Nauticus (Propulsion) – the modern survey scheme for machinery

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Introduction

Det Norske Veritas (DNV) is currently revising the classification rules for machinery and systems applying risk and reliability methods. The new rules are based on assessment of functional integrity with criteria for safety of personnel, safety of vessel with equipment, safety of the environment, safety of cargo and vessel availability.

Nauticus (Propulsion), the world’s first set of risk based machinery rules for survey of diesel driven propulsion has been offered from January 1999. This Class Notation is part of the NAUTICUS suite of notations all aimed at giving the shipowner an improved information model as a basis for decision-making.

These revised rules form a solid scientific basis for continuous improvement of future rules in light of operating experience data and represent a significant step towards the IMO approach for rule development based on Formal Safety Assessment.

The way to Formal Safety Assessment

IMO has proposed to apply risk-based methods (Formal Safety Assessment {FSA}) in the development of new rules and regulations within the shipping industry. A guideline for Formal Safety Assessment has been worked out. The guideline describes the following steps:
1. Identification of hazards
2. Risk assessment
3. Risk control options
4. Cost benefit assessment
5. Recommendations for decision making
6. Presentation of FSA results

The classification societies in the International Association for Classification Societies (IACS) support the approach but also acknowledge the fact that the guideline can be fulfilled in many ways.

Three of the most important conditions for performing detailed qualitative risk assessment are availability of:

1. Risk acceptance criteria
2. Mathematical models for degradation
3. Statistical failure data

The IMO Guideline does not define the risk acceptance criteria level. Thus it is currently a practical problem to apply the FSA Guideline, but we believe that these limits will be agreed upon not too far into the future.

Mathematical models for degradation of structures and static equipment are today to a great extent available. They take into consideration material, medium and stresses the material is exposed to etc. For machinery systems and components this is not the case to the same extent. One important reason for the lack of models is the enormous number of failure modes and varieties of equipment and applications.

The mathematical models need to be calibrated by comparison with statistical data on failure modes and frequencies. The availability of such data is, for machinery systems and components, poor and normally not detailed enough for use in risk assessment.

Both IMO and IACS are aware of these current weaknesses, but both are convinced that in principal application of risk assessment methods is the right direction to go. Meanwhile practical approaches have to be found which comply with the principals of the FSA guidelines but which partly will be less quantitative than a “full” FSA.

In order to improve the knowledge about failure mechanisms and frequencies, DNV is currently promoting both internal and external research projects. The objective is for future DNV Rules to be fully based on the Formal Safety Assessment procedure.
The DNV approach to machinery rules

DNV have established a simplified method based on well-proven techniques. It is applied by DNV also within other industries than shipping and represents a significant step towards the IMO approach for rule development based on FSA. The DNV risk matrix for machinery rules is shown above.

The new rules are based on assessment of functional integrity with criteria for safety of personnel, safety of vessel with equipment, safety of the environment, safety of cargo and vessel availability. These revised rules form a solid scientific basis for continuous improvement of future rules in light of operating experience data.

The DNV approach is to:

- Have life cycle focus ensuring consistent DNV involvement “from cradle to grave”
- Ensure that the built-in reliability gives acceptable risk level when the vessel leaves the yard
- Ensure that degradation during operation is detected and corrected before the acceptable risk level is exceeded
- Focus on applicable and cost-beneficial survey methods

The first practical result of this work is Nauticus (Propulsion).

Nauticus (Propulsion)

Nauticus (Propulsion) is a voluntary class notation. The notation offers an alternative to traditional class schemes for propulsion machinery for the in-service phase. Surveys onboard focus on performance evaluation, mechanical integrity & wear assessment and detection of potential fire and explosion hazards. Condition monitoring methods for condition assessment is supported. The risk based approach combined with specific acceptance criteria for key parameters and survey methods alternative to the traditional one of opening-up, has made it possible to focus on the essentials and allow extended flexibility for overhaul intervals as long as acceptance criteria are met.
Nauticus (Propulsion) opens up for closer integration between classification, and the operator’s onboard maintenance system. The DNV surveyor will review maintenance history and the information found will form part of the basis for drawing conclusions about machinery condition.

The major benefits to the owners are

- Class focused on the most critical items
- The Class survey will to a smaller extent than today interrupt the operation of the propulsion plant, as DNV will accept information stored in the maintenance history file.
- Encourages and supports condition based maintenance (optimization of the operation & reduced unexpected maintenance)
- The number of class required opening-up surveys will be reduced, and the total number of surveys is reduced if the evaluation of the condition demonstrates acceptable condition.
- Access to statistics from systematized/standardized maintenance registration

The last point is illustrated in the figure below.

![Figure 2: Number of surveys 5-year cycle for a typical propulsion machinery](image)

Survey reports for ships that have the Nauticus (Propulsion) class notation assigned will include statements on the actual condition of the propulsion plant. Contrary to tradition, class will now verify conditions and not only express a view when class acceptance criteria are violated. Presentations like the one below, which is a presentation from the performance evaluation tool applied by the surveyor, will be included in the reports.
Requirements for assignment of the Class Notation

The operator has to apply, and be approved for, the Nauticus (Propulsion) class notation. The notation is assigned for each ship. Finalising the approval (and initial survey), a separate agreement will be established, describing the scope and conditions for assignment of the class notation. Since the maintenance history file is important as information carrier for the condition evaluation, requirements are given to and documentation has to be submitted on:

a) the maintenance philosophy
b) the Maintenance Management System.
c) the Condition Monitoring System.
d) implementation of condition based maintenance strategy covered by the Rules
e) the baseline performance data.

Philosophy

The maintenance philosophy shall prove that the maintenance strategy for the ship complies with the intentions laid down in the Nauticus (Propulsion) class notation. When establishing a maintenance program, a variety of maintenance strategies exist. The maintenance philosophy must show that the maintenance strategy for the equipment and components subject to condition monitoring surveys is actually condition-based as defined in Figure 3.
The philosophy shall outline competence and training requirements to the crew executing the maintenance, i.e. operating the Maintenance Management System and the Condition Monitoring System. It is a condition that the Chief Engineer is in possession of an authorisation letter from DNV permitting him to undertake surveys which later may be credited as Class Surveys.

The Maintenance Management System (MMS)

The MMS must as a minimum contain a description of the following:

- items or systems included, specifying which are subject to class survey
- time intervals at which maintenance jobs are to take place
- the maintenance procedures to be followed
- procedures for recording or documenting maintenance jobs
- where condition monitoring is an integrated part of the system, parameters relevant to the class notation/agreement must be evaluated with respect to chosen parameters and alert limits
- capability of recording maintenance and corrective actions carried out since last annual survey on class related items

It is worth mentioning that the MMS shall include work orders for calibration of the Condition Monitoring equipment and how often condition measurements are to be performed (the intervals between condition measurements must be shorter than the survey intervals).
The Condition Monitoring System (CMS)

In principle, all vessels designed and built for unattended machinery space operation have the basic instrumentation needed to fulfil the requirements to instrumentation as required by Nauticus (Propulsion). In addition the following is needed:

- Electronic cylinder pressure measurement equipment
- Vibration measurement equipment
- Possibilities for oil analysis (oil samples can be sent for analysis ashore)
- Instrumentation according to DNV Tailshaft Monitoring (TMON) notation including measurement of stern tube bearing temperature

The instrumentation shall be evaluated and accepted for:

- Absolute accuracy
- Relative accuracy
- Stability
- Fitness for the operating environment.

Implementation of the condition based maintenance strategy

The history of condition monitoring and condition based maintenance is fraught with examples of investments in condition monitoring technology failing to provide the expected benefits. The root cause is usually that while the technology for collecting condition data is given full attention, the organizational issues that need to be addressed are neglected. There is, unfortunately, a tendency to forget that condition data has no intrinsic value; it is only when utilized in a meaningful manner (i.e. having a positive impact on ship operations) that it acquires value. It is therefore absolutely essential that both technical and organizational issues be addressed.

As indicated by Figure 4 below, organizational issues quite often have the largest impact on goal achievement. Therefore, DNV has requirements to the implementation of the condition-based maintenance strategy, which must be fulfilled before the class notation can be assigned.
Baselines
Baseline data must be established and available to the Society before the notation Nauticus (Propulsion) is assigned. In this context, baseline data are data recorded at a reference condition (normally "as-new" condition). The baseline data are used when evaluating future in-service condition. The in-service data must be corrected to the same ambient conditions as the baseline data.

The baseline data may be obtained from sea trials or other equivalent tests where the performance is considered to be as designed, and the operating conditions are clearly defined. Baselines are typically defined for performance parameters on diesel engines.

Formal assignment of the Nauticus (Propulsion)

After the approval of the above items, an initial survey is carried out to confirm that the system is operated as intended and in accordance with the approval. The class notation will be formally assigned upon successful completion of the initial survey.

Maintaining the Class Notation

Any class notation can be deleted if the obligations stated in the Rules and/or the agreement between the shipowner and Class are not fulfilled. Such compliance is checked during the periodical surveys.
The Maintenance Management System (MMS) must as a minimum include records of inspections, maintenance, damages, defects and relevant corrective actions. These records are to be kept as objective evidence of the effective functioning of the system. The records are to be readily accessible to the attending surveyor.

DNV shall be informed about changes to maintenance intervals for the items covered by the class surveys. Otherwise, the maintenance must have been performed approximately according to the approved plan.

The owner is obliged to report to DNV all damages occurring on parts, which are subject to survey. Damage frequencies exceeding what is expected can be subject to special investigation from DNV in order to identify the cause and improve the situation.

**Nauticus (Propulsion) Pilot Project**

Nauticus (Propulsion) rules and procedures was tested onboard five vessels for a period of approximately one year.

**Benefits/lessons learned by the owners/crew**

The testing has proven that the crew considers the scheme to give considerable added value to the maintenance and operation of the vessels compared to existing survey arrangements. Condition deterioration not previously noted by the crew and superintendents was detected. With proper overhaul, this reduced the probability of failures. In addition, opportunities for operational cost savings were identified, especially related to the performance of diesel engines.

**Lessons learned by DNV**

The testing revealed the following aspects which led to improvements in the program:

- Some of the proposed surveys were not found to be cost-beneficial.
- Some of the surveys were redefined due to the fact that they were too general to be applicable for all propulsion system designs.
- Some of the acceptance criteria were adjusted.

A test of 4 different makes of diesel engine cylinder pressure measurement equipment was also done. The test showed that the absolute accuracy of such equipment is not always acceptable. The deviation between repeated measurements is, however, within acceptable limits. Thus, it is important to be cautious when baselines are established. Preferably the same measurement equipment to be applied during operation should be used for baseline data measurements.
Nauticus (Propulsion) in the market

The positive feedback has continued after the test period. Before full-scale marketing has started 25 ships has applied for the notation. The ships range from conventional bulkers and tankers to advanced cruise vessels as well old ships and ships not yet delivered from the yard.

Conclusion

The experience gained has convinced DNV that it is feasible to formulate rules and design classification programs based on risk and criticality evaluations. In the months to come, several risk based rule products will be released both for ships in operation and for design, manufacturing, installation and testing of equipment and systems onboard.