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14. ABSTRACT
The project dealt with mechanical issues related to hybrid ship hulls made with composite panels attached to a steel truss. The steel truss was designed to carry the bending loads of the hull girder, whereas the composite skins were designed to carry shear and water pressure loads. Experimental and numerical evaluations of the concept were performed. A six meter (20 ft) model, which had been built and initially tested in 2004 under a separate grant, was turned upside-down and tested to verify performance under hogging loads. After these hogging tests, the model was turned back and tested to failure after simulated internal blast by removal of select panels. Material tests and elastic-plastic analyses were performed. Four journal papers describing the work on the present hybrid ship hull concept have been submitted for publication (three have been published and the last one has been accepted).

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FINAL REPORT

Vierendeel Type Steel Truss / Composite Skin Hybrid Ship Hulls

ONR Grant N00014-03-1-0597 monitored by Dr. G.S. Barsoum

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Abstract

The project dealt with mechanical issues related to hybrid ship hulls made with composite panels attached to a steel truss. The steel truss was designed to carry the bending loads of the hull girder, whereas the composite skins were designed to carry shear and water pressure loads. Experimental and numerical evaluations of the concept were performed. A six meter (20 ft) model, which had been built and initially tested in 2004 under a separate grant, was turned upside-down and tested to verify performance under hogging loads. After these hogging tests, the model was turned back and tested to failure after simulated internal blast by removal of select panels. Material tests and elastic-plastic analyses were performed. Four journal papers [1-4] describing the work on the present hybrid ship hull concept were submitted for publication (three have been published and the last one has been accepted).

Work Performed

A six meter steel/composite hybrid ship hull model had previously been manufactured under an ONR contract. In the first phase of the present research this model was turned upside-down and loaded under simulated hogging loads, Fig. 1. Hogging loads bend the ship hull upwards in the middle and result in longitudinal tension in deck panels and compression in bottom panels. The loading of the model correlated well with numerical finite element analyses, except the fact that the steel longerons yielded prematurely. The reason was found by fabricating and testing sub-component specimens of the longerons, Fig. 2, which showed that the premature yielding was due to welding induced stresses. By using an "effective" yield strength, the numerical analysis correlated very well with the tests even after significant yielding of the steel truss, Fig. 3. The hull specimen was loaded to design load and showed no indication of damage except for some yielding of the steel. The yielding could be reduced by some design changes.

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In the second phase of the research, the behavior of the hybrid hull under severe damage was investigated. Both numerical and experiment investigations were performed. The hybrid ship hull concept presently investigated, consisting of a steel truss and composite sandwich panels, may provide very good "limp home" capabilities after major damage. The sandwich panels can be attached to the steel truss such that they can be blown out in a controlled fashion to ventilate a large internal blast. The steel truss can be designed to provide much ductility. The hull could be designed to have sufficient strength for the ship to reach a port even after extensive damage. This was studied using the six meter model. Damage was simulated by complete removal of sandwich panels. Select panels were removed one by one and the hull was tested to the design load after each panel had been removed. After nine panels had been removed, from all different areas of the hull, it could still carry the design load although with considerable, non-reversible deformation of the hull girder. The hull was eventually loaded to final failure, Fig. 4, which occurred at 25% above the design load.

In conclusion, all tests and analyses were very successful and the results clearly indicate that the steel/composite hybrid ship hull concept has great potential. This is presently being backed up with larger scale fatigue tests.

Papers published

1. Cao, J., Grenestedt, J.L., Maroun, W.J., "Steel Truss/Composite Skin Hybrid Ship Hull, Part I: Design and Analysis," Composites Part A: Applied Science and Manufacturing, Volume 38, 2007, pp. 1755-1762.

2. Maroun, W.J., Cao, J., Grenestedt, J.L., "Steel Truss/Composite Skin Hybrid Ship Hull, Part II: Manufacturing and Sagging Testing," Composites Part A: Applied Science and Manufacturing, Volume 38, 2007, pp. 1763-1772.

3. Cao, J., Grenestedt, J.L., Maroun, W.J., "Testing and analysis of a 6-m steel truss/composite skin hybrid ship hull model," Marine Structures, Vol. 19, 2006, pp. 23-32.

4. Grenestedt, J.L., Cao, J., Maroun, W.J., "Test of Extensively Damaged Hybrid Ship Hull," accepted, to appear in Journal of Marine Science and Technology.

Figures

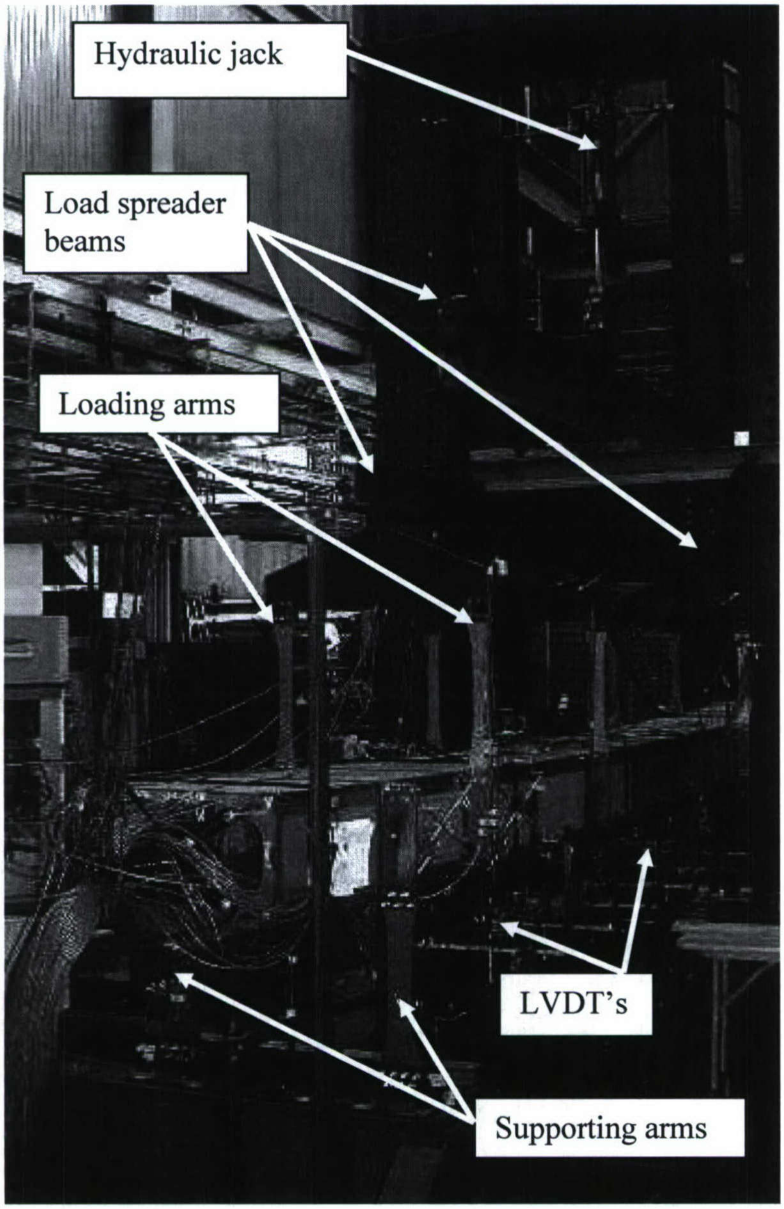

Fig. 1. Six meter hybrid ship hull model mounted in the test rig for hogging loading.

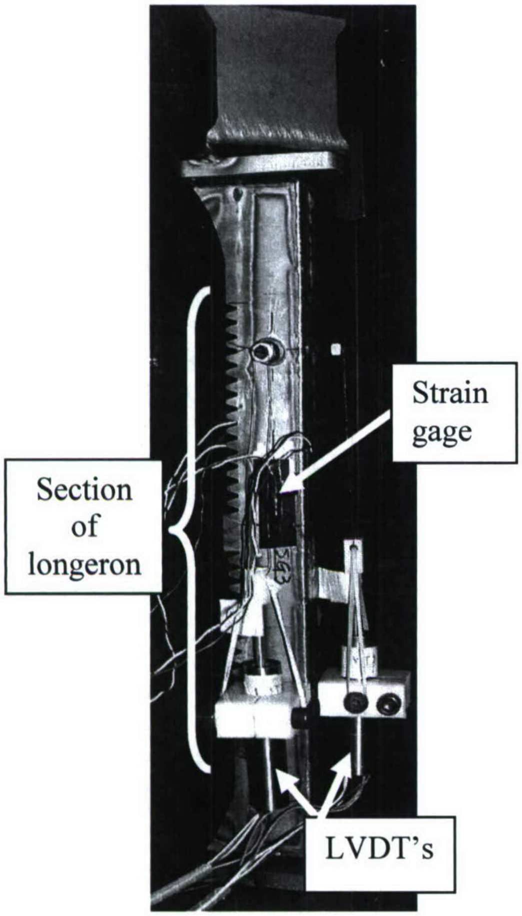

Fig. 2. Sub-component of a steel longeron, used for evaluating effects of welding induced stresses.

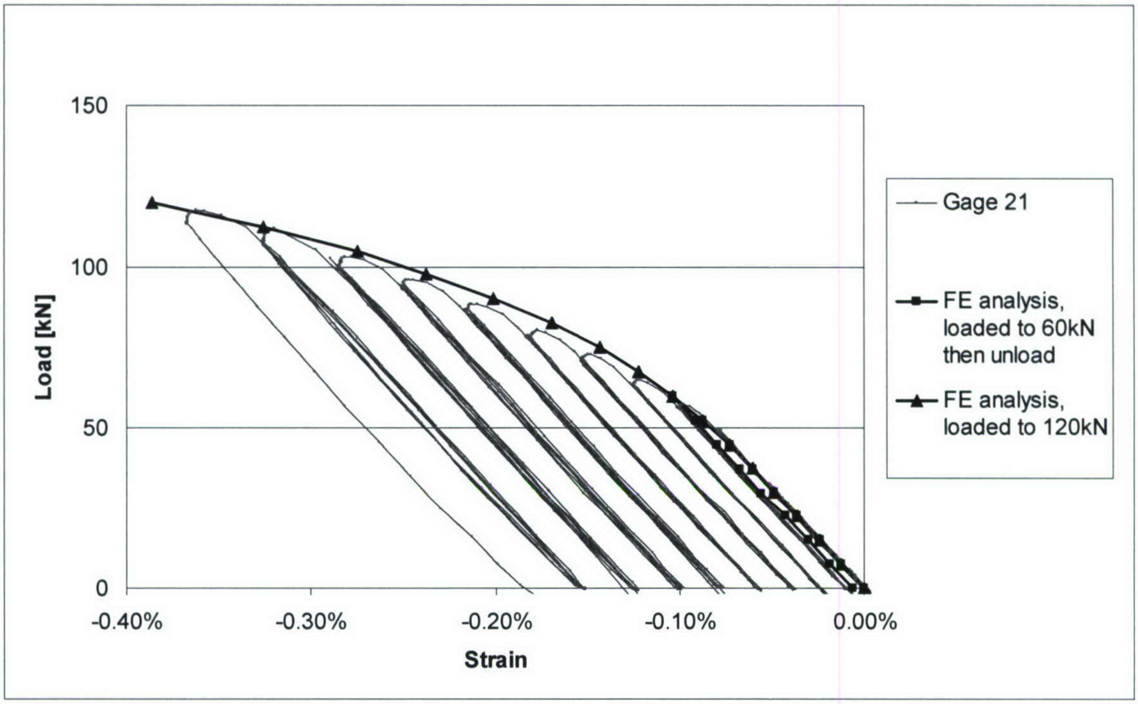

Fig. 3. Typical stress-strain curve from test ("Gage 21") and FE analysis.

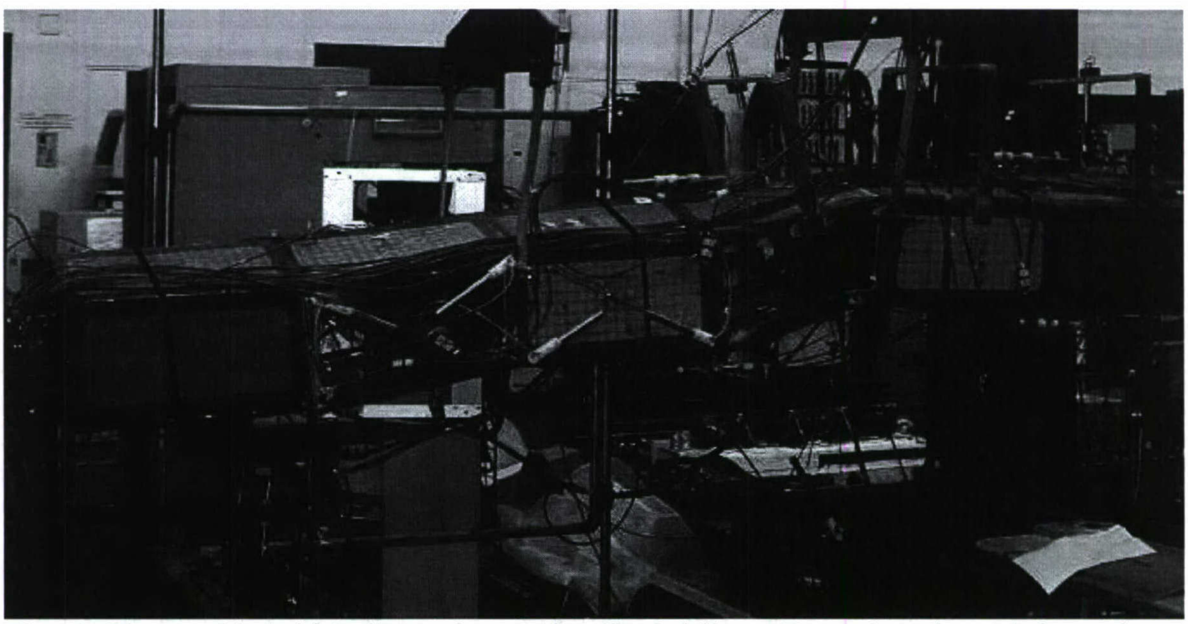

Fig. 4. Photo of hybrid hull specimen after final failure. Extensive shear deformation occurred where side panels had been removed.