SSC Project Recommendation for FY 2016

Arresting Cracks in Marine Structures –

How cold expansion can extend the fatigue life of crack arrest hole (CAH)

The Contractor shall provide a Principal Investigator (PI), tools (both software and hardware), facilities, and other necessary support and to perform the work accomplish the desired outcome of this solicitation. The PI shall be responsible for formulating the work, reviewing and evaluation of the results, reporting to the Project Technical Committee (PTC) during periodic review meetings/conferences. The PI shall also ensure that the project is progressing per the defined milestones and that there is no cost overrun.

1.0 OBJECTIVE.

1.1 The objective of the research project is to assess the applicability and viability of implementing cold expanded crack arrest holes (CAH) as a "long-term" temporary repair for marine structures. In order to consider and qualify this repair technique in the marine industry, experimental studies, numerical analyses (FEM), and a full scale field test are required. A guidance document is also needed to aid in the implementation of this technique on marine structures.

2.0 BACKGROUND.

2.1 Fractures are a critical issue for marine structures, as they can pose major safety and environmental hazards. Components subject to cyclic loading are particularly at risk. When cracks are found on a vessel they are evaluated and if deemed critical, immediate permanent repairs will be required. However, a permanent repair may not always be feasible or may be prohibitively expensive due to operational requirements. In this case, a suitable temporary repair implemented, often, in combination with enhanced in-service performance monitoring may be considered.

2.2 Crack arrest holes, accepted as a temporary repair to retard the crack growth until permanent repair, can be performed and are typically permitted on a case-by-case basis and is accompanied with an enhanced inspection program. This is a process by which a hole is drilled at or just in front of the tip of the crack to relieve the localized stress concentration. This method is preferred because it is relatively inexpensive and less time consuming compared to a permanent weld repair. However, there are certain limitations in using a CAH, such as the hole diameter of the CAH must be sized correctly for the given loading, crack dimensions, and structure geometry (Dexter 2003). An undersized CAH will temporary retard crack growth, but the crack will eventually re-initiate on the other side of the CAH and continue to propagate. Due to the history of crack re-initiation and propagation, increased monitoring and inspections by vessel personnel and classing Society coincide with this repair, which can be costly for the asset's owner.

2.3 Considering aluminum vessels, the fracture issue becomes more critical than the one for a steel vessel. Aluminum has a crack propagation rate under fatigue loading that can be as much as 30 times greater than that of steel under the same applied stress intensity factor range (Sielski 2007).

2.4 An enhanced solution to this method is a process called cold expansion technology (Reid 2013), which has been used extensively by the aerospace industry for over 40 years to improve fatigue life of fastener holes. And over the past decade, the technology's scope has expanded to encompass improving the fatigue life of crack arrest holes in aerospace, bridge, and railroad industries. Cold expansion is a process by which an oversized ball bearing or tapered mandrel is drawn through a drilled hole, plastically yielding the material around the hole and leaving a residual field of compression. Cold expansion technology has been tested and shown tenfold improvement of fatigue life in comparison to traditional CAH.

2.5 In order to consider this repair technique in the marine industries experimental studies, numerical analyses, and a full scale field test are needed to demonstrate the use of the cold expansion technology in marine steel/aluminum and provide sufficient experience and documentation to support consideration of this improved temporary repair technique for in-service marine vessels. This would provide financial benefits by giving owners greater flexibility in planning for permanent repairs as well as reducing the associated costs of enhanced inspections for situations where permanent repairs may not be feasible along with an improvement in safety.

3.0 REQUIREMENTS.

3.1 Scope.

3.1.1 The Contractor shall conduct an assessment of the state of the art in cold expansion technology for marine structures on fatigue damage accumulation of CAH. Also, the Contractor shall summarize past experimental and in-service results for the use of the cold expansion technology for other industries in order to carry out a program to demonstrate that the repair is equally effective for marine applications.

3.1.2 The Contractor shall conduct a program (including experiment, numerical analysis, and field test) to evaluate the effectiveness of the cold expansion technology for marine steels/aluminums.

3.1.2.1 The primary goals for laboratory testing will be to compare the fatigue performance of the traditional crack arrest hold with and without the cold expansion and to determine the necessary inspection interval for temporary repairs as a result of the demonstrated fatigue life.

3.1.2.2 The numerical analysis (2D or/and 3D FEM) should validate the laboratory testing results and facilitate the prediction of fatigue life.

3.1.2.3 The full scale field test should be performed to demonstrate the effectiveness of cold expansion technology.

3.1.3 The Contractor shall create a guidance for implementation of the cold expansion technique as well as advise on any limitations of this technology in marine structures.

3.1.4 The Contractor shall present all the results in the form of a report and submit it to the Ship Structures Committee.

3.2 Tasks.

3.2.1 Task 1 – Literature Review *(2 months)*.

3.2.1.1 Literature survey on cold expansion technology for marine structures and literature survey on cold expansion technology for other industries *(2 months)*.

3.2.2 Task 2 – Laboratory Testing (*9 months*)

3.2.2.1 Create a laboratory testing plan to identify testing requirements, testing facility, proper testing material (steel/aluminum), proper fatigue loading range and frequency *(2 months)*.

3.2.2.2 Conduct fatigue experiment in two phases: 1) prepare the specimens with initial cracks, drill CAH, then prepare two comparison sets of specimens (one with cold expansion and the other one without cold expansion) and 2) perform fatigue test *(6 months)*.

3.2.2.3 Compile the laboratory testing results and findings in a report *(1 month)*.

3.2.3 Task 3 – Finite Element Analysis *(6 months)*.

3.2.3.1 Build finite element models of laboratory testing specimens (with and without cold expansion on CAH). Different approaches to FE modeling shall be tested such as mesh size, boundary conditions, applied compression stress, etc. *(2 months)*.

3.2.3.2 Perform nonlinear finite element analysis of fatigue damage for selected fatigue loading range and frequency *(2 months)*.

3.2.3.3 Compile the finite element analysis results and findings in a report *(2 months)*.

3.2.4 Task 4 – Field Testing *(14 months)*.

3.2.4.1 Create a field testing plan to identify testing requirements, testing vessel, crack location, testing material (steel/aluminum), cracking location, and estimated fatigue loading range and frequency *(2 months)*.

3.2.4.2 Conduct a full scale field test on a crack with **propagation**. A monitoring system may be needed to monitor the crack condition and determine the reinitiate crack propagation time after applying the cold expansion on CAH *(11 months)*.

3.2.4.3 Compile the field test results and findings in a report *(1 month)*.

3.2.5 Task 5 – Reporting *(4 months)*.

3.2.5.1 Submit biannual reports on the results and findings compiled from the above mentioned tasks to the Ship Structures Committee *(2 months - variable)*.

3.2.5.2 Compile all task (Task 1 to Task4) reports into a master report along with creating a guideline on the implementation of the reported techniques and submit to the Ship Structures Committee *(2 months)*.

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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 as posted on the website http://www.shipstructure.org.

6.0 PERIOD OF PERFORMANCE.

6.1 Project Initiation Date: date of award.

6.2 Project Completion Date: 18 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: 18 months.

7.2 Total Estimate: $85000.

8.0 REFERENCES.

8.1 Dexter, R. J. et al. (2003). Fatigue Strength and Adequacy of Weld Repairs. *SSC-425*;

8.2 Reid, L. (2013). Arresting Cracks in Steel Bridges: Using Proven Aerospace Technology. *Presentation at the meeting of Western Bridge Preservation Partnership*, San Diego, CA;

8.3 Sielski, R. A. (2007). Research Needs in Aluminum Structures. *10th International Symposium on Practical Design of Ships and Other Floating Structures*, Houston, TX.

NOTE: No proprietary information is contained within this outline document. It is understood that the document may be posted on the SSC Website regardless if the project is selected to be funded.