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Fatigue Analysis of Swaged Bulkheads (#2018-454)

NSRP SDMT Panel Meeting

Presented by Kolby Pearson and Jessica Skogberg







Swaged Bulkhead Overview

- Plate pressed to form "bumps" at interval similar to traditional stiffeners
- Also called swedged, pilaster, or crimped
- Reduce overall cost of ship design, construction, and life cycle maintenance
 - Reduced part count
 - Decreased weld lengths
 - Easier paint application
 - Improved paint adherence







Expected Benefits of Swaged Bulkheads





T-AO 205 Class Potential Cost Savings (Per Ship)

- Cost reduction of ~\$720k
- Decrease material expenses by ~\$164k
- ~8400 hour reduction in labor
- Savings of ~80 tonnes in deckhouse weight



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Previous Studies of Swage Technology

2005 <u>Study of Swage Applicability on T-AKE</u>

-2014

- Feasibility of application of swage panels in the deckhouse of T-AKE
- Limited to non-load bearing locations
- Concluded that further investigation needed regarding application to structural bulkheads.

2010 Swage Panel Analysis Verification (NSRP Panel Project 2010-611)

- Validated analytical methods of applying various loads to swaged and traditionally stiffened bulkheads
- Results compared to physical model tests
- **2011** <u>Swage Bulkhead Analysis Verification</u> (NSRP Research Announcement 2011-459)
 - Compared swages to traditional T and bulb stiffeners
 - Phase I Worked with Marinette Marine to compare steel and aluminum
 - Manufacturing cost comparison study
 - Phase II Examined effects of variations in swage geometry, plate thickness, and steel grade

Phase III • Studied real-world outfitting: bulkhead cutouts, penetrations, attachments (eg: electrical panel)





Previous Studies of Swage Technology

2015- Swage Panel SVR Rule Development (NSRP RA 2015-402)

2018

- Phase I Text Fixture designed, built, and commissioned at SDSU Structural Lab in Phase I
- Conducted global FEA of representative trailership to determine potential swage placement
 - Fabrication of testing of specimens to obtain data to support ABS rule change.
- Two swage geometries and one traditionally stiffened panel were tested in both shear and compression. Data compared to FEA and reviewed by ABS to validate proposed rule change.

2016 <u>Qualification of Alternative Structures</u> (2005-333)

- Laid the groundwork for incorporation of swage panels into combatant vessels
- Worked with the Navy Technical Warrant Holders to complete validation plan for swage on combatants
- Proposed validation test matrix including fatigue, shock, in-plane, out-of-plane, and combined loading



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Previous Studies of Swage Technology

2018- Integration of Outfitting and Structural Details (NSRP RA 2018-444)

- Validated the strength and behavior of swage bulkheads with common structural details including outfitting and stiffener cutouts
 - Conducted physical testing of Swage specimens in compression and shear load profiles
 - Validated results with Finite Element Analysis
 - FEA predicted panel compression strength within goal of 25%



2019







Fatigue Analysis of Swaged Bulkheads: Project Goals

- Investigate fatigue life of swaged bulkheads through physical testing and Finite Element Analysis and compare to the fatigue life of traditionally stiffened bulkheads
- Demonstrate that swaged bulkheads have equivalent fatigue strength or better than a structurally equivalent stiffened bulkhead.
- In advanced preparation for future testing: design and construct Test Fixture Modification to apply out-of-plane loads to swage panels (load condition required for future Navy approval).
- In conjunction with BIW, a Swage Implementation Plan was created in order to facilitate the integration of swaged bulkheads into US Navy ships for specific applications by determining the next steps for testing.

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Fatigue Analysis of Swaged Bulkheads RA

Three Key Deliverables:

- 1. Fatigue Analysis and Testing
 - Partner: SDSU
 - Phase 1 and 2 (in progress)
- 2. Test Fixture Modification Design and Construction
 - Partner: SDSU
 - Phase 1 and 2 (in progress)
- 3. Swage Implementation Plan
 - Partner: BIW
 - Phase 1 (complete)

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Fatigue Study Approach

- Explore the fatigue properties of swage bulkheads through:
 - Finite Element (FE) models
 - Physical testing using force controlled cyclic loading
 - Testing full scale specimens to fatigue failure/crack initiation
 - Compare swaged bulkheads and traditionally stiffened bulkheads using both methods
- The physical testing is being conducted on the Swage Test Fixture at San Diego State University's (SDSU) Structural Engineering Laboratory.





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Test Specimen Designs



Remaining Specimen Designs to be Tested

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Swage Above Swage Test Specimen (In-Progress)

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Fatique Details – Coupon Testing



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- Coupons details developed to get baseline information on potential weld and material fatigue failures
- Coupon details
 - Simple
 - Cutout
 - Welded
- Tested at high frequency up to 10 Hz

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Instrumentation Plan





Instrumentation Plan Swage Above Swage Specimen

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Fatigue CrackSAN DIEGO STATEUNIVERSITYBath Iron

Finite Element Analysis





Instrumentation Plan – Center Swage

Pre-test Finite Element Analysis





Testing Results



- Red line shows regression analysis curve of completed coupon tests
- Two full-scale specimens tested with third in progress
- Crack initiation of specimens plotted on regression analysis curve





Test Fixture Modification for Out-of-Plane Loading

- Move forward in accelerating implementation of swaged bulkheads by designing the parts needed to adapt the existing test fixture so that it may be used to apply out-of-plane load profiles.
- Design
 - NASSCO is working with San Diego State University (SDSU) on the research, calculations, and drawings as part of the design work to be able to apply out-ofplane loads.
- Fabrication and Installation
 - NASSCO will build Test Fixture Modification that will be installed at the SDSU Structural Laboratory.





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BIW Shock Survey

- Examined modal and shock responses of swage bulkhead foundation attachments compared to a traditionally teestiffened panel
- Recommended physical testing on swage and tee-stiffened panels for direct comparison





Swage Pathway to Technical Acceptability



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Swage Implementation Plan





San Diego State University

Swage Implementation Plan

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Non-Combatants Combatants: Discussion with Navy Technical Warrant Holder for Shock Assess concerns for swaged bulkheads with regards to shock and DDAM study completed by BIW Tosting to

Feasibility Study To encourage adoption of swaged bulkheads in shipyards, pursue feasibility study to serves as example of best practices and methods of incorporating swaged bulkheads in new

construction and repair

Production

Discussion with Navy Technical Warrant Holder for Vulnerability Assess concerns for swaged bulkheads meeting requirements for protection consistent with required methodologies

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Covid-19 Impacts

- Project schedule has been impacted by pandemic
- SDSU: lab availability, test preparation, and attendance
 Testing Delays
- Technology Transfer Events
 - SDMT Panel Meeting (virtual)
 - SNAME 2020 (virtual)





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Questions?

