11-08 Fatigue Crack Growth in Aluminum Structures under Ship Fatigue Loading Spectra

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1.0 OBJECTIVE.

1.1 This project will develop a means of predicting fatigue crack growth for aluminum ship structures

2.0 BACKGROUND.

2.1 Aluminum ship structures are particularly susceptible to failure because of the relatively high rate of fatigue crack growth in aluminum. Assessment of the service time required before a crack will grow to a critical size that could cause hull girder failure is done through crack growth analysis using the range in the stress intensity factor (K) as a variable. Data relating the crack growth per fatigue loading cycle (da/dN) to K for aluminum alloys was provided by the recent Ship Structure Committee report SSC-448, Fracture Mechanics Characterization of Aluminum Alloys for Marine Structural Applications.

2.2 During a typical fatigue loading cycle on ship structure, the stress at the crack tip changes from tension to compression. During the time of compressive stress, and for part of the tension portion of the loading cycle, the stress intensity is less than the value needed to open the crack tip, K_{OP}, no crack growth occurs because of the effects of crack closure. Crack closure is accounted for during fatigue testing, such as that for SSC-448 by methods that determine K_{OP} by measuring the crack opening displacement during a loading cycle and observing nonlinearities in the load vs. crack opening displacement curve. With an estimate of K_{OP} so determined, the effective range of the stress intensity factor, $K_{effective}$, is determined. The plots of da/d/N vs. DK that are provided in sources such as SSC-448 are actually functions of $K_{effictive}$.

2.3 Predicting crack growth in actual ship structures requires a means of estimating the value of K_{OP} in order to determine $K_{effictive}$. The problem is difficult because in addition to full stress reversal happening during loading, the actual loading sequence is random in nature. In order to develop a method for estimating K_{OP} for fatigue crack growth calculations in aluminum ship structures an experimental program must be carried out. Such a program was conducted for steel tanker structures (Tomita et al., 2002) but no such experimentation has been performed for aluminum ships and craft.

2.4 The effects of crack closure can reduce the effective stress intensity factor by one-half or more. Because the da/dN vs. K relationship has an exponent of about 3, the rate of fatigue crack growth can be overly estimated by a factor of 8 or more if no proper account of crack closure is made. This project is needed because while it is important to understand the danger that an aluminum ship may be in from fatigue crack propagation, such calculations must be realistic.

3.0 REQUIREMENTS.

3.1 Scope. (Identify the phases of the project).

3.1.1 The Contractor shall conduct an assessment of available data on fatigue crack propagation of aluminum structures, particularly those under random loading with stress reversal.

3.1.2 The Contractor shall identify the typical fatigue loading spectra for aluminum ships and determine the range of stress intensity factors to which the structure would be subjected during its service life.

3.1.3 The contractor shall develop and conduct a test program for determining the value of K_{OP} during fatigue loading of aluminum ship structures.

3.2 Tasks. (Identify the tasks to carry out the scope of the project).

3.2.1 The Contractor shall conduct a literature search for past efforts to determine fatigue crack growth during random loading with stress reversal.

3.2.2 The Contractor shall develop a typical fatigue loading spectrum for use assessing fatigue crack growth in aluminum structures. This loading should also include an estimate of fatigue crack sizes that will be used in the testing program in order to determine the range of stress intensity factors at the crack tip.

3.2.3 The Contractor shall design an experiment for testing a structure representative of an aluminum ship to determine fatigue crack growth rates during realistic random loading with stress reversal.

3.2.4 The Contractor shall develop a method for estimating the values of K_{OP} and $K_{effective}$ during calculations of fatigue crack growth in aluminum ship structures.

3.2.5 The Contractor shall prepare a report on the project using SSC standards as guidance.

3.3 Project Timeline. 12 months.

4.0 GOVERNMENT FURNISHED INFORMATION.

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

5.0 DELIVERY REQUIREMENTS. (Identify the deliverables of the project).

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 information for approval to the Project Technical Committee and the Ship Structure Committee Executive Director concerning the test materials, test specimen geometry, load fixtures, and intended load levels prior to the beginning of testing.

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: $150,000.

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

8.0 REFERENCES.

8.1 Tomita, Y., K. Hashimoto, N. Osawa, K. Terai, and Y. Wang. Study on Fatigue Design Load for Ships Based on Crack Growth Analysis, in Fatigue Testing and Analysis Under Variable Amplitude Loading, American Society for Testing and Materials Special Technical Publication STP 1439, 2002.

9.0 SUGGESTED CONTRACTING STRATEGY.

9.1 Full and open contracting beyond existing government level of effort contracts should be used for this project to ensure the participation of fracture experts that are not part of the usual teams bidding of government level of effort contracts.

NOTE:

- Please do not submit any proprietary information in this outline. This will be posted on the SSC Website regardless if the project is selected to be funded.

- All projects will be competed via Government Services Administration (GSA) or Commerce Business Daily (announced)