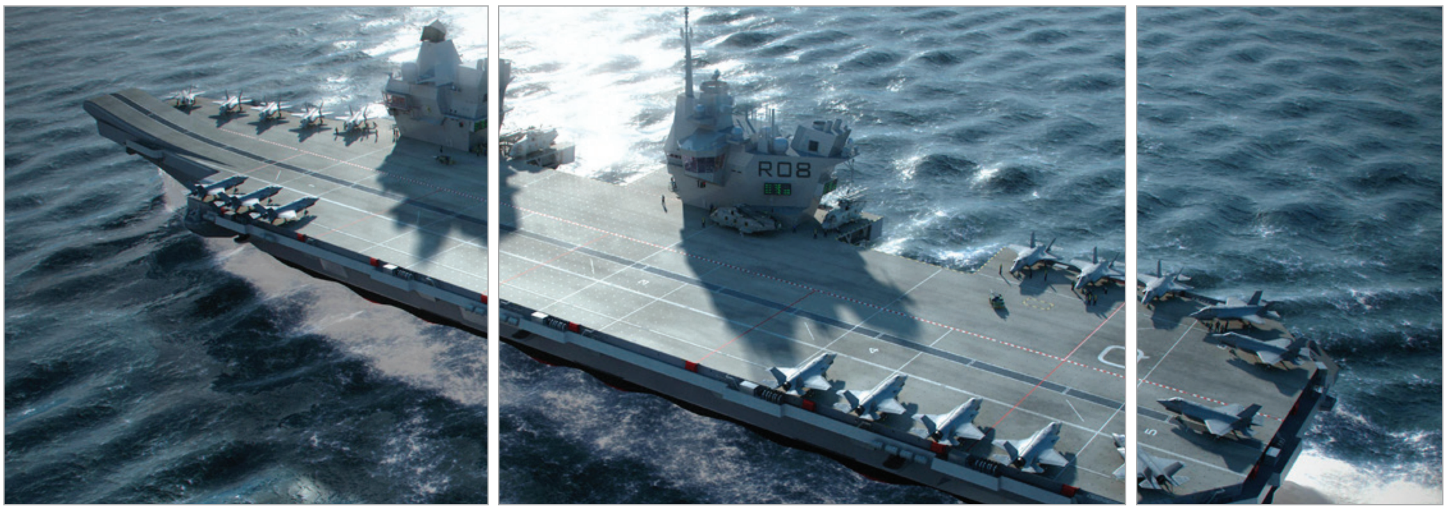
Driving a Structurally Efficient Design of the Queen Elizabeth Class Aircraft Carrier



aircraft carrier alliance
Delivering the Nation's Flagships

Key Highlights

Industry
Marine

Challenge
Investigate whether a simulation-driven design process can provide right first time design solutions to the marine industry

Altair Solution
Design optimization technology applied to select areas of the vessel to minimize material use and reduce fabrication cost

Benefits
Design targets met in the most structurally efficient way possible

When making key decisions at the concept and preliminary design phases of a naval ship project, the designer is often obliged to work with limited data on the major structural design drivers for the vessel. This traditional approach to naval ship design is largely subjective and although it may involve using the best engineering judgement, inefficiency and even structural problems can be locked-in from the start. This can result in increased material use, weight and unnecessary complexity, as well as high design and manufacture cost in the end product.

The traditional design approach brings with it a number of issues. Undesirable structural arrangement constraints, driven by high-level design decisions, can be finalized early on leading to a higher likelihood of costly iterative changes being required later in development.

Simulation-driven design acts to solve these issues by providing naval architects with a greater and more in-depth understanding of the design drivers at the concept phase, thus enabling more informed design decisions to be made at this critical stage.

'Simulation-driven design' processes blend structural simulation with optimization technology to mathematically and logically explore design solutions. Employing this approach reduces the number of design iterations; reducing the design cycle while ensuring an optimal structural solution that meets design targets.

The potential for this technique to assist

Keywords: Topology optimization, material and weight saving

“Together with Altair, a number of opportunities were identified to use HyperMesh and OptiStruct for the analysis of local structures and identification and removal of redundant material, leading to weight and cost saving benefits.”

Aircraft Carrier Alliance, Official Statement

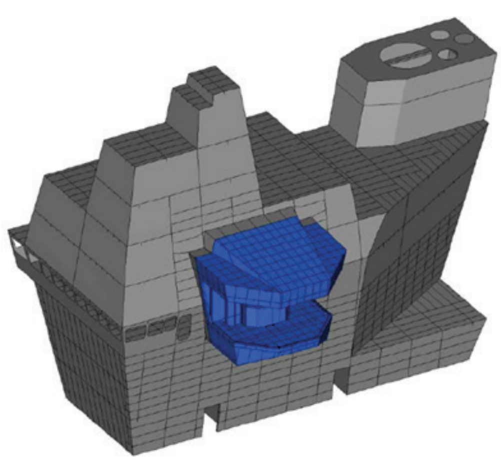
in the design of marine structures was recognized by the Aircraft Carrier Alliance (ACA), the group of companies responsible for the design and manufacture of the Queen Elizabeth Class aircraft carrier for the UK Royal Navy. To evaluate the potential of simulation-driven design under the unique requirements of naval ship design, the ACA partnered with Altair ProductDesign to carry out a series of projects to address complex structural design issues.

Right First Time, Structurally Efficient Design Solutions

The goal of all the projects undertaken was to apply optimization technology to help drive efficient, right first time design solutions to a series of structural regions of the vessel. The first structure explored was the vessel's double-bottom, which would be subjected to significant hydrostatic pressures and dynamic loads from large equipment items. In addition the structure must conform to a ‘Confined Space Access and Escape Arrangements Policy’ that required the placement of access openings through the floors in the double-bottom. It was the floors in particular that were the subject of attention. Altair ProductDesign utilized topology optimization techniques using 'OptiStruct', part of Altair's HyperWorks suite of simulation tools, to help drive an efficient design solution.

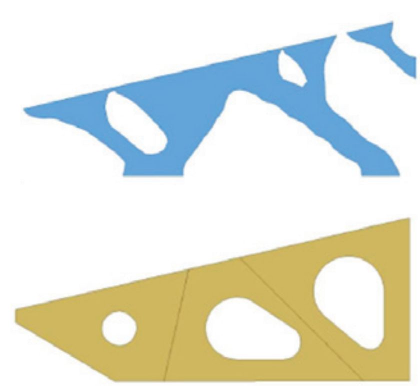
By identifying designable and non-designable space within the floor structure and applying the known loads and constraints, the team could identify where best to locate access openings without compromising structural performance.

In general the topology optimization process can identify the best locations for global structures such as bulkheads and local structures including openings within those bulkheads, ensuring optimum performance while eliminating redundant material within the structure. The process not only achieves an efficient structural solution but also acts to reduce structural weight and minimizes stress concentrations, a leading cause of



Aft Island with Flight Control (FLYCO) Module

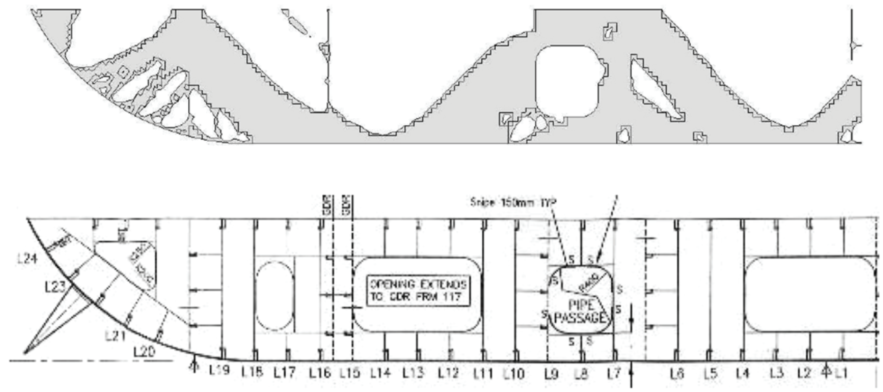
FLYCO Module Global Topology Optimization



Local Topology (top) & Resulting Design Interpretation (bottom)

About Aircraft Carrier Alliance

The Aircraft Carrier Alliance (ACA) is a unique partnering relationship between industry and the UK Ministry of Defence. Established in 2003, the ACA has four members, Babcock, BAE Systems, Thales UK and the UK Ministry of Defence.



Topology Optimization and Resulting Design Interpretation for a Typical Double Bottom Floor

remedial work later in the design process. Once topology optimization had identified the best locations for the positioning of access openings within the double-bottom floors, size and shape optimization was employed on the resulting design interpretation. This step further improves the stress response of the structure and minimizes the steelwork mass required to meet the design targets. Applying optimization methods, Altair ProductDesign created a structure 9% lighter than the baseline design, while meeting all stress targets which the baseline design failed to meet.

In another example of the effectiveness of simulation-driven design, the Altair ProductDesign team used the process to identify an optimum design for the aircraft carrier's flight control (FLYCO) module. The FLYCO module structure is comprised of a large glazed area supported between an upper and lower sponson structure. These sponson structures are required to meet natural frequency and deflection targets and are therefore subject to the complex interactions of mass and stiffness.

Topology optimization was first employed to identify the optimum global positioning of stiffening webs within the package envelope of the module. This was followed by a further round of topology optimization to identify the optimum load paths within those webs, such that openings could be cut without compromising structural performance.

Finally, size and shape optimization was employed to fine-tune the plate thicknesses and opening sizes to minimize mass and design complexity while meeting design targets. The outcome was a structure that met the natural frequency, deflection, stress and buckling targets. The structure used fewer parts than a traditional design and was 16% lighter, resulting in reduced fabrication cost.

Additional simulation-driven design projects by Altair ProductDesign and the ACA included the aircraft carrier's stern platform and transverse bulkheads.

Future Potential

Growth of optimization-focused, simulation-driven design within naval marine engineering has been slower than its automotive and aerospace counterparts largely due to a low turnover of new ship designs to facilitate rapid development and adoption of new design technology.

Simulation-driven design offers many of the same benefits to the ship building industry as it does to vehicle and aircraft manufacturers. Optimized ship structures will result in reduced material and fabrication costs by identifying lighter, more efficient structures that minimize the need for complex local solutions to address problems introduced at the concept phase. In addition simulation-driven design ensures that the above benefits can be achieved in fewer design cycles while helping to eliminate remedial design work to solve local structural issues.

The projects that the ACA undertook with Altair ProductDesign identified the shortcomings and challenges associated with the traditional ship structure design processes. It was demonstrated that simulation-driven design can provide benefits to ship structural design and manufacturing through cost reduction, mass reduction, and improved structural performance and efficiency.

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About Altair

Altair empowers client innovation and decision-making through technology that optimizes the analysis, management and visualization of business and engineering information. Privately held with more than 1,800 employees, Altair has offices throughout North America, South America, Europe and Asia/Pacific. With a 25-year-plus track record for innovative product design and development, advanced engineering software and grid computing technologies, Altair has more than 3,500 corporate clients representing the automotive, aerospace, government and defense, and consumer products verticals. Altair also has a growing client presence in the life sciences, financial services and energy markets.

About Altair ProductDesign

Altair ProductDesign is a global, multi-disciplinary product development consultancy of more than 700 designers, engineers, scientists, and creative thinkers. As a wholly owned subsidiary of Altair Engineering Inc., this organization is best known for its market leadership in combining its engineering expertise with computer aided engineering (CAE) technology to deliver innovation and automate processes. Altair ProductDesign firmly advocates a user-centered, team-based design approach, and utilizes proprietary simulation and optimization technologies (such as Altair HyperWorks) to help clients bring innovative, profitable products to market on a tighter, more efficient time-scale.

www.altairproductdesign.com

About HyperWorks

HyperWorks is an enterprise simulation solution for rapid design exploration and decision-making. As one of the most comprehensive, open-architecture CAE solutions in the industry, HyperWorks includes best-in-class modeling, analysis, visualization and data management solutions for linear, nonlinear, structural optimization, fluid-structure interaction, and multi-body dynamics applications.

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