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Management aspects on Condition Based Maintenance – the new opportunity for maritime industry

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ABSTRACT

The maritime industry is in many aspects using maintenance strategies from the past. Land based industry used to take influence from shipping to organise the maintenance in the 70:ties. Now industry is perusing new strategies that give better reliability and are more profitable. By focusing on reliability the indirect effects from doing the wrong maintenance can be reduced considerably. Shipping industry has from a maintenance aspect been doing the wrong things correct for many years. The opportunity is now to do the right thing correct instead.

The traditional economical tool of a cost budget for each individual part of the organisation does not show the effect on the profit that maintenance has. The profit is there to take - but invisible to the decision makers.

By maintaining the value of the assets the vessel can be used for a longer period even after the investment is written off. This is a very profitable period for the ship and the return on investment can be optimised. Concordia is one shipping company that have oil tankers. They put additional professional maintenance staff onboard and save millions of dollars per ship by doing this. The increased reliability improves the just-in-time docking, gives less spare part consumption and a longer production life of the vessel. The labour cost is higher but the positive effect on the profit is even bigger.

Condition monitoring has been introduced on several hundred vessels with limited or no success. In most of these cases the condition-monitoring tool has been purchased without considering the necessary change of the organisation onboard and the need for an organised knowledge transfer between crews.

The classification of the ship has also in the past been interpreted as a limitation to make the necessary changes for successful implementation of the more modern condition monitoring strategies. This obstacle is now being removed. DNV is introducing the new associated DNV survey arrangement Machinery CM (condition monitoring) classification that will open up a new opportunity for the maritime industry. This will however require a complete change of culture where the priority of the labour hours and the allocation of resources have to change focus.

This paper will cover the economical aspect of condition monitoring, the strategically important considerations and the link to the new DNV classification. The paper intends to show that the correct maintenance strategy creates both profit and better return rates, to a much larger degree than shown by traditional economic models. Instead of simply regarding maintenance as a cost factor, to be kept as low as possible, modern management can treat it as a means of realizing the profit potential inherent in each vessel.

1. THE CONDITION BASED MAINTENANCE (CBM) OPPORTUNITY

DNV is now introducing the new associated DNV survey arrangement Machinery CM (condition monitoring) classification. These statements are taken from the DNV home page, Fig 1.

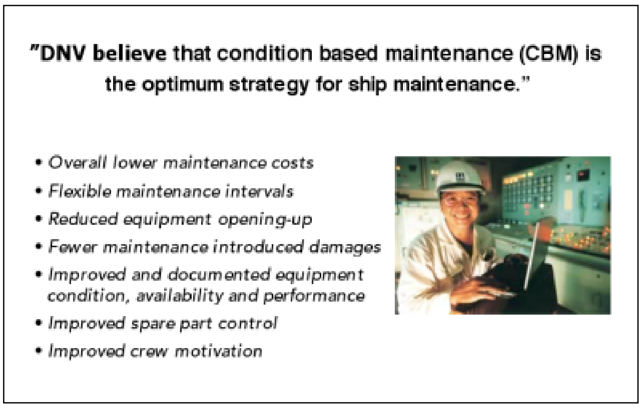

Fig 1: Statements from DNV

Shipping has a number of opportunities when implementing the condition monitoring activity on rotating machinery.
The traditional classification of the ship can require that the machine should be opened according to operation hours, even if it is in good condition. This unnecessary work can be avoided by the new associated DNV survey arrangement Machinery CM classification. DNV lists the machines onboard and gives general guidelines how they should be measured. The advantage is that the maintenance work can be planned according to actual condition and the reliability increases. DNV will allow for trending the readings and show the results as bas for the survey. The unnecessary work of opening good machines can be avoided, labor costs and spare part consumption goes down. The lubrication intervals of the bearings can be based on condition. This will reduce bearing failures prolong the lifetime and reduce power consumption. The breakdowns, the unplanned and the unexpected maintenance will be reduced to increase the safety. The quality of the alignment of the shafts can be measured and the misalignment corrected. This will increase the lifetime and reduce energy consumption.

The benefits are many and this opportunity can increase the profits in shipping substantially if the new modern practices are implemented.

2. WORLD CLASS PERFORMANCE

International competition forces companies in all branches of industry towards an ever-higher standard of performance. Today, it is not sufficient to be among the leaders within your own field. Investment capital looks for maximum returns, so you are competing with every company in the market. To meet the challenge, management must use new tools and strategies.

Shipping is today regarded as one multi-linked process where each aspect has to be fine-tuned to achieve maximum results. The maintenance budget is a significant cost and thus very important for the overall economic result. The problem with maintenance, from an economist point of view, is that its costs are easily measured while its contributions to the vessels revenues are not. "We can cut down on maintenance to save money" is an argument that most often is wrong. Cuts of maintenance costs lead to problems elsewhere, so this kind of saving can become very expensive. Low quality machines and spare parts together with unskilled labor inevitably give higher overall costs. The machines break down more often and unskilled crew creates new problems when they open up for inspections or repair machines.

3. ASSET VALUE PER EMPLOYEE INCREASE EVERY YEAR

The trend in maritime industry has been towards larger vessels operated by less people. Machines have as far as possible replaced human labor. Operating large ships with a relatively small crew must necessarily also shift the focus of management as it has done in land-based industry. The approach in industry is described by the term "Asset management". Maintaining the technical life of the vessel past its economical life has a positive effect on the final economic results of the asset.

Traditional management takes a fairly narrow view. It works by departments, trying to make each part of the ongoing activities as efficient as possible. Quite often, this does not produce the optimal total result, because "improvements" in one sector can have greater negative effects on other activities. Incentives for the purchase department to lower purchase prices can result in cheap products and spare parts that don't fit, break, give higher energy costs, hard to maintain, reduced reliability etc. The savings in one department increases the costs in others so the overall profit is reduced.

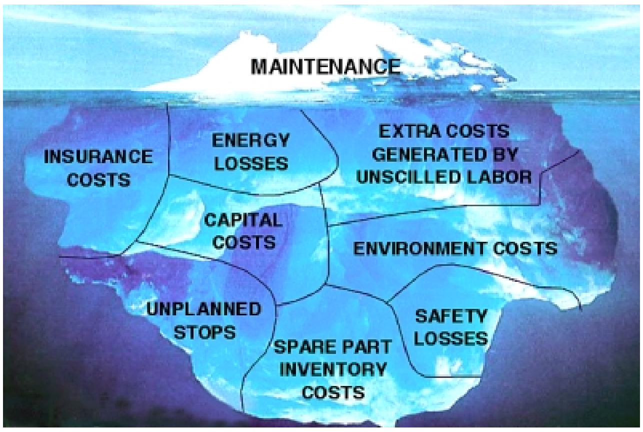

Fig 2: The indirect costs in maintenance

Budgeted maintenance costs are usually only the top of the iceberg. The real costs, often in the form of indirect costs, are hidden, or turn up in some other part of the organization, fig2.

4. WHERE DOES CONDITION MONITORING FIT IN?

Condition monitoring of rotating machines has been used for more than 30 years. The technical developments in form of instrumentation and software have been significant during this time. The handheld instruments have become small and powerful analytical tools supported by user-friendly software. The condition monitoring effort must however also fit into an overall reliability commitment to work.

Reliability has to be supported by a maintenance policy so the entire organization can focus on the correct thing to do. The benefits of the CM program are recognized when the results from the measurements actually are used to support the correct maintenance activity.

The support of reliability and maintainability starts already with correct design and procurement. The purchase department must work from the Life Cycle Cost (LCC) approach and the products they buy should be of such quality and design that they are easy to maintain and do condition monitoring on. The machines that are purchased can be fitted with adapters or permanently installed transducers for measurements with portable instruments or with online systems for even better protection. The condition monitoring can then easily be made already from the start. Retrofit often takes longer and can sometimes be technically difficult to do, fig3 & 4.

Fig 3: Adapter for shock pulse measurement with electronic ID tag

Fig 4: Four channel protection system

5. TRADITIONAL STRATEGY FOR MAINTENANCE

In a traditional maintenance strategy the resources are to a large extent used to open up machines that are in good condition, it is difficult to make changes. There is simply no time; the resources are organized for, cleaning and lubrication:

5) Time based overhauls
6) Redundancies are designed into the process
7) Corrective work

Everybody is working hard driven by unnecessary planned stops, breakdowns, and unplanned stops. The management is chasing ways to cut maintenance costs because the company is not profitable enough. No one knows how to calculate the contribution from maintenance. To introduce condition monitoring in a company with this culture always fails. If the program starts it will normally be short lived, the resources for doing condition monitoring is needed to do “more important work - overhaul machines”.

6. RELIABILITY DRIVEN MAINTENANCE

The successful companies implement condition monitoring as part of a maintenance strategy that supports the activity. The management must allow for a change of priorities in the maintenance work. The implementation is critical and it is important that everybody realises what the new priorities are and why they are made. The maintenance resources in the organisation must now be focused on the activities that drive the reliability of the ship:

Cleaning and lubrication
1) Design out the repetitive problems
2) Increase the lifetime of the machines
3) Condition monitoring during normal operation
4) Condition monitoring during planned stops
5) Time based
6) Redundancies
7) Corrective

The condition-monitoring program becomes necessary, as the pre-warning time of developing machine problems are vital for the strategy. The maintenance work is carried out during planned stops and all unplanned activities are considered as a problem that has to be prevented from occurring again. The unnecessary overhauls and breakdowns are eliminated so the labour hours can be freed to work on improving the quality of the machines. Condition monitoring is also used to identify the route-cause of the problem so the right corrections or design changes are made. In a world-class company there must always be time for improvements in machine design and procedures. Always asking if you do the right thing according to the strategy.

This strategy becomes a positive spiral that feeds on itself with, fewer breakdowns, less spare part consumption, better planning of needed man hours, increased safety, better environment and improved reliability.

When a full cultural change has been made only 20% of the work is actually spent on the traditional maintenance work. The resources can be allocated to maintain the asset value of a ship and the reliability improved at a lower cost; the profits go up.

7. USING CONDITION MONITORING TO ITS POTENTIAL.

The most difficult challenge is to create a structure were condition monitoring is part of the maintenance strategy. Once done the next challenge arises, to use CM to its potential. Even companies that are considered successful very seldom follow up the economical effect of the program or look for ways to develop the program to cover the entire vessel even if the potential for earning more money is there. To become successful it is important to evaluate the economical contribution of condition monitoring on a regular base. Only then will the foundation for the program be allowed to expand and cover the entire ship.

These are some examples of key performance indicators that can be followed to measure the effect:

- Maintenance cost/Asset value
- Condition monitoring hours/ Total hours of work
- Time based hours/ Total hours of work
- Hired labor hours/ Total hours of work
- Total hours unplanned repair/ Total repair time
- Average shock pulse and vibration level
- Stock of spare parts/Asset value
- No. of purchase orders of spare parts
- No. of withdrawals from stock
- Docking time/waiting time

8. CASE STUDY FROM INDUSTRY

Let us compare with some other key performance indicators from industry. This study was made at Hallsta paper mill in Hallstavik, Sweden and an example how the contribution from the program can be analyzed. The mill produces 785.000 tons of paper per year. The key performance indicators were selected as:

1) No. of machines included in CBM (condition based maintenance)
2) No. of measuring points per inspector
3) Pre warning time

Result:

1) In total there are 8 inspectors that cover 16.000 measuring points at the mill. The applications consist of some 800 rolls and 4.000 auxiliary machines in the plant.
2) In total this makes an average of 2.000 points/ inspector.
3) In order to evaluate the pre warning time from the first detection of a damage to the time when the component was changed the data bas covering 6200 measuring points was analyzed. It consisted of 2300 machines and covered the period between 1993-1999. Some of the machines that were studied consisted of:
   - 74 fans
   - 1070 el. motors
   - 103 pumps

The average pre-warning time from detection to corrective activity is 69 days and 95% were changed within the period of 59 to 78 days. The differences in pre warning time for the various applications can also be seen in the enclosed graph fig 5. The pre-warning time on electrical motors, pumps and fans are similar for ships according to the experience from SPM.

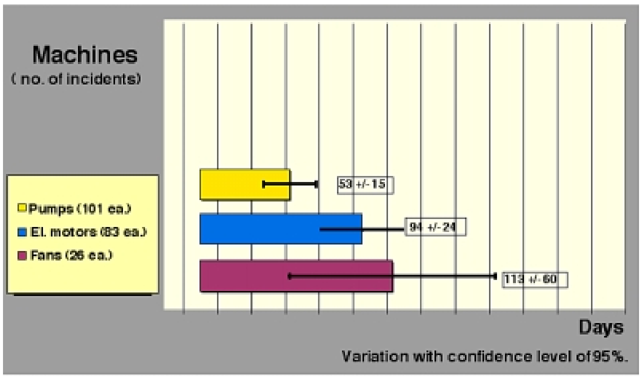

Fig 5: Case study on pre warning time for bearings

During this period there were no catastrophic failures on the equipment that was included in the program, so all incidents could be detected and failures avoided.

The number of rotating machines can run close to 1000 units on a large ship so it is important to set up the program in a cost effective way where one person could handle the entire ship.

9. SELECT A CBM STRATEGY THAT WORKS

The results from the condition-monitoring program must be easily understood by a number of key persons that not are experts in understanding what the data means. This is the first important consideration to make. When the condition-monitoring activity only involves complicated vibration analysis the program will never take off. It takes several years of daily measurements to become an expert on your own machines with this technique. Great care should instead be made to see that the software and instrumentation could give clear evaluated answers in easily understood form, like green-yellow-red trends.

The study from industry shows that the vast majority of the readings are good. 75% are in good condition 20% on observation and only 5% actually show risk for damages. To determine that a machine is good must be fast and accurate, don’t spend time to analyze good machines. This sounds like an unnecessary statement because it is so obvious. Never the less many companies have fallen into the trap to do full analysis on everything.

9.1 WHAT DO WE NEED TO KNOW?

The way to avoid an overkill of analysis is to start with the question; what do we need to know? By studying the incident reports from the past it is possible to see what kind of incidents need to be detected. From previous studies by SPM it is known that bearing failures, unbalance and misalignment cause the big majority of incidents on electrical motors, fans and pumps. Realizing this incident history the program can be set up to focus on these problems on a large number of auxiliary machines.

9.2 FRONT LINE CONDITION MONITORING!

The methods that can detect these most common problems and present the results in green yellow red are preferably selected. SPM recommends shock pulse measurements for bearings and rms vibration based on the ISO standard for unbalance and misalignment for most of the machines.

9.3 SECOND LINE CONDITION MONITORING!

For special machines that have more complex configurations, specified by DNV, and other critical moving parts like gearboxes, vibration analysis in various forms can be used. It is however also possible to use smart ways to convert complicated vibration data into green-yellow-red with for example the EVAM method by SPM.

This dual approach for hand held measurements makes it possible to run the program in a cost effective way on a large number of machines. Little time is spent on analyzing unnecessary data and it is easy to report the results of the readings.

9.4 CONTINUOUS MONITORING!

The critical machines where the effect of a breakdown effects safety or the costs becomes large are candidates for continuous monitoring. There are also cases where the developing time damages is short where protection systems with automatic shut down can be justified, fig 6.

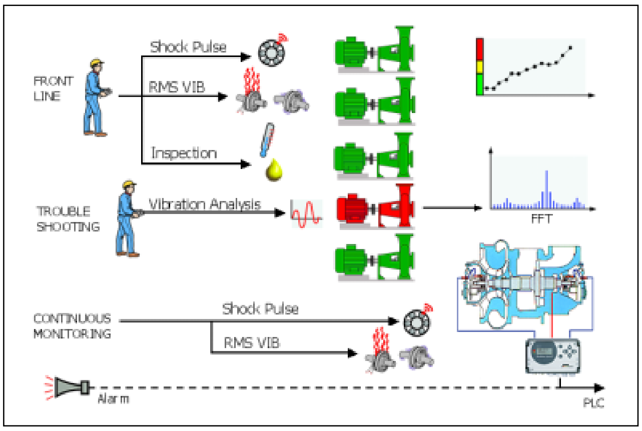

Fig 6: Condition monitoring strategy

10. THE SHOCK PULSE METHOD FOR MEASURING ON BEARINGS

The Shock Pulse Method (SPM) is the easiest and most reliable method for front line monitoring of rolling element bearings. It was developed by SPM Instrument AB in Sweden in the 1960ties and has been used ever since. Shock pulses are transient pressure waves in the material, caused by mechanical impacts. When a metal ball hits a metal bar, the first result of the impact is the shock pulse. Its magnitude is a function of impact velocity and independent of the mass and shape of the colliding objects.

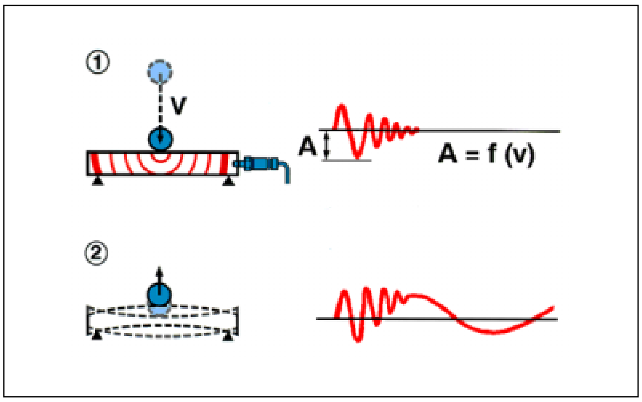

Fig 7: Shock pulses and vibration

The next result is a vibration of the bar. The transducers are constructed to measure only the shock. The shock wave excites the shock pulse transducer at its own resonance frequency of ≈ 32 kHz, thus amplifying the signal. The SPM measuring circuit is electrically and mechanically tune to filter out all other vibration. Consecutive shock waves are registered as a rapid sequence of pulses with different magnitudes. All rotating bearings generate shocks. Their magnitude depends on the state of the bearing surfaces and on the lubricant film between rolling element and raceway.

A low level shock carpet indicates an undamaged, well lubricated bearing. When the oil film is too thin, there is metallic contact between the bearing surfaces and the level of the shock carpet rises. The typical development of the shock signal during a bearing's life time is shown by this curve. If the bearing is properly installed and lubricated, its shock signal remains low and stable during most of its life. Installation faults are indicated by an abnormally high shock level right from the start. Stress in the surfaces increases the shock level. This is followed by a rapid, large increase when visible damage sets in. Surface damage and metallic particles in the lubricant produce individual shocks which are much stronger than the shock carpet.

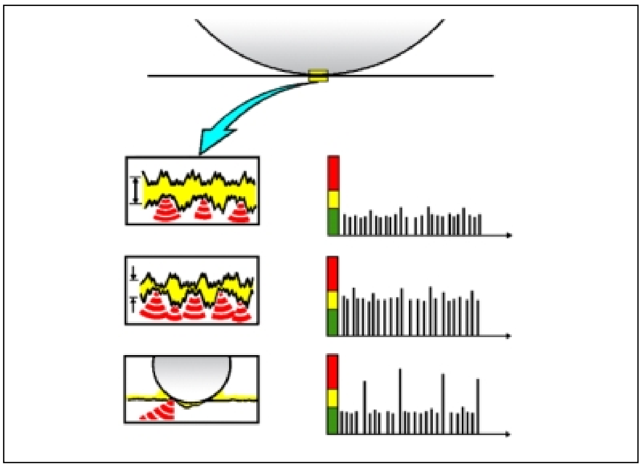

Fig 8: Bearing condition determines the shock value

The advantage of the SPM Method are few and easily obtained input data (rpm and shaft diameter), allowing a direct evaluation of the measuring result (green - yellow - red condition display by the instrument). Bearing condition can be monitored throughout the bearing's life time (detection of installation faults, poor lubrication, misalignment).

11. VIBRATION SEVERITY

Vibration severity measurement is the ISO recommended method for general machine condition monitoring. To assess general machine condition and detect out of balance and misalignment, one can measure vibration severity according to ISO 10816. Vibration severity is defined as the RMS level of vibration velocity, measured over a frequency range of 10 to 1000 Hz. This requires a different transducer type and a different way of signal processing. Instead of measuring the amplitude of a transient at a single high frequency, the vibration severity reading represents an average of all vibration components within a wide and comparatively low frequency range.

Vibration severity is directly related to the energy level of machine vibration, and thus a good indicator of the destructive forces acting on the machine.

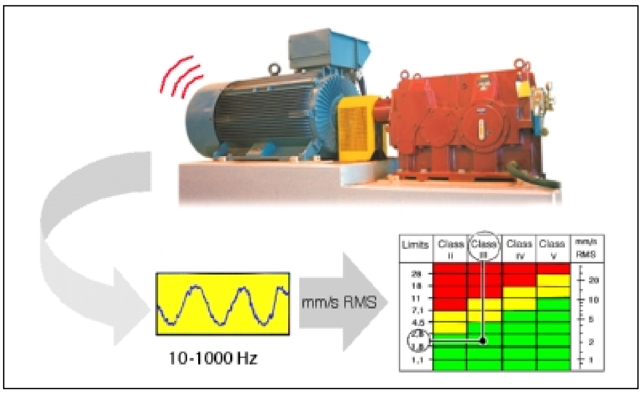

Fig 9: Vibration severity

12. INSTRUMENTATION FOR USE ONBOARD THE VESSEL

The instruments for use onboard should preferable be multifunctional and easy to use. This shows an example of an instrument from SPM that is intended for both front and second line use depending on how it is programmed.

SPM® Method
Vibration severity
EVAM® Method
SPM spectrum
FFT
Temperature
R.P.M.
Alt. measuring systems
Recording
Check points
Comments
Measuring point identification
Balancing

Fig 10: Leonova by SPM

13. SPECIAL CONSIDERATIONS FOR CBM ON SHIPS

The big difference from land based industry is crew change on regular bas and that still some ship owners insist on using unskilled personal in the machine room, in the belief that this is more cost effective. The shipping companies that are using unskilled crew are not candidates for CBM.

Knowledge transfer: In a fleet with skilled personal the training should be made for one or two inspectors per ship and offered every time before boarding the ship. The shipping company can have its own specialist that does the training or use the vendor of the equipment to set up the regular training program. The inspector should from the start have a good knowledge of machinery and know how to work on a computer.

The bigger the turnover of the crew is with new persons coming in often the more difficult it is to keep the program running. A general rule is to focus on carrying out front line condition monitoring when starting a program. The second line analysis is unrealistic to do without having the same inspectors rotating in the same fleet.

Some ship owners with several ships in the fleet have solved the problem of transferring knowledge by having the inspector onboard carry out front line measurements and one or two specialists rotate in the fleet when deeper analysis is needed.

Standardize the program: Start with preparing the pickup points by installing permanent adapters so that the same point always is measured. In some cases transducers are used to get access to the correct point. Set up the software so that it is similar in the fleet, if the inspector comes to a new ship this saves time and improves the quality of the program. Use the same instruments and measuring techniques all to facilitate the knowledge transfer between crews.

Start by walking: In the DNV classification for CM some machines require full vibration analysis. SPM recommends that you start with the front line program that will cover the large majority of the machines before you include the more difficult machines.

14. OUTSOURCING VIBRATION ANALYSIS

Some navies and commercial ship owners have also been contracting condition-monitoring specialists that do a few regular inspections per year. This approach does not replace the CBM program on most ships. Random tests cannot exchange routine measurements onboard where some machines have to be followed daily if damage is developing. If the specialist not can be available on short notice and spend the required time from case to case, it is not condition based maintenance but rather trouble shooting for special events. This activity can on the other hand be good complements to a front line condition monitoring program onboard the ship.

15. TURBO CHARGER EXAMPLE

The turbo charger is a good example where it is very profitable to go from time based to condition based maintenance. The change of a bearing package for an ABB turbo charger type 714 costs some 25.000 USD, a breakdown where the shaft has to be changed costs up to 120.000 USD. Considering that the bearings always are changed at the wrong time when going by running hours this is a very expensive maintenance strategy.

CBM will increase the safety against catastrophic failures and lower the maintenance costs as the bearings normally can operate a longer time, there are turbo chargers that run well over 30.000 hours before having to change the bearings.

The technical solution can consist of using a hand held instrument and measure shock pulse and rms vibration every month as long as the bearing is OK. The measuring intervals are then shortened as damages develop. Using an online protection system, can increase the safety; see fig 10.

Specially designed transducers and bulkhead unions are installed to get access to the bearing housing, see fig 12.

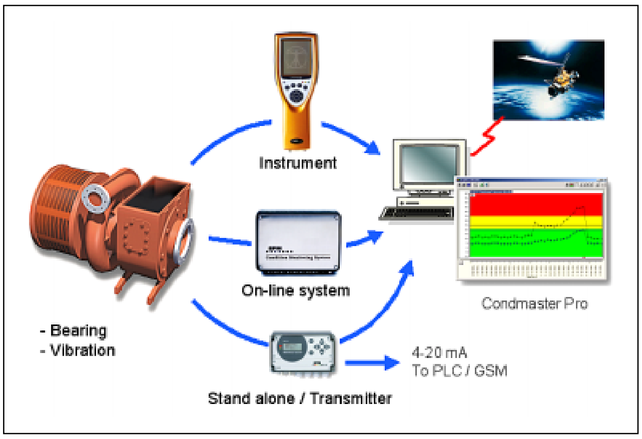

Fig 11: Condition monitoring options for turbo charger

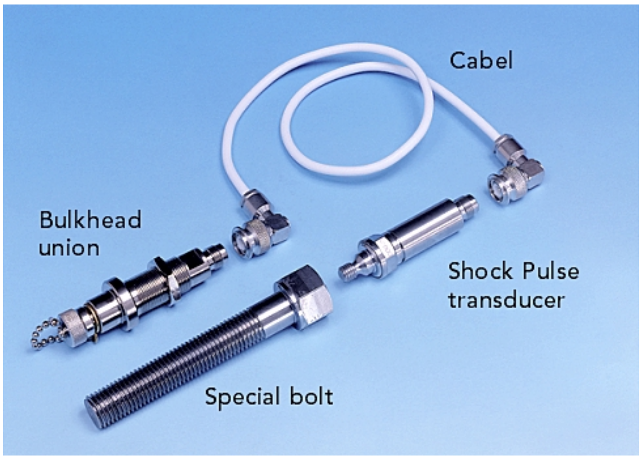

Fig 12: Accessories for measuring on turbo charger

16. SUMMARY

Maritime industry has a big opportunity to increase profits when implementing the new associated DNV survey arrangement Machinery CM (condition monitoring) classification.

There are however strategic considerations to make when introducing CM on a ship. Condition monitoring has in the past been introduced on several hundred vessels with limited or no success. In most of these cases the condition-monitoring tool has been purchased without considering the necessary change of the organisation onboard and the need for an organised knowledge transfer between crews.

The maintenance strategy has to support the CM activity and the results from the program must be utilized to change the priority in the maintenance work. The instrumentation and software should be selected to carry out front line CM onboard the vessel and more complicated analyses should be implemented as second line only.