SSC Project Recommendation for FY 2021

Predictive Maintenance of Ship Structural Details

1.0 OBJECTIVE.

1.1 The objective of this project is to develop a predictive maintenance for ship structural details.

2.0 BACKGROUND.

2.1 Ship structural maintenance had been studied extensively in 1990s when a life extension of oil tankers was called. The development of Very Large Crude Carriers (VLCC) and the use of high tensile steel (HTS) at that time caused significant fatigue cracks in oil tankers.

Preventive maintenance, corrective maintenance, risk based maintenance, and their combinations are the common maintenance practice in shipping industries. Predictive maintenance is used in shipping industry with the name "condition assessment" (TSCF, 1989).

At the core of a condition assessment is a multi-step spectral fatigue analysis procedure developed by the first principle. Given the uncertainties developed in each step, significant uncertainties are accumulated in spectral fatigue analyses which result in a large bias between the predicted and real fatigue lives (Xu, 2001). As a result, in-service conditions and remaining fatigue lives of ship structural details cannot be assessed with reasonable accuracies.

2.2 Given the fact that we cannot predict the in-service conditions and remaining fatigue lives accurately, an integrated Inspection, Monitoring, Maintenance, and Repair (IMMR) system was developed for ship structural details in 1996 to reengineer the ship structural maintenance system (Xu, 1997).

The integrated IMMR includes 1) a first principle based IMMR planning, e.g., probability based or risk based IMMR planning, and 2) a knowledge based IMMR planning.

The knowledge based IMMR system is to complement the first principle based IMMR planning. It used a combination of model-based diagnosis, heuristic classification, and case-based reasoning: model-based diagnosis to identify the details of a large class of possible problems, heuristic classification to identify the presence a set of idiosyncratic problems, and case-based reasoning to compare observation with previously identified cases.

Twenty more years later, this knowledge based IMMR system has become a data driven predictive maintenance, an emerging maintenance program in manufacturing, defense, and oil industries.

2.3 The predictive maintenance is to first predict when equipment, machine, or system failure could occur (based on certain factors), followed by preventing the failure through corrective maintenance. In theory, the predictive maintenance is the minimum cost maintenance because tasks are performed only when warranted.

Predictive maintenance cannot exist without condition monitoring and assessment, which is defined as the continuous monitoring and assessment of equipment, machine or system during process to ensure the optimal use of equipment, machine or system.

At the core of the predictive maintenance is Artificial intelligence (AI), a development of expert or knowledge systems in 1990s. AI is developed on the basis of data driven modeling. Many of these artificial intelligence based systems are powered by machine learning (statistical regression analysis, pattern classification), some of them are powered by deep learning (neural networks) and some of them are powered by very boring rules (rule based expert system).

2.4 This project is a pathfinding study of an AI based real time ship maintenance system (Xu, 2021). An AI based real time ship maintenance system is to integrate predictive maintenance, structural health monitoring system, and digital twin on the basis of the data driven methodology.

3.0 <u>REQUIREMENTS</u>.

3.1 Scope.

3.1.1 The Contractor shall perform a literature review on the ship structural maintenance, predictive maintenance, and machine learning.

3.1.2 The Contractor shall identify and develop a methodology for utilizing in-service cracking data with spectral fatigue analysis data to drive a data driven fatigue damage evaluation model. This methodology shall be demonstrated by a typical ship structural detail fatigue damage evaluation.

3.1.3 The Contractor shall develop a predictive maintenance model for a typical ship structural detail, and demonstrate the model can be extended in the structural health monitoring system and digital twin.

3.2 Tasks.

3.2.1 The Contractor shall review the ship structural maintenance, and predictive maintenance in manufacturing, defense, and oil industries.

3.2.2 The Contractor shall review the fatigue cracking database and spectral fatigue analysis database provided by project sponsors. The Contractor shall develop a ship structural detail classification system based on the review of the database.

3.2.3 The Contractor shall develop methodologies to derive data driven fatigue evaluation models for ship structural details.

3.2.4 The Contractor shall demonstrate a data driven fatigue evaluation model for a typical ship structural detail.

3.2.5 The Contractor shall develop a predictive maintenance model for a typical ship structural detail.

3.2.6 The Contractor shall prepare a report.

3.3 Project Timeline.

	Month																	
Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
3.2.1	■	■																
3.2.2		■	■	■														
3.2.3				■	■	■	■											
3.2.4							■	■	■	■								
3.2.5										■	■	■	■					
3.2.6													■	■	■	■		
Reporting			■			■			■			■			■	■	■	■

4.0 GOVERNMENT FURNISHED INFORMATION.

4.1 Standards for the Preparation and Publication of SSC Technical Reports.

5.0 DELIVERY REQUIREMENTS.

5.1 The Contractor shall provide quarterly progress reports to the Project Technical Committee, the Ship Structure Committee Executive Director, and the Contract Specialist.

5.2 The Contractor shall provide a print ready master final report and an electronic copy, including the above deliverables, formatted as per the SSC Report Style Manual.

6.0 PERIOD OF PERFORMANCE.

6.1 Project Initiation Date: date of award.

6.2 Project Completion Date: *18* months from the date of award.

7.0 GOVERNMENT ESTIMATE. These contractor direct costs are based on previous project participation expenses.

7.1 Project Duration: *18* months.

7.2 Total Estimate: $100,000

7.3 The Independent Government Cost Estimate is attached as enclosure (*1*).

8.0 REFERENCES.

8.1 Tanker Structure Cooperate Forum (1989) "Guidance Manual for the Inspection and Condition Assessment of Tanker Structures".

8.2 T. Xu, et al (1997) "Reengineering the Ship Structural Maintenance System", Dept. of Civil and Environmental Engineering, University of California at Berkeley, Berkeley, CA 94720.

8.3 T. Xu, (1997) "Fatigue of Ship Structural Details – Technical Development and Problems", Journal of Ship Research.

8.4 T. Xu, et al (1999) "Uncertainties in the Fatigue Lives of Tubular Joints", Proceedings of Offshore Technology Conference, Houston, TX.

8.5 T. Xu, (2014) "From Oil Platforms to High-Tech Cleanrooms – Reliability Applications in Facility Design", Proceedings of the 33rd International Conference on Ocean, Offshore, and Arctic Engineering (OMAE).

8.6 T. Xu, (2021) "A Proposal for the development of an AI based real time ship maintenance system", Tao Xu & Associates.

9.0 COST ESTIMATE.

Direct Labor			
Labor Category	Hours	Labor Rate	Price
Principal	320	$300	$96000
Other Direct Costs			
Travel			$4000
Total Price			**$100,000**

Note:
Labor rates are fully loaded including salary plus an allocation of costs for overhead, G&A, profit/fee, and any escalation for option years.