closed up in spaces to detect defects and Technicians rely heavily on the automated systems to indicate if machinery is running out of the allotted parameters. The usage of condition-based monitoring in the RN has not changed much since its inception. The equipment and systems used to collect and analyse machinery have been upgraded, however a move towards a fixed, more robust system would see a greater amount of useable data sent ashore for analysis. Remote operation of Naval assets and the heightened security measures required for military applications have slowed the move towards worldwide real time collection of data. Nevertheless, this does not have to result in a complete rejection of modern data analysis and there are a number of commercial users who operate in remote locations and with a similar requirement for security of the data collected. How the Royal Navy interacts with the fourth industrial revolution has the potential to guide the future of Naval combat; however as many industries have found, the move to the automated future doesn't come without its own set of challenges.

Keywords: Condition Monitoring, Data-driven Diagnostics, Reliability Centred Maintenance, Remote Monitoring, Marine Systems

1. Introduction: Condition Based Monitoring

Condition based monitoring (CBM) and reliability centred maintenance are two concepts which complement each other in their execution. When applied and analysed correctly CBM can afford operators and maintainers a far greater accuracy in predictions of equipment failures, along with the ability to move towards a reliability centred approach to maintenance of assets. It is well known that this move represents a considerable reduction in maintenance costs as well as a considerably 'greener' approach to plant operation. A watch keeper while conducting rounds and inspecting equipment, is continuously comparing their observations to previous observations as well as known parameters to determine if equipment is still running correctly. This method allows a large amount of equipment to be surveyed at any one time. This organic form of trending data is the underlying principle of CBM which moves to levels of data collection, capacities and accuracy unachievable by human senses. The larger data sets comprising of multiple pieces of similar machinery give a greater sample size on which to base trend data and can greatly speed up development times of machinery still in build.

Author's Biography
SLt Nick Chrumka is the Assistant Marine Engineer Officer in HMS Defender currently deployed with the UK Carrier Strike Group. A Mechanical Engineer by degree he worked for Helix Autosport as a Design and Production Engineer specialising in Computer Aided Design and Manufacturing. In 2019 he was promoted to the head of engineering and design overseeing numerous Tier 1 Automotive supply projects as well as a company move to a new production facility. He joined the Royal Navy as an Engineer Officer (ME) where he deployed in HMS Forth to the Falklands and later joined the Machinery Trials and Assessment Unit of the MCTA in between his professional training at HMS Sultan.

2. Benefitting from Local Data

The Platform Management System (PMS) on the Royal Navy’s Type 45 Destroyer currently allows engineers onboard to analyse the data it collects in what it calls ‘Trend View’. This is currently used to better understand machinery failures, however there is limited training available for this function as well as little documentation for the majority of the data it is able to display. The system itself has a large store of data collected, and presents an excellent opportunity for analysis of the plant. Since their introduction, the Type 45 Destroyer has had an enormous amount of development put into the platform around the operation of the plant in abnormally hot climates. The two WR21 gas turbines onboard each Type 45 have seen reliability issues since their introduction owing to operation in hotter climates as well as greater running hours than originally planned. The engineering departments on deployed ships operating in such conditions conduct classification trials to set out the operating states of machinery. The underpinning theory behind this trial is centred around the point at which the WR21’s Electronic Engine Controller (ECC) stops governing the engine on power turbine speed and begins governing on power turbine exhaust temperature (PTET). This was one of the many outcomes of Project Napier commencing in 2014 which was stood up to address the shortcomings in the propulsion plant of the Type 45. The two veins of the project were the Equipment Improvement Plan (EIP) and the Power Improvement Plan (PIP) which sought to target some of the ship’s shortcomings in propulsion. (RINA - The Royal Institution of Naval Architects, 2017)

The Queen Elizabeth class of aircraft carriers have an hourly recording of data from PMS. Their version of PMS onboard was originally planned to automatically give specific alarms based on the data collected from its sensors. This however, was culled due to cost and now the user simply gets an alarm stating that there has been a mimic alarm which then they have to investigate.

HMS Defender has seen some of the best reliability from its WR21s out of all the Type 45s. This can be partly accredited to the close working relationship between the ships company, its engineers and Rolls Royce which has bought about a significant change in the way that the ship operates its plant. Like most gas turbines the WR21 begins to present reliability issues when used for long periods at low load. With this bringing itself to the attention of the media it understandably represents more than just an availability issue. The rectification of this comes from feedback from the ships company and analysis by Rolls Royce of the logged data from the ship. Little knowledge exists on ships for interrogating logged data but if members of the ships company had been trained to analyse the data recorded, solutions could have been brought about earlier.

3. Remote Data Analysis

Acoustic data collected for the purposes of Vibration Analysis (VA) is currently analysed by CMAT in Portsmouth. This takes advantage of a number of deep specialists to accurately investigate data collected with the team publishing reports to fleet and platform to be actioned by the ships company. This does however add a delay to the actioning of results, but the advantage of VA is that defects within machinery can be detected far sooner than human senses could notice changes in a piece of machinery’s tone, vibration or heat. Being able to detect these changes in advance can prevent the excessive wear that an imbalance or misalignment could cause, and allow rectification work to be carried out. This would allow repairs to be conducted on machinery in place before reaching the point of failure, as opposed to being forced to replace components that have failed. Real time monitoring remotely, is still a way off due to the limitations posed by both data connectivity at sea and the sheer volume of data this would generate. A regular interval of data collection to be sent for detailed analysis is a possibility but this increases the work load on the departments who would have to collect the data locally.

Buy in from the ships company is a significant factor affecting the flow of data leaving the ship, and even from a single unit it can vary in quality based on a number of human factors such as morale and fatigue. The result of this is that timeliness and accuracy of collection varies significantly from platform to platform, and from month to month depending on individual ships programmes. Fixed sensor systems on the plant with a centralised method of collection would reduce this workload greatly, providing a more reliable data set from which to base analysis.

The environmental aspect of operating heavy machinery has been disregarded for many years, and it is now being highlighted the detrimental effect it can have on the environment. Although changing the way maintenance is planned in the fleet may result in an increase in the frequency at which some components are replaced, most adopters of CBM notice that they achieve a significant net decrease in the overall frequency of component replacement. CBM has been utilised effectively in the renewable energy sector for many years. It is particularly pertinent in its application in wind turbines. Due to the nature of their energy source when bearings fail, they fail catastrophically and can lead to fire and or significant structural damage. The use of VA has enabled operators to better predict failures and this has led to a significant increase in availability. (Schaeffler, 2014)

4. Fuel Consumption vs Hours as a method of quantifying work done

When implementing a planned maintenance strategy, the maintenance schedule traditionally has been driven by equipment run time hours. Although this method works well for equipment that runs consistently at a steady speed and loading, it relies heavily on quality control during manufacture of components to allow for all products to fit into the bell curved maintenance plan laid out. When operating machinery that has been produced in small batches where little data is available, or the equipment in question is being operated in remote locations where OEM support is almost unachievable other methods of deriving maintenance patterns can be used. Changes to climate, altitude, moisture, loading, changes in runtime usage are all factors that would push a piece of equipment outside the standard maintenance schedule provided by a supplier.

The mining and crushing industry is one that, similar to the RN, operates in remote, hard to access locations with considerable costs associated with unplanned downtime. Such as Caterpillar, a market leader in large commercial engines, bases the majority of their maintenance intervals on fuel used rather than hours run. Both hours of runtime and quantity of fuel consumed are recorded however fuel usage gives a far greater indication of how hard a piece of machinery has been run.

The Royal Navy currently bases planned maintenance on hours of runtime. Maintenance serials such as washing gas turbines are planned around hours of engine run time rather than any other factors that would contribute to the coking up of the engine. To move to a more effective operating model such as the one employed by Caterpillar may offer the RN a better way to manage planned maintenance, especially when considering the variability of factors such as fuel quality as well as usage. Whilst at times this might result in a higher frequency of serials such as GT washes it seems likely that it would result in higher overall engine availability as the increased preventative maintenance should reduce the number of interruptions to the Ship's Programme caused by unplanned maintenance.

5. Implementation

Given the lack of bandwidth available to British warships, the data set collected would need to be managed based on collection strategy. Periodic collection of the data set would allow for much greater amounts of data to be collected. Real time data collection would be limited by the bandwidth of the vessel along with the amount of data points being recorded; this could be reduced in size by exporting the raw sensor data and conducting all post processing for analysis of the data ashore. Implementing real time analysis onboard a RN asset presents a number of challenges given the nature of the warfighting environment. This puts the system online and as we move into a world relying more heavily on the Internet of Things (IOT), this space is becoming more appealing to criminal actors as the adoption of this new technology increases. Completely 'sand boxing' the system would ensure the greatest level of security of the data, but does not resolve the limitation presented by the current lack of available bandwidth. With all security questions raised and considered the system similar to those already on the ship would have to be a standalone isolated system receiving only controlled updates through approved channels, at least until there is a better solution to the bandwidth issue.

There are two methods of execution for implementing an improved CBM scheme into the Royal Navy fleet. The first being detailed training on CBM to enable ships company to interrogate data locally, the second is a lighter training package to give a wide understanding of the data collected and have a method of displaying tailored information to the engineers onboard. The second could be expanded into the platform management system which is already in place. This would give operators the ability to fine tune the warnings and trips on this system, and could broaden understanding of the plant from even the most junior of ranks. The ships PMS network already allows a level of flexibility around the ship as there are network connection points in various compartments. This would allow this extra functionality to be implemented without clogging an already crowded Ships Control Centre. Having a data logging capability with increased sensor integration would reduce the administrative burden on the engineering departments as sending data shoreside is simply a question of downloading the data and sending it off. Fixed sensors would remove a number of variables (the individual holding the probe, angle, force, damage to the probe in between readings) and lead to increased accuracy of the data being collected. This also further reduces the work load within the department.

6. Alarm Fatigue

The modern Navy is relying increasingly heavily on automated systems for monitoring equipment. This reduces the manning requirements for vessels and ultimately the largest portion of any company's budget, paying its employees. Now watchkeepers monitoring these systems are presented with user interfaces displaying warnings and alarms from pre-determined parameters. With small batches of ships where the platforms are themselves the prototypes the ability to understand issues early on and to begin implementing methods of rectification are key. PMS currently incorporates an alarms and warnings system within it, where the system delivers a considerable number of spurious readings to the watch keeper which has been known to lead to alarm fatigue. For example, on any morning watch, the Engineer Officer of the Watch receives a multitude of alarms when the ships company get up and start showering as the fresh water ring main pressure drops. The fact that this is a known issue at a set time of day means that there is an increased risk that a more serious alarm would be ignored. The thresholds at which these warnings become active is initially set at an OEM level however the maintainers have the ability to change these. The Type 45 platform is the first platform the Royal Navy has operated with a fully computer driven management system. Better understanding of the systems, the sensors, and the monitoring parameters would allow removal of spurious alarms reducing watch blindness therefore shortening response times for genuine faults. (Barbara J. Drew, 2014)

7. Training

Fundamentally, buy in from the equipment operators and maintainers is key to delivering any change in operation. Currently feedback from the Machinery Vibration Analysis unit within the MCTA suggests a lack of understanding of why vibration analysis is conducted and how it is beneficial to the ship, preventing the collection of good quality data. Reports of different acoustic recordings all identical and all within a matter of minutes of each other would suggest the engineering technician tasked to conduct the recordings 'might' have collected all the readings from the same pump rather than walking about the ship and collecting. Increasing the training requirement for this capability at a more junior level should prevent this occurring, but it requires assurance from analysis teams that can quickly spot when data is not being correctly recorded to drive this change forward effectively.

Royal Navy training at every level of employment is excellent in both development and in empowering each individual to work in a safe and efficient manner, however funding remains a key limitation to the level of provided training. The move towards operation of increasingly specialised pieces of equipment significantly increase the training burden and cost for each individual engineer. Any company offering specialised engineering equipment offers training packages and this is usually where shortcomings in funding for projects start to become apparent. For example, sailors are currently sent for commercial training for PMS however this has been reduced from a five-day course to a single day of training. Whilst this reflects an immediate reduction in costs of training, the net result is harder to judge as reducing training is likely to lead to increased costs later due to equipment being operated less effectively. Investment in training will ultimately result in a workforce that is more willing to trust in the equipment they operate, as they have a higher understanding of the impact of their actions.

As a government owned entity, the Royal Navy operates very differently to nearly every other operator of large equipment. The Navy operates its assets predominantly based around process and as a result has driven its engineering projects around the perceived budget without looking further into the actual factors driving the costs. The Type 45 project was initially for a batch of 12 vessels. This was then reduced to 8 and again to 6 the Navy now operates. With the obvious increase in the share of development costs per vessel this has an adverse effect on public perception. Along with reducing the availability of the platform and the appetite of suppliers to provide spares and support.

8. Conclusions

Any large-scale changes to how an organisation the size of the Royal Navy operates will never be easy and often push back from within the organisation itself can be considerable. However, closely targeting smaller areas of the organisation can prove considerably more effective in driving change. Small changes over time offer a lower initial cost outlay as well as the scope to build redundancy in suitably qualified and experienced personnel. Worldwide operations present the issue of ever-changing logistics routes and last minute support for deployed vessels cannot always be guaranteed. Planning maintenance into a deployment and in the run up to will require operators to trust the data they are presented with.

Reducing variables in any technical process increases the accuracy of its products. The introduction of fixed sensors to the fleet's existing VA process will remove the crucial human variable from the data collection process. The addition of an integrated system on platforms to collect and analyse data will help change the understanding of the vessel as well as aid early detection of defects. This will also free up spare capacity within the department as both the data collection, analysis and distribution are automated. The accuracy of data collected is key as the Royal Navy move towards data driven decisions in the future. Although the initial cost to implement a change of this scale will potentially discourage adoption, the larger impact on the rest of the fleet will most likely outweigh the initial cost outlay. Attempts to initiate real time monitoring on platforms are still dependant on connectivity at sea, and therefore are still a long way off.

The key components required to adopt a modern data driven approach to maintenance already exist within the Royal Navy. The move towards a 'big data' methodology will help the service better understand its vessels and the challenges faced. The introduction of new platforms into the fleet presents an excellent opportunity to realise the potential of this methodology at the start of a class lifespan. This will provide useful data well ahead of the inevitable obsolescence of components as well as a considerable time saving in the initial trials stage of platform development.

Therefore, better adoption of CBM would allow a migration away from periods of unplanned maintenance and the considerable capitation rate associated with this. The increase in platform availability and stability in the planning horizon will significantly reduce the through life cost of the various platforms the Royal Navy operate.

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