DAMAGE TOLERANCE OF STEEL / COMPOSITE HYBRID SHIP HULL

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Abstract

The paper deals with mechanical testing of an intentionally damaged six meter long model of a steel / composite hybrid ship hull. One of the benefits of the hybrid concept presently investigated is the potential to incorporate efficient "blow-out panels" in the design. These panels are designed to quickly release pressure from an internal blast. The residual strength of the hull girder after an internal blast was determined experimentally, using the hybrid hull model with a number of panels removed to simulate the blast damage. The specimen was extensively instrumented. The experiments proved that the hull had considerable strength even with nine panels removed.

1 Introduction

Composites are rapidly spreading in the marine sector, where they provide benefits such as low weight, high strength, good fatigue resistance, excellent thermal and sound insulation, flatness for signature requirements, corrosion resistance, etc. On the other hand, steel has different benefits, including high ductility, high stiffness, isotropy, ease of manufacturing, assembly and outfitting. By combining these materials in a so-called hybrid ship hull, consisting for example of a steel truss closed out with large composite sandwich panels, synergetic benefits may be achieved. One particularly strong argument for studying hybrid ship hulls is the expected ability to efficiently release pressures of large internal blasts. The composite panels can with relative ease be constructed such that they will tear off from the steel truss and be blown out in a controlled fashion when subjected to a major internal blast. Another strong argument is the stringent fire requirements of ships, which often dictate the use of special fire resistant composite materials that unfortunately tend to be rather brittle. A steel truss / composite sandwich panel hybrid ship hull may introduce considerable ductility which would not be present in an all-composite fire retardant structure.

Some of the structural challenges of hybrid ship hulls, and attempts for their solutions, have been dealt with in, for example, [1-5]. The present paper deals with how a hybrid ship hull may survive the extensive damage that could be expected from a major internal blast.

2 Hybrid Ship Hull Test Specimen

A hybrid ship hull model consisting of a welded non-magnetic stainless steel truss closed out with 60 vacuum infused glass fiber skin / foam core sandwich panels was manufactured. The specimen is shown in Fig. 1. The steel truss consisted of five longerons along the whole length of the specimen, and 13 open frames or bulkheads. The composite panels had a foam core except along the edges, where the two skins came together to form a single skin edge. The panels were adhesively bonded to the steel truss.

Fig. 1. Hybrid ship hull specimen

The hybrid hull specimen was instrumented with approximately 200 strain gages and 30 LVDT's and subjected to simulated sagging and hogging loads. Loads were introduced from a single overhead hydraulic cylinder, through a statically determinate load tree, into brackets welded onto the steel truss. The specimen was essentially loaded in six point bending, in such a fashion that at the design load both the maximum bending moment and the maximum shear load according to the design requirements were simultaneously obtained. However, the maximum bending moment and the maximum shear load did not occur at the same location, as they would in a three or four point bending test. The experimental setup is shown in Fig. 2.

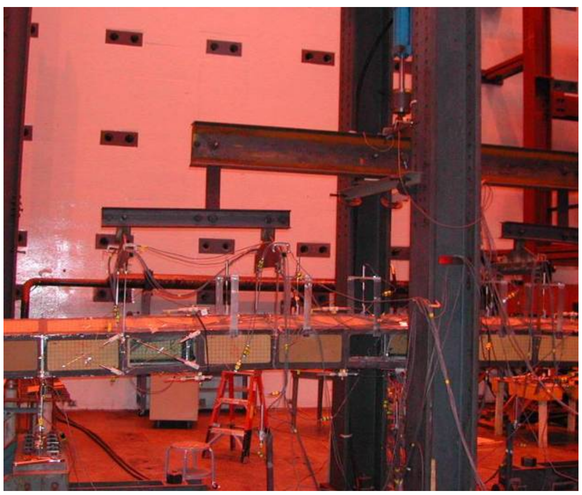

Fig. 2. Experimental setup for testing the hybrid ship hull model

3 Test Procedure

The ship hull model was investigated experimentally by subjecting it to loads corresponding to the worst cases of sagging and hogging. The hull handled the loads without any damage in the composite panels or the adhesive joints between the panels and the steel truss. However, due to residual stresses after welding of the truss, plastic yielding of the steel started earlier than expected.

After these preliminary tests, the hull was damaged and re-tested in order to evaluate how the structure would handle extensive damage which could be the result of a major internal blast. The approach was to remove complete sandwich panels and load the structure to design loads. This was repeated nine times. Even after nine panels from all regions of the hull had been removed, the structure could still carry the full design load.

The specimen was finally loaded until complete failure, which occurred with nine panels removed at 25% above the design load. A part of the hull after completed testing is shown in Fig. 3.

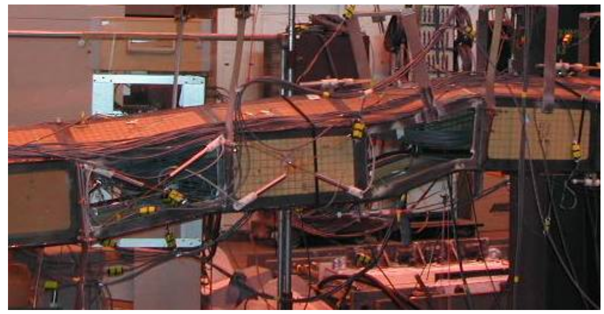

Fig. 3. Specimen after final failure

4 Numerical Analysis

All stages of the testing were analyzed by Finite Elements (FE). The agreement between the experimental the FE results was in general excellent. The analysis naturally required kinematic and material non-linearities. The deformed ship hull with nine panels removed is shown in Fig. 4.

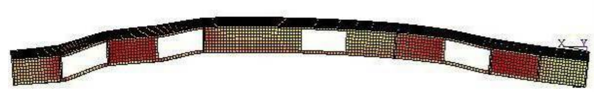

Fig. 4. Deformed ship hull specimen (displacements exaggerated)

5 Conclusions

A presumably new type of ship hull structure was studied experimentally and numerically. The structure proved to have a number of benefits, including excellent damage tolerance.

References

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