SSC Project Recommendation for FY 2018

Low Temperature Steel Selection

1.0 OBJECTIVE.

1.1 The objective of this project is to revisit the criteria that are currently used to match required grades of steel to their thicknesses and anticipated operating temperature. The potential benefits include reduced construction and maintenance costs, and a better understanding of actual safety levels.

2.0 BACKGROUND.

2.1 Under Classification Society rules and other commercial and military ship standards, higher (more notch tough) grades of steel are required as plate thicknesses increase and as design temperatures become lower. Currently, IACS covers this issue both through its Unified Requirement (UR) S6, Strength of Ships – Steel Grades and through UR I2, Polar Class Ships - Structure. The two are somewhat contradictory. I2 incorporates considerable actual successful service experience with High Arctic vessels and offshore structures that did not use the fairly exotic steels that S6 would have required.

2.2 Both sets of URs and other ship design rules base low temperature performance only on Charpy test energy absorption values, although this test method replicates neither the loading regime (stress distribution and strain rate) nor the constraints (thickness and edge effects) of realistic ship applications. Charpy testing is convenient and relatively cheap to undertake, but provides limited information on the true fracture toughness of many materials.

2.3 Charpy testing generally shows that transition temperature is dependent on the size of the test specimen; however, it is widely understood that this is predominantly a constraint effect inherent in the test process or specimen geometry rather than a material property [1], [2].

2.4 Other industries using similar types of low temperature steel - for example the pipeline industry – do not use the same philosophy as regards material qualification when considering increased thickness; and certainly do not have the same thickness/grade requirements as those applied to ships [3].

2.5 This suggests:

2.5.1 Current approaches to ship steel material grade selection are unlikely to provide consistent levels of safety;
2.5.2 Alternative material selection approaches may offer construction and maintenance cost savings;
2.5.3 Alternative acceptance material selection criteria are needed to permit acceptable equivalent approaches.

2.6 The potential cost savings are significant. Welding of higher strength or toughness steels such as FH grades with increased plate thickness requires special processes that are difficult or more costly to implement in a shipyard environment and give rise to production quality issues. Repair of higher grade steels has greater production problems, and may also run into issues of material availability.

2.7 This proposal focuses on steel grades specified for low temperature ship designs, (a) because the basic transition temperature problems are more severe for low temperature steels and (b) because plate thicknesses in ice-classed vessels tend to be relatively high. However, the same challenge of setting more appropriate acceptance criteria exists for all ship types and environments. The work proposed under this project could therefore establish a more general road map for ship construction material selection.

3.0 **REQUIREMENTS.**

3.1 Scope.

3.1.1 The Contractor shall conduct the work required by this project in three phases:

i. Literature review
ii. Experimentation
iii. Data analysis and reporting

3.1.2 In Phase 1, the Contractor shall identify the state of the art understanding of the use of fracture mechanics theory to selection of steels for low temperature applications and relationships between thickness and steel toughness,

3.1.3 In Phase 2, the Contractor shall undertake fracture mechanics testing to derive fitness-for-purpose criteria for a commonly used notch-tough steel.

3.1.4 In Phase 3, the Contractor shall develop a more general methodology for the application of the approach to the demonstration of steel grade acceptability for ship construction projects.

3.2 Tasks.

3.2.1 Each phase of the project shall be accomplished through one or more tasks.

3.2.2 In Phase 1, the Contractor shall undertake a comprehensive literature review related to the selection of fracture mechanics criteria for low temperature (non-cryogenic) steel construction of a range of thicknesses appropriate to ship construction. This review will cover not only shipbuilding but also oil and gas, mining, railway, and other related industries.

3.2.3 In Phase 2, the Contractor shall:

i. Develop a suitable testing program for approval by the Technical Committee. As preliminary guidance, it is envisaged that this will involve testing using the CTOD (Crack Tip Opening Displacement) methodology on a single steel grade (AH or EH) at a minimum of four thicknesses and an appropriate range of testing temperatures. Charpy and tensile test data for the material will also be required to establish a correlation baseline.
ii. Source the steels from reputable suppliers such that the four thicknesses of steel all satisfy the material grade requirement and are produced using similar chemistries and processing practice.
iii. Undertake the testing program using suitably qualified and certified personnel and equipment. Data collection shall cover both numerical results, test result validity criteria and also visual assessments of the fracture surfaces.

3.2.4 In Phase 3, the Contractor shall:

i. Analyze the experimental data collected in Phase 2.

ii. Develop and justify a proposed serviceability profile for the steel covering temperature and thickness effects (as appropriate) based on the test results and best practices for fracture control.

iii. Propose how a more general approach could be developed to facilitate the use of direct fitness-for-purpose assessments of fracture toughness in shipbuilding applications.

3.3 Project Timeline: the anticipated duration of this project is twelve months. This includes three months for Phase 1, up to three months for material sourcing followed by approximately two months for Phase 2, three months for data analysis and the development of a draft final report, and one month for review and finalization of the final report.

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 an interim report at the end of Phase 1, including a preliminary version of the results of the literature survey and final proposals for the testing program in Phase 2

5.3 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 As noted above, this project will require approximately 12 months to complete, including all the tasks identified at Section 3.2.

6.2 Project Completion Date: 12 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: 12 months.

7.2 Total Estimate: $150,000

7.3 The Independent Government Cost Estimate: To be provided with full proposal.

8.0 REFERENCES.

[1] Shoemaker, A.K., *Factors Influencing the Plane Strain Crack Toughness Values of a Structural Steel*, J. Basic Engrg., Trans. ASME, Series D, vol 91, pp. 506-511, (1969).

[2] Benzerga, A., V. Tvergaard, V., and. Needleman, A., *Size Effects in the Charpy V-Notch Test,*International Journal of Fracture, 116 (2002)

[3] McFadden, T., and Bennett, L., *Construction in Cold Regions*, Wiley and Sons, 1991

9.0 SUGGESTED CONTRACTING STRATEGIES