Application of a Reliability-Based Design Loads Generator (DLG) to Determine Hull Pressure Forces for use in Finite Element Models

1.0 OBJECTIVE

1.1 Evaluate the Design Load Generator (DLG) method for determining design critical hull pressure forces and its ability to support the structural design process.

2.0 BACKGROUND

2.1 The current method suggested by the American Bureau of Shipping for applying lifetime maximum hull pressure forces to a finite element model is based on using an equivalent wave. Basically what the approach entails is determining the lifetime maximum hull girder load and then coming up with an equivalent regular wave that results in the same bending moment response. The associated hull pressure forces from this regular wave are then applied to the FE model. Although expedient, the current process of using an equivalent regular wave is flawed as the pressure distribution that is applied does not contain a realistic spatial distribution of hull pressure forces.

2.2 With the DLG method, an ensemble of input wave trains can be generated where the extreme responses approximate the asymptotic extreme value distribution. As a result, the loads analyst can determine critical wave events that result in lifetime maximum loads. The benefits of the DLG method are twofold. First, the method offers potential savings in the time and effort required to estimate long-term loads. Second, the wave events which are generated by the DLG method will provide the structural designer with the means to apply first principles based hull pressure forces to their finite element models, thus, allowing a vessel’s structural design to be evaluated deterministically for that specific response.

3.0 REQUIREMENTS

3.1 Scope: The following phases of work define high-level Contractor requirements.

3.1.1 The contractor will develop a set of lifetime maximum vertical bending moments based on Weibull analysis methods. The resulting predictions will be used to set equivalent regular wave based hull pressure forces, consistent with classification rules.

3.1.2 The contractor will apply the DLG method to predict hull pressure forces consistent with a lifetime extreme event. The contractor will evaluate traditional methods for applying hull pressure forces to FE models with first principles approach available with the DLG method.

3.1.3 The contractor will develop a series of guidelines outlining the preferred approach for utilizing the DLG process within the ship structural design process.

3.2 Tasks: The Contractor shall carry out the following tasks in performing project work scope

3.2.1 The contractor shall perform nonlinear time domain simulations using the Large Amplitude Motions Program (LAMP) for two select hull forms. Using the generated loads time histories, predictions for lifetime maximum vertical bending moments will be made. (2 months)
3.2.2 The contractor shall utilize the DLG process to develop an ensemble of extreme wave events for the two hull forms. The resulting series of extreme waves will be used as input to the LAMP program to predict extreme vertical bending moment for the three hull forms. (1 month)
3.2.3 In order to confirm that the DLG generated waves represent an extreme response, the contractor shall compare the extreme responses generated by the DLG method against the Weibull predictions performed in task 3.1.1. The contractor shall then apply the DLG based wave train to the FE models of the three hull forms. A comparison of the resulting loading on the model with traditional regular wave methods will be made. (1.5 months)
3.2.4 The contractor shall develop guidelines for using the DLG process within the ship structure design process. (1.5 month).

3.3 Project Timeline. 6 months from the date of award

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 detailed report that:

5.2.1 Explains the underlying theory of the DLG method.
5.2.2 Description of the LAMP suite of software used in the analysis.
5.2.3 Simulation models of the target hull geometries.
5.2.4 Finite element models, hull pressures and description of the results.
5.2.5 Describes the limits and capabilities of existing classification societies procedures with results obtained from the DLG method.

5.2.6 Guidelines outlining the procedures to be used for applying the DLG process as part of the ship structural design process.
5.2.7 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: FY 2018 date of award.
6.2 Project Completion Date: 6 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: 6 months.
7.2 Total Estimate: $150,000

8.0 **REFERENCES**

8.1 ABS Guide Safehull-Dynamic Loading Approach for Vessels, December, 2006.
8.2 Kim, Dae-Hyun, Troesch, Armin Walter. 2010. An Application of Design Load Generator to Predict Extreme Dynamic Bending Moments. 29th International Conference on Ocean, Offshore and Arctic Engineering (OMAE2010), 2010(49118), 635-643.
8.3 Kim, Dae-Hyun, Engle, Allen and Troesch, Armin Walter, 2011. Estimates of long term combined wave bending and whipping for two alternative hull forms, SNAME Annual Meeting, 2011.
8.4 Alford, Laura K., Kim, Dae-Hyun, & Troesch, Armin W. 2011. Estimation of extreme slamming pressures using the non-uniform Fourier phase distributions of a design loads generator. Ocean Engineering, 38,748-762.
8.5 Lin, Woei-Min, Bergquist, J. R., Collette, M. D., Liut, D., Treakle, T. W., Weems, K. M., Weems, M. H.C., & Zhang, S. 2008. Large Amplitude Motion Program (LAMP) for Ship Motions and Wave Loads Predictions. Tech. rept. Science Applications International Corporation, 4321 Collington Road, Suite 250, Bowie, Maryland 20716, USA.
8.6 Shin, Y. S., Belenky, V. L., Lin, W. M., Weems, K. M., & Engle, A. H. 2003. Nonlinear Time Domain Simulation Technology for Seakeeping and Wave-Load Analysis for Modern Ship Design. Trans. SNAME, 111, 557-583.
8.7 Jensen, J Juncher. 2008. Extreme Value Predictions and Critical Wave Episodes for Marine Structures by FORM. Ships and Offshore Structures, 3(4), 325-333.
8.8 Jensen, J Juncher. 2009. Stochastic Procedures for Extreme Wave Load Predictions - Wave Bending Moment in Ships. Marine Structures, 22(2), 194-208.

9.0 <u>Suggested Contracting Strategy</u>

9.1 Contracting Strategy

- 9.1.1 NSWCCD: MIPR funds from USCG to NSWCCD Code 6510
- 9.1.2 University of Michigan: Utilize existing Level of Effort contract between NSWCCD and the University of Michigan.