SSC Project Recommendation for FY 2024

Update to the Safe Speed in Ice Methodology Using Advanced Ice Material Models

Submitted by:
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1.0 OBJECTIVE.

1.1 Ship Structure Committee (SSC) report 473 developed a methodology for the determination of a non or low ice classed vessel's capability when operating in ice. This report used cutting-edge technology at the time (2017), however significant progress has been made for the explicit modelling and simulation of ice-ship interaction.

1.2 The first objective will be a literature review of all currently available techniques to explicitly model ice, including all required inputs, outputs, other parameters, etc. and how they can be used in numerical modelling of ship-ice interaction.

1.3 The second objective is to update the safe speed methodology to reflect the increase in computational capability and explicit ice modelling techniques that have been developed since the initial SSC report, including the establishment of the parameters and properties required.

2.0 BACKGROUND.

2.1 SSC report 473 developed a methodology for the determination of a non or low ice classed vessel's capability when operating in ice. This methodology used the same load model defined in the International Association of Classification Societies (IACS) Polar Class Rules. This load model considered a glancing collision at the bow with the corner of an ice wedge. Using the assumed ice impact model, the vessel's particulars, hull shape, along with several other operational assumptions, allowed for the calculation of the normal contact force from the ice-structure interaction.

2.2 The Polar Class Rules incorporate a limited plastic response in the ship structure when subjected to the design load to ensure extreme loads due to the ice-structure interaction do not lead to immediate structural failure. However, this load and ship structural response design point did not consider the deformation and response of the ice during the impact. The load imparted by the ice to the ship structure is taken as a simple pressure-area relationship.

2.3 The methodology developed in SSC report 473 allowed for several of the assumptions within the Polar Class Rules load model to be further explored/expanded upon. This allowed for the determination of ship specific ice operational capability using Nonlinear Finite Element Analysis (NLFEA). The ice model used within the methodology was a tuned plastic model with element deletion using a Design of Experiments (DOE) approach that closely matched a typical pressure area relationship.

2.4 Since the initial SSC report was published there are several newly developed methodologies that provide a means to explicitly model ice. These methodologies show promise in the simulation of ice-ship interaction to the point where both the ship structural and the ice can be explicitly modeled as the interaction occurs. An update to the safe speed methodology using these new methods will allow for more accurate modelling of ship ice interaction.

3.0 REQUIREMENTS.

3.1 Scope

3.1.1 The Contractor shall conduct the work in three phases:

3.1.1.1 A literature review of all available ice models and how to implement the models in a finite element simulation environment.

3.1.1.2 Series of ship ice interaction simulations using NLFEA for several different hull models of varying ice class, as well as varying ice models.

3.1.1.3 Reporting of the outcomes from phase one and two, including an updated safe speed methodology and guidance on ice modeling in finite element simulation environments.

3.1.2 In Phase 1, the contractor shall perform a comprehensive literature review of all known ice models used in simulation environments. This will include models used in Discrete Element Method (DEM) simulations for completeness and potential implementation in a finite element environment. This review will include but is not limited to plastic, mohr-coulomb, crushable foam, and peridynamics models. The key output from phase 1 will be a list of ice models, their key components, typical values for those components, and how they can be implemented into a finite element environment.

3.1.3 In Phase 2, the contractor shall perform a series of NLFEA of varying ship hullforms, ice classes, and ice models. The contractor will leverage a series of hulls for varying vessel types and sizes from past projects, but where possible will use the models created during the previous SSC report. The overall intent of the project is to document the process of determining safe speed in ice, including key inputs for the various ice models under investigation. Each structural model will have a set of inputs including the ship parameters and speed, location and geometry of the local impact, and the ice parameters and properties. The outputs for each model will include a full description of the contact load (force, pressure, shape, time-history). The load will then be used to assess a set of structural responses (of plate, frame, grillage, and possibly larger elements) against the defined safe speed structural response limit. The speeds derived by this approach are best referred to as "technical safe speeds". A more general consideration of safe speeds would need to include uncertainties.

3.1.4 In Phase 3, the Contractor shall write a report outlining the results of Phase 1 and 2.

3.2 Tasks.

3.2.1 In Phase 1 the contractor will develop a detailed plan for the proposed work.

3.2.1.1 <u>Project Kick-off Meeting</u>: Review project objective, scope, and administration to ensure a common understanding of the project is held by the Contractor(s) and the Project Technical Committee.

3.2.1.2 <u>Literature Review of ice load models and properties</u>: Perform a review of available data to establish ice properties and expand on the ice load models used in the original SSC report.

3.2.1.3 <u>Establish Safe Speed Structural Response</u>: Limits of structural response (plastic or elastic limits) will be decided, and the rationale of the decision recorded for each of the structural elements that form a bow panel for longitudinally and transversely framed ships.

3.2.2 In Phase 2, the Contractor will establish the ice properties for the various ice models that are needed for the set of bow ice interaction scenarios. the Contractor will create structural models for the bow region panels for each ship type, exercise the models under the varying ice models, and establish the safe speed for the ship.

3.2.2.1 Ice Model Considerations: For the varying ice models develop a list of all key inputs, including typical values for those inputs. The outputs will include a full description of the ice load model and how to implement the models in a finite element environment.

3.2.2.2 Structural Response Determination: Each structural model is to be gradually loaded using the various ice models and the response (of plate, frame, grillage, and possibly larger elements) assessed against the defined safe speed structural response limit.

3.2.2.3 Discussion of Uncertainties: The uncertainties associated with the various ice models and the safe speed determination process are to be discussed / presented so that the technical community has an understanding of the limitations of the process.

3.2.3 In Phase 3 the contractor will write a comprehensive report, outlining all of the outcomes from phase 1 and 2.

3.3 Project Timeline. The anticipated duration of this project is 12 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 monthly status reports by the 8th of the month following the month being reported on.

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

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 Project Initiation Date: date of award.

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: This project is expected to take 600 hours to complete. The contractor is asking for $100,000 USD, which would be approximately 75% of the total cost to the contractor. The contractor will give the remaining 25% of the total cost as in-kind. The contractor’s cost to license the required software (~$100,000) will also be considered in-kind.

8.0 REFERENCES.

8.1 SSC-473 Report.

9.0 SUGGESTED CONTRACTING STRATEGY.

9.1 Direct contracting with the contractor (ABS). The contractor currently has several contracting mechanisms with both the US and Canadian governments.