

11-04 Effect of Cold Temperature and Fatigue Load Cycles on Ship Hull Steel

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1.0 OBJECTIVE.

- 1.1 Numerous studies were undertaken to evaluate the integrity of aged ship structures considering fatigue as one failure criterion and strength (ultimate load carrying capacity) as the other failure criterion. However, ship hull experiences both fatigue and ultimate loads during its service. Several researchers have expressed serious concerns on the detrimental effect of the fatigue load cycles on the mechanical properties such as yield and ultimate strength, modulus of elasticity, and ductility of ship hull steel. The presence of very cold temperature may even worsen this effect. Therefore, this study will be undertaken to understand the combined effect of fatigue load cycles and cold temperature on the mechanical properties of ship hull steel.

2.0 BACKGROUND.

- 2.1 A ship in service, experiences continuous fatigue load cycles in addition to service loads and residual and other locked-in stresses. Thus, fatigue damages accumulate over the service life of the ship and the ship hull is expected to lose its structural integrity and fail in fracture when the fatigue life of the ship hull is reached. Thus, the fatigue life and fatigue failure is one of the major design considerations for the ship structures.

Ship structure is also designed for its ultimate strengths to ensure that the failure of ship hull does not occur due to application of ultimate loads such as one from slamming effect or impact with an iceberg, rock, and landing dock. However, the strength design is undertaken assuming the ship hull material is virgin and thus, no consideration is made to account the damages due to fatigue that can accumulate during its service. In reality, a ship hull in service for a considerable period of time will have accumulated damage due to fatigue load cycles and this damage is expected to alter the mechanical properties of ship hull material. The change in mechanical properties due to accumulated fatigue damage may be detrimental and if that is proven to be true then the current design practice of ship hull structure assuming the material is virgin will be subjected to review.

The ice in the Arctic region is melting at a rate much faster than ever due to the global warming. As a result, the Northwest Passages in the Arctic Ocean which connects the Atlantic and Pacific Oceans through the Canadian Arctic Archipelago and provides a shorter shipping route between Europe and Asia is becoming more viable and imminent for the shipping industry. It is expected that more commercial ships, pleasure crafts, and coastal patrolling vessels will be navigating through the Northwest Passages and for much longer period in the near future. As a result, these vessels will also experience Arctic cold weather for much longer period of time. It is anticipated that the Arctic cold temperature will only act as a catalyst for the speculated damaging interaction between fatigue damage and mechanical properties of ship hull steel. Therefore, this project is proposed for a detailed experimental and possibly numerical study to determine the combined effect of Arctic cold temperature and fatigue damage on the mechanical properties of ship hull steel material.

- 2.2 The project idea has arisen from a number of recent developments and activities. The area of aging processes in ships is a complex subject that deserves increased attentions. The Northwest Passages are becoming more viable and imminent for the shipping industry. The coming area of challenge and scientific development will be the area of interacting among various loads, extreme weather, and response effects. Aging involves several of these interacting effects such as corrosion, fatigue, and plastic deformations. Navigation of vessels through the Northwest Passages requires interactions of these effects in Arctic cold temperature. In coming years, we will need to tackle these combined effects if we are to come to grips with aging processes in ships especially those will be voyaging in the Arctic Northwest Passages and get a true assessment of safety of these vessels. This project focuses on one of these issues and aims to provide us a key tool for such work. Without the ability to determine the effect of fatigue

damages and cold temperature, we will be left with an inaccurate understanding of the behavior of hulls of aged ships which will be navigating through the Northwest Passages.

3.0 REQUIREMENTS.

3.1 Scope.

- 3.1.1 The Contractor shall conduct an extensive literature review on various fatigue damage models applicable to ship hull structures.
- 3.1.2 The Contractor shall undertake a detailed test program to determine the effect of fatigue damage and cold temperature on the mechanical properties ship hull steel.
- 3.1.3 The Contractor shall investigate if a numerical model can be developed to simulate the test behaviors.
- 3.1.4 The Contractor shall provide recommendations on how to evaluate the effect of fatigue damage and cold temperature on various mechanical properties based on the test data obtained from this study.

3.2 Tasks.

- 3.2.1 Task 1 - The Contractor shall conduct a literature review of the various damage prediction models that may be applied to ship hull steel subjected to fatigue load cycles and Arctic cold temperature.
- 3.2.2 Task 2 - The Contractor shall conduct necessary laboratory tests to validate if any available model can be used to predict the effect of cold temperature and fatigue cycles on the mechanical properties of ship hull steel.
- 3.2.3 Task 3 – The Contractor shall conduct laboratory tests to determine the effect of fatigue damages and cold temperature on mechanical properties of ship hull steel.
- 3.2.4 Task 4 - The Contractor shall investigate if a numerical model for predicting the test behavior can be developed for future study.
- 3.2.5 Task 5 - The Contractor shall then provide recommendations on how to evaluate the effect of fatigue damage and cold temperature on various mechanical properties of ship hull steel.

3.3 Project Timeline. The study will take 24 months.

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: 24 months from the date of award.

7.0 **GOVERNMENT ESTIMATE.** These contractor direct costs are based on previous project participation expenses. Estimated costs include salary of one Doctoral Student for 24 months, expenses for consumables, and computing aids. The University of Windsor will provide faculty and laboratory technician support as in-kind contribution. The cost estimate includes the overhead costs, charged by the University of Windsor.

7.1 Project Duration: 24 months.

7.2 Total Estimate: \$ 100,000 (Canadian Dollars)

7.3 Cost Estimate Breakup:

1. Salary of a doctoral student for 24 months	= \$40,000
2. Consumables such as materials, gauges, hydraulic oil	= \$20,000
3. Equipment such as servo-valve and extensometer	= \$15,000
4. Computer, upgrade in data acquisition system, and documentation etc.	= \$15,000
5. Rental cost for an environmental chamber	= \$5,000
6. University of Windsor overhead cost	= \$5,000

Total = Can \$100,000

8.0 **REFERENCES.**

- 8.1 XueKang, G and Torgeir M (2002). Long-term Fatigue Damage of Ship Structures under Nonlinear Wave Loads. Marine Technology, Vol. 39, No. 2, pp. 85-104
- 8.2 Bily, M. (1993). Cyclic Deformation and Fatigue of Metals. Elsevier, Amsterdam, Germany
- 8.3 DNV Classification Note 30.7 (2003). Fatigue Assessment of Ship Structures. Det Norske Veritas, Høvik, Norway
- 8.4 IACS (2006). Common Structural Rules for Bulk Carriers. IACS Limited, London, UK.
- 8.5 ABS (2008). Rules for Building and Classing Steel Vessels. ABS Publications, Huston, USA
- 8.6 Petinov, SV (2003). Fatigue Analysis of Ship Structures, Backbone Books, NJ, USA
- 8.7 Ellyin, F (1997). Fatigue Damage, Crack Growth and Life Prediction. Chapman & Hall, London, UK

9.0 **SUGGESTED CONTRACTING STRATEGY.**

- 9.1 The project will be executed by a graduate (doctoral) student under the supervision of the applicant. The graduate student work on this project as the student's doctoral dissertation. Thus, the SSC funding will be the major source of support for the proposed work.