LIFE CYCLE OF SHIPS AND OFFSHORE STRUCTURES RISK-BASED STRATEGIES FOR THE NEXT GENERATION OF MAINTENANCE AND INSPECTION PROGRAMS

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Summary

The maritime industry has seen increased interest in applying risk-based approaches to better manage the integrity of ships and offshore units in service. The IMO's initiative in setting Goal-Based Standards will also be reflected in justification of maintenance and inspection regimes for marine assets from a performance-based standpoint. The development of risk-based strategies for the next generation of maintenance and inspection programs for various ships include the application of Reliability-Centered

Maintenance (RCM) for machinery systems and Risk-Based Inspection (RBI) for hull structures and fixed equipment systems.

By applying RCM principles, an operator can improve the reliability of vessels' machinery systems. Risk assessment techniques (FMECA) and RCM analysis are used to determine relevant failure modes and equipment criticality. These inputs provide a process feed for optimization of maintenance tasks for maximum uptime. Further, spares management can be optimized using the RCM process. A sustainment process is also discussed so the operator can keep preventative maintenance tasks current as the system ages, new failure modes are identified or system modifications occur.

RBI inspection planning includes risk assessment coupled with the understanding of applicable degradation mechanisms and consequence of failures in the structure in order to develop an inspection program for the asset. Structural analysis plays an important role in this process. For structures, analysis data generated as part of the design process is used to predict the likelihood of failure and account for the degradation that structures inevitably suffer. Combined with an assessment of consequence of failure, structure is risk ranked, inspection methods and frequencies optimized, and then aggregated into an RBI plan. Hence, this process can be regarded as a vehicle for incorporating design information in the inspection process in an integrated way. This represents a significant improvement in integrity management (IM) approach over traditional methods where there is little, if any, interaction between the design and in-service phases of the life of the asset. Further, targeted inspection and data collection of asset health for critical areas within the hull leads to overall risk reduction.

1. Introduction

As analysis techniques become more sophisticated, ships and offshore structures have become more complex and innovative. As a result, their designs, with certain unique aspects in their configuration, do not necessarily mimic those of their predecessors. In particular, naval vessel design emphasizes minimum structural weight in order to maximize payload. Compounding this problem is the fact that many organizations differentiate between the "Capital Expenditure" and the "Operational Expenditure" segments. This can mean that design features which improve a vessel's operability, inspectability and maintainability are rejected at the procurement stage in the interest of decreased initial costs and, as a result, the traditional, prescriptive inspection and maintenance methods are no longer the most effective. It is imperative that those elements of the vessel's structure or machinery systems more prone to deterioration and damage be identified early in the design process.

While there remains a strong need for traditional rule-based and prescriptive approaches, marine assets are becoming more complex, have a higher degree of novelty, and many aspects of their designs are falling outside or ahead of the development of traditional Class Rules. Risk and reliability-based technology is finding increased application because of the greater use of performance-based criteria and because of the current demands from clients for more flexibility in the way classification services are provided. Ever-expanding technologies often require the abandonment of trusted methods, the stretching of boundaries and the adoption of new, unfamiliar procedures. Risk and reliability-based design, operation and integrity management programs are all becoming more commonplace in this environment.

In addition, the operator's control of the integrity management of assets must now reach far beyond the minimum. Society expects due diligence and proactive management from vessel operators. Today's organizations must also adapt to constant advances in technology while burdened with the mandate to do more with less as budgets grow leaner.

Companies with effective asset integrity management programs strive to consider these facts throughout the life-cycle of that asset. The leading edge operators will consider operability and maintainability from the initial concept and detailed design (how best can it be designed for optimum inspectability and maintainability?), construction (what can I do now to minimize future inspection and maintenance needs?), installation (what baseline am I starting with?), and onward through operation (what are my inspection and maintenance results telling me?) and the potential upgrading the asset (what can I do to improve performance?).

Traditional practice as exemplified by prescriptive Rules and standard methods lacks the flexibility to respond to these demands. Risk and reliability-based methodologies allow systematic and rational ways for dealing with variations and deviations from the "standard" approach. These more advanced methods of maintenance and inspection strategy development follow along an evolutionary continuum that other industries are also following (see Figure 1 at the end of the chapter).

This chapter will describe an approach to developing both Risk-Based Inspection and Reliability-Centered Maintenance plans for vessel structures and machinery that have the potential to result in significantly improved asset integrity management and possible cost savings. The methods presented herein aim to support optimized life-cycle integrity management of ships and offshore units by utilizing risk and reliability-based methods.

2. Risk-Based Approaches

The marine and offshore industries are drawing upon the lead set by other industries (nuclear, aircraft, etc.), in the application of risk-based approaches for design and in-service inspection. Risk-based methodologies for inspection plan optimization originated in the nuclear industry in the 1970's and over the years have migrated into other industries such as the downstream petrochemical industry in the 1980's and 1990's. These approaches are now moving into the upstream sector of the oil and gas industry and, to a lesser extent, the shipping industry.

Of particular interest has been the application of risk-based inspection (RBI) and reliability-centered maintenance (RCM) techniques in which experience-based data related to various degradation mechanisms are applied to set inspection and maintenance frequencies and scopes. The implementation of these risk and reliability-based techniques into the development of a plan provides an alternative to prescriptive time-based inspection and maintenance planning.

Figure 1 provides a schematic on the evolution of inspection and maintenance plan strategies. The compliance-based strategy (Phase 1), also referred to as rule-based, is generally representative of the traditional class or regulatory requirements. Inspection plans derived from such an approach have generally been developed based on years of experience and tend to provide a broader brush inspection plan and a minimum standard. These approaches are based on the experience obtained from inspections performed on unrestricted trading vessels. The condition or performance-based methods (Phases 2 and 3) represent the next logical step in the evolution from traditional methods. Degradation models and input from subsequent inspections are used to forecast the condition of the structure for fixed equipment. When the condition is predicted to reach a predefined threshold, inspections are conducted. This method relies heavily on the likelihood of structural degradation but does not explicitly include the associated consequences, which is a key aspect of the next evolutionary step, the risk-based approach (Phase 4). The risk-based methods include aspects of the condition-based methods using trending techniques to estimate likelihood, but also factor in an estimation of the consequences of the structure's degradation and potential failure, enabling the program resources to be optimized and focused toward inspecting those items which have a greater overall risk weight. Once those items are identified, optimum methods of inspection or maintenance are then selected.

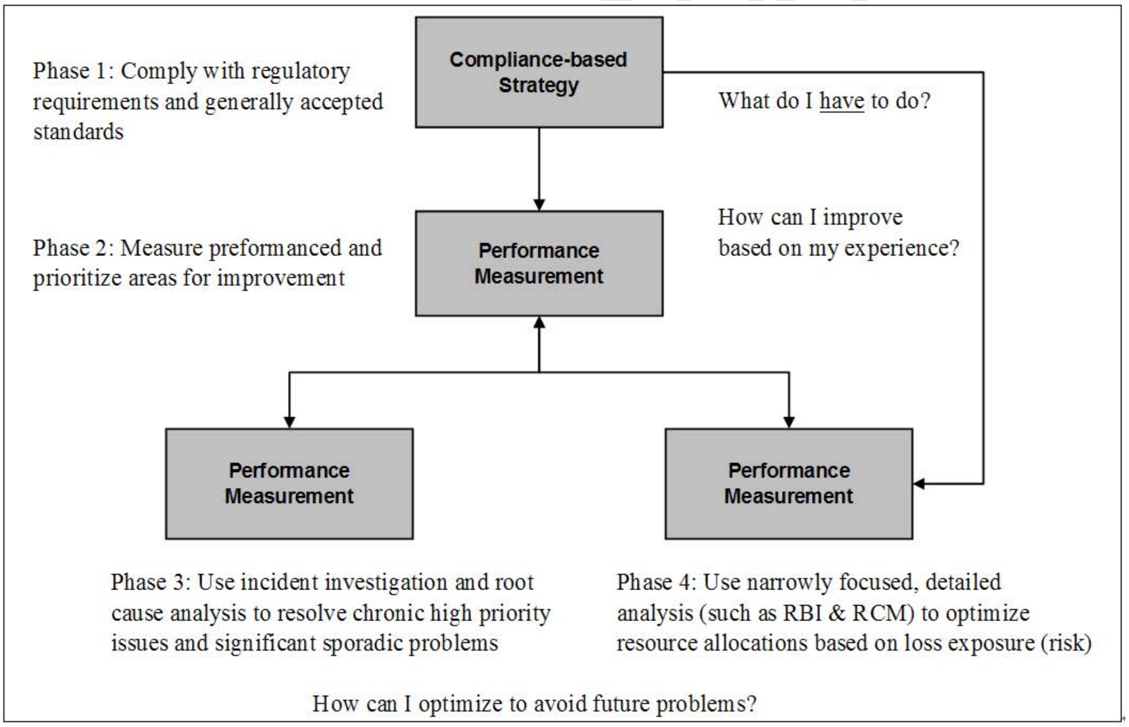

Figure 1. Evolution of Inspection and Maintenance Strategies

3. Rationale and Benefits of RBI

RBI for hull structures is becoming more widely used within the offshore oil and gas industry. Slowly, such concepts are also seeing application via marine operators who see a way to tailor their inspection programs for a specific ship type and also to have a mechanism to adapt the program as the vessels age. Operators feel there are significant benefits in developing RBI plans that are tailored to their asset in regard to both design and operation. By taking this approach, the inspections are more targeted and the operational constraints better managed, resulting in a more optimized inspection program while maintaining the same level of safety.

Figure 2 demonstrates the basic purpose of RBI – to allocate resources in accordance with risk. In other words, the goal of a risk-based inspection study is to allocate the resources (inspection manpower and costs) to those areas where there is the most probable benefit to risk reduction.

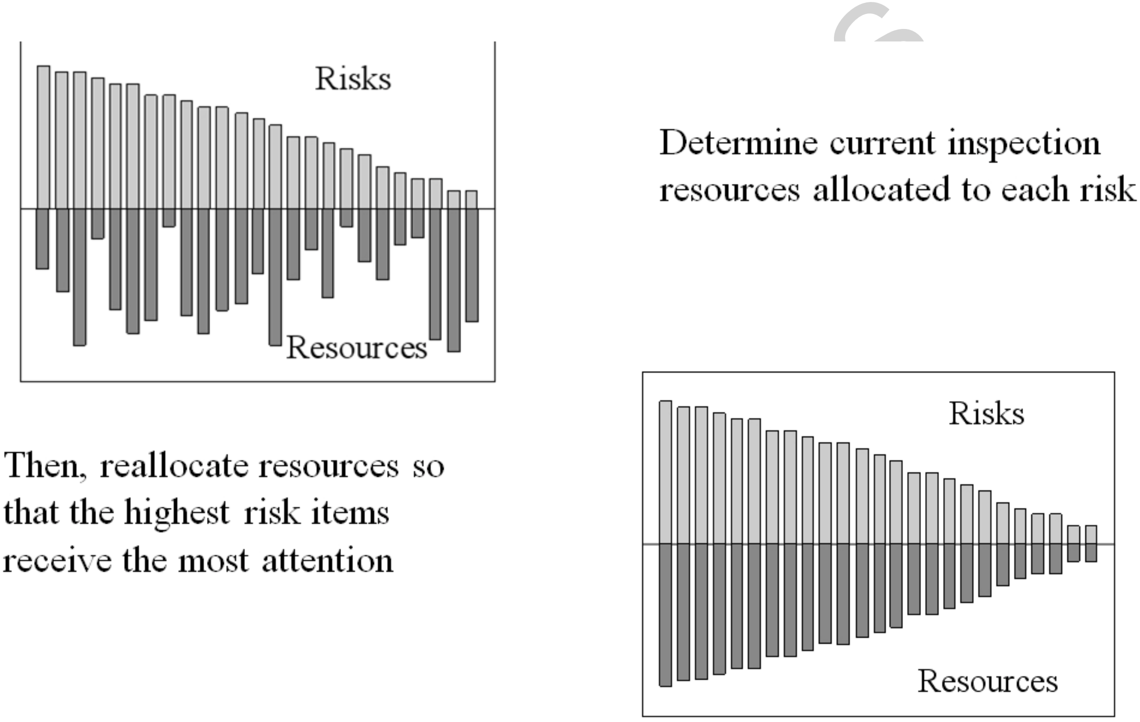

Figure 2. RBI Concepts

Both the traditional approach to hull integrity (largely class-based) and an enhanced risk-based approach lead to the ultimate goal of confirming the hull structure is properly maintained in accordance with industry and statutory standards. For the risk-based approach, a major contributor to the development of such a plan is the foundation of experience from the Class Rules which begins with the historical experience of the class society. The main drivers which have sparked the industry's interest in RBI for hull structures are the potential benefits of implementing such a plan. There are significant benefits in developing a plan that is tailored to a specific class or type of vessel rather than following a rule-based approach. The following provides a list of some key benefits from a risk-based inspection plan.

- Asset Specific Plan – The plan is tailored for the particular design and operational variables such that resources are focused on the highest risk components. This can influence, where possible, inspection frequency and/or compartment inspection sequencing, work scope, degree of connection sampling, etc. The advantage of this is more focused inspections which target the critical components within the structure. The plan can also incorporate overall business requirements, such as required asset utilization or compartment downtime limitations.

- Demonstrable Basis for the Inspection Plan – An RBI plan provides a rational basis for the extent and methods of inspections based on combining structural analysis and structural reliability results. This allows additional flexibility for inspection planning and execution, and provides a better understanding of what items are critical and when they become critical.
- Formal Approach of Collecting Information and Assessing Inspection Results – In order for an RBI plan to be executed and updated, data must be captured in a format that can be organized and assessed to verify the condition of the hull. Often with typical inspection data, the inspections are completed and compared to prescribed acceptable limits to determine if mitigation is required. Generally, this is the extent of the data's usefulness. For RBI, the data collected from the inspections is used to validate and update the degradation models and determine if adjustments in future inspections are warranted (as a result, some form of electronic integrity data management tool is typically required to store and trend data).
- Potentially More Cost-Effective – An RBI plan may provide justification to extend inspection frequencies, which may reduce the number of inspections and associated costs. However, this may not always be the case. In some cases, inspection intervals for compartments may be reduced and inspection scopes may be more rigorous, offsetting any cost savings that may be obtained in other compartments. Regardless of the cost, an RBI plan provides a means for risk reduction and a rational basis for the intervals and inspection scopes which are optimized based on the asset's service conditions.

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Biographical Sketches

Chris Serratella is a graduate of Stevens Institute of Technology with a Bachelors of Science degree in Mechanical Engineering. He has over 20 years of experience related to engineering and risk assessment of marine and oil and gas production facilities both onshore and offshore. He has held several positions within both ABS and ABS Consulting. While in the role of Chief Engineer for the Marine and Offshore department within the Risk Consulting Division of ABS Consulting, he led or participated in numerous independent engineering and risk assessment services related to marine vessel and offshore oil and gas facilities, with an emphasis on floating offshore oil and gas production and storage. He is currently in the role of Director of Applied Innovation for the ABS Technology Department. His primary focus is in the lifecycle management and development of both prescriptive and risk and reliability-based in-service inspection and maintenance regimes for marine and offshore facilities, focusing on machinery, topside production facilities and structures.

Dr. Ge (George) Wang is Manager, Advanced Analysis Department, ABS Greater China Diovision. He has 20 years of experience in research, design and analysis of marine structures. His areas of competency include marine casualty analyses and investigations, marine corrosion and mitigation, risk and reliability analysis, and design of ships and offshore structures. Dr. Wang serves on Editors Board for the Journal of Offshore Mechanics and Arctic Engineering, Journal of Ship and Offshore Structures, Journal of Marine Science and Technology. From 2003-2009, he was the Committee Chairman for the International Ship and Offshore Structures Congress, leading Specialist Committee on Collision and Grounding (2003-2006), and

Specialist Committee on Condition Assessment of Aging Ships and Offshore Structures (2006-2009). As the Secretary of Practical Design of Ship and Other Floating Structures (PRADS), he organized PRADS 2007 in Houston, TX. He also served as PhD and MS thesis committee for Massachusetts Institute of Technology in 2007-2009, University of Michigan in 2007-2009, Norwegian University of Science and Technology in 2009, Colorado School of Mines 2003-2007, National Yokohama University in 2008-2009, Dr. Wang has 100 publications (books, book chapters, journal papers, conference papers). Wang holds a Doctor's Degree from the University of Tokyo, and a Master's and Bachelor's Degree from Shanghai Jiao Tong University.

Robert M. Conachey, P.E. came to ABS in 1986 and is a Senior Managing Principal Engineer in the ABS Marine Technology & Technology Support Group. He received his Bachelor of Science in Naval Architecture and Marine Engineering from Webb Institute of Naval Architecture. At this time Mr. Conachey is pursuing studies in Industrial Engineering for his Masters of Science. He has extensive experience in the areas of rotating equipment design along with risk analyses of machinery systems. He has been involved in several major technology-related projects for improving machinery reliability. He has also been a part of the Operational Safety & Evaluation Group at ABS. The first project was the development and implementation of the ABS Reliability-Centered Maintenance Program. Another project was the development of the ABS Guide for Vessels Operating in Low Temperature Environments. Currently, Mr. Conachey is developing Guidance Notes for Machinery Condition Monitoring.