FLUID STRUCTURE INTERACTIONS
RESEARCH GROUP

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Strength Assessment of Damaged Ship Structures

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Background to the Damaged Ship Research

Despite the advances in modern navigational techniques, ship to ship or ship to land collisions continue to occur in both fine and adverse weather, during good and poor visibility, day or night. As recently as November 2010 the Northlink ferry MV HROSSEY was struck by the supply vessel MAERSK FINDER leaving two deep gouge marks in the side of the vessel, partially penetrating the steel plate above the waterline. In October 2009, 18000 gallons of fuel oil was leaked off Galveston, US, following the collision between the aframax crude tanker Krymsk and the offshore supply vessel AET Endeavour. In many of these events, vessels remain afloat and in need of emergency assistance.

After an incident, it is often difficult to determine and model the precise damage scenario due to the inability to survey the area. Each scenario will have variability in geometrical and material properties, which will affect the residual strength of the structure. Variations in these aspects are not accounted for in methods currently utilised in damage response scenarios. Therefore, to be able to more accurately analyse the damage and provide better guidance to the crew in real time, it is important that this variability can be analysed allowing an understanding of worst and best case scenarios, the probabilities of these occurring and their affect on the structural strength.

In accordance with Regulation 37.4 of the Revised MARPOL 73/78 (2008) Annex I, it is stated that "All oil tankers of 500tons deadweight or more shall have prompt access to computerized, shore based damage stability and residual structural strength calculation programs". Such computer programs can be crucial to the safety of the crew in being able to provide guidance on how to protect the vessel from further damage due to the loading on the damaged vessel, or simply to indicate if the damage is too extensive and the vessel should be abandoned.

Research Aim

To develop a method, procedure or collection of data that can be used to assess, or aid in the assessment of, the residual structural strength of a damaged vessel, through better understanding of the physical problem in relation to the behaviour and physical limitations of damaged ship structure.

Current Emergency Response Methods

- Shore based emergency response services utilise a progressive collapse analysis to determine the residual structural strength of a vessel based on damage information fed back from the ship's crew.
- In such an analysis, the vessel is discretised into stiffened plate elements (Figure 1). Ultimate strength is assessed by increasing the bending curvature of the vessel to calculate the induced strain in each element.
- Element failure is assessed against pre calculated stress-strain and load-shortening curves to assess tensile or compressive failure modes as applicable.
- Curvature is then further increased until the section cannot support the bending induced stresses and the ultimate strength is calculated.
- In a damage scenario, the damaged elements are removed from the section prior to commencing the analysis.
- Such an assessment only takes into account the strength of each individual intact element and does not account for how the damage itself has affected the local strength of the surrounding structure.

Methodology

- In order to take into account the large number of potential variables in a damage scenario, it is proposed that a response surface is used to allow prediction of either the peak stress in the structure for a given loading scenario or its ultimate failure load limit state.
- The response surface is created from the results of a number of FEA cases which satisfy the requirements to successfully create the response surface by incorporating appropriate variations in the characteristics that may occur in a damage scenario.
- It is believed that through the use of response surfaces, a modified progressive collapse methodology could be developed that can better account for damage in a ships structure when assessing its ultimate strength and account for potential longer modes of failure

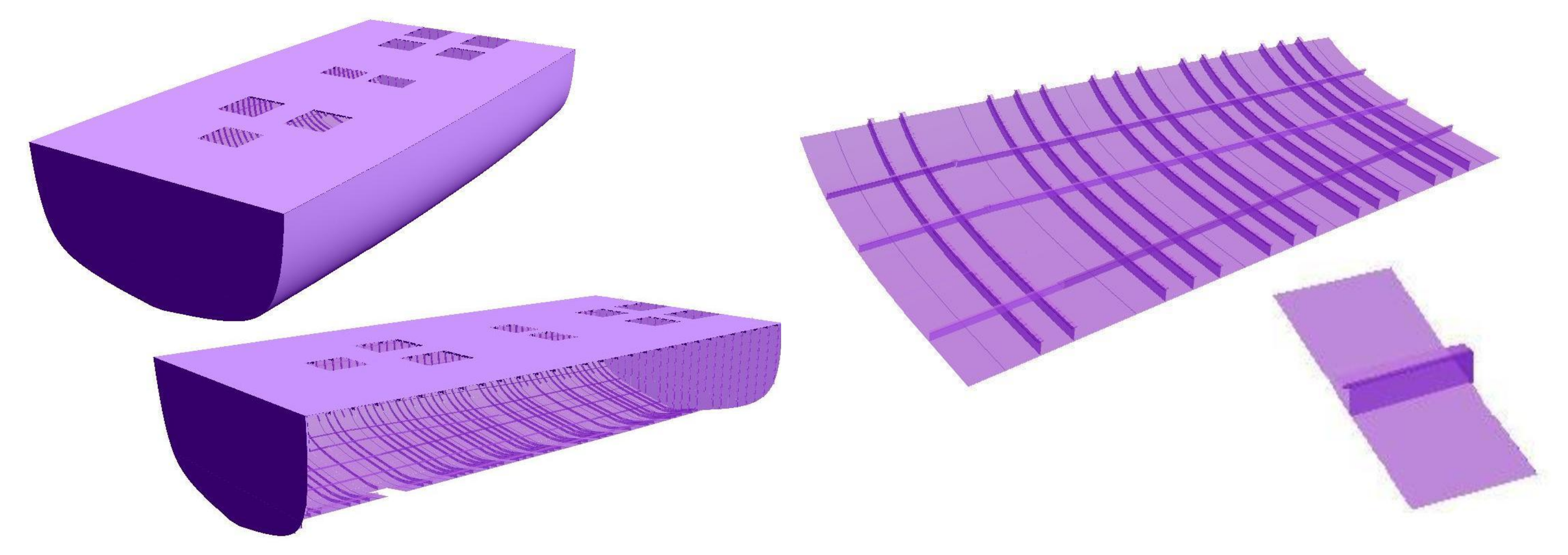
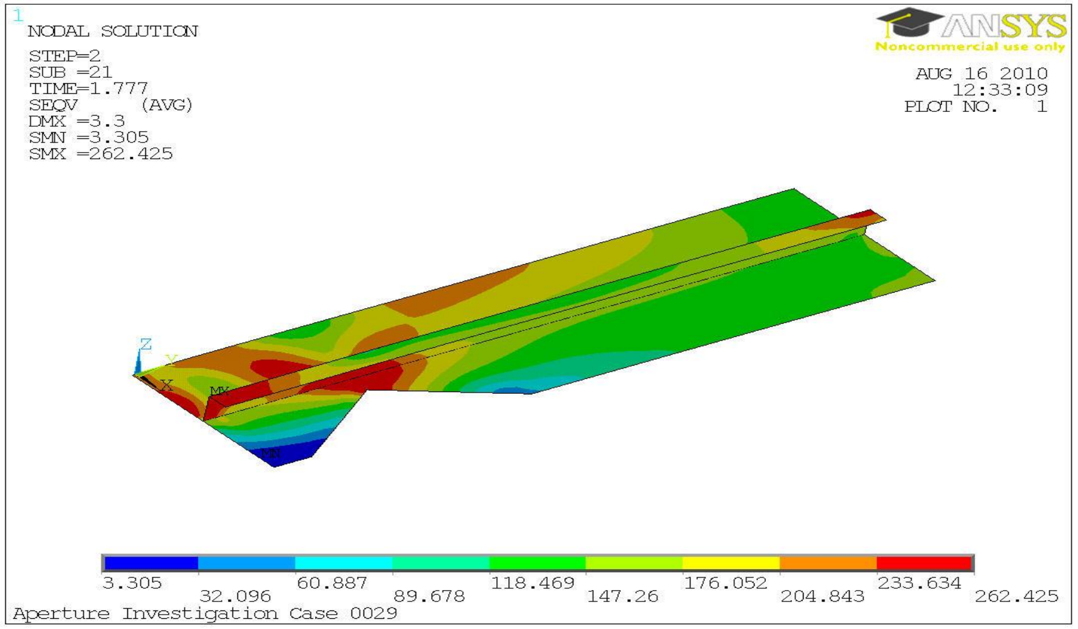


Figure 1: Compartment Level, Grillage and Stiffened Plate Structural Models



Figures 2: FE von Mises Stress Plot of a Damaged Stiffened plate under Compressive loading

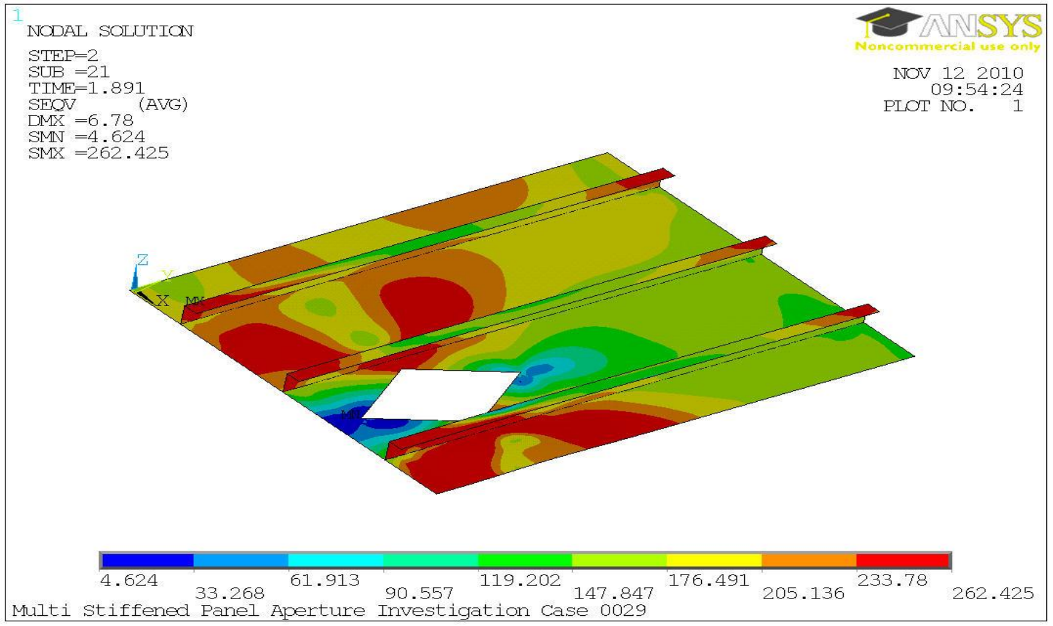
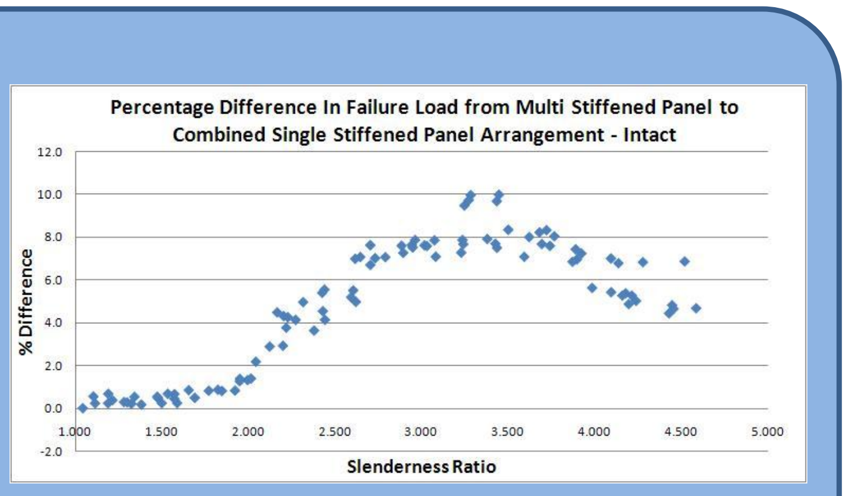
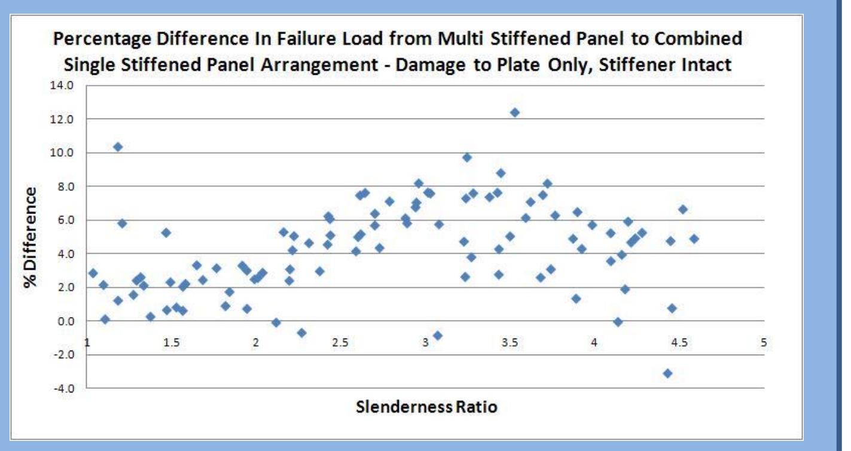
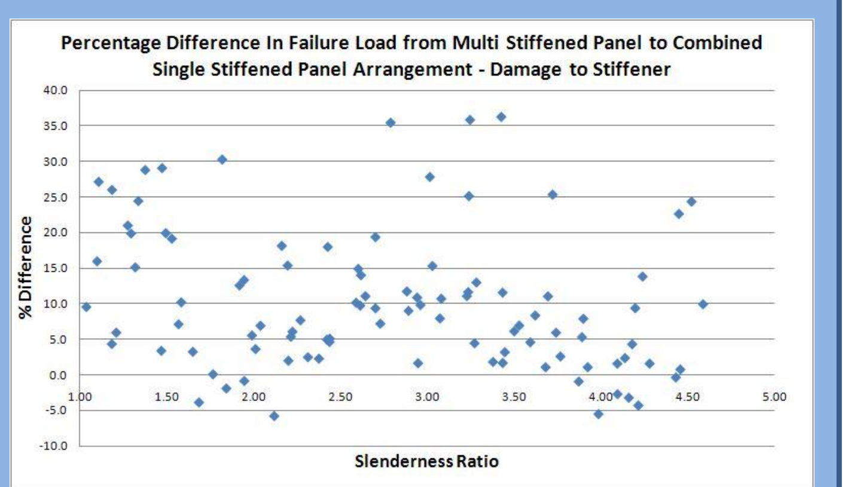


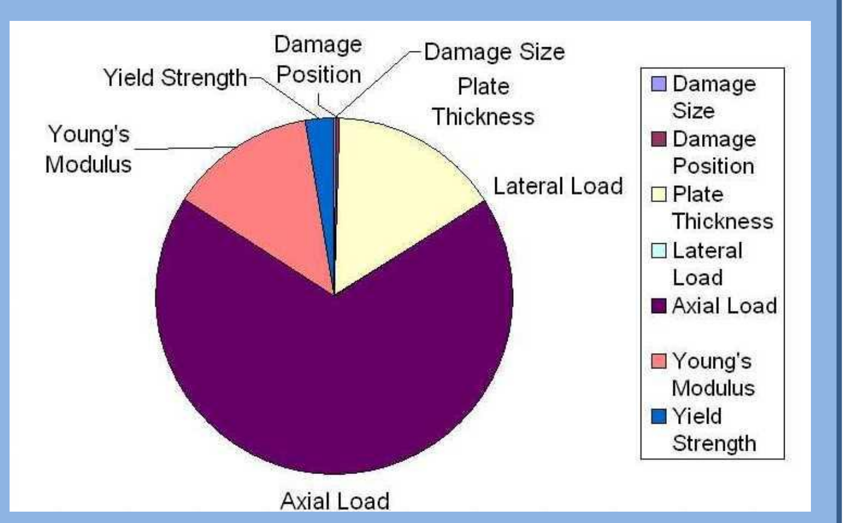
Figure 3: FE von Mises Stress Plot of a Damaged Stiffened panel under Compressive loading

Stiffened Panel Analysis









A large number of FEA cases have been run in order to create the desired response surfaces.

Initial modelling was undertaken of a single stiffened plate, as used in the progressive collapse analysis, modelled by discrete plate approach (Figure 2), both intact and damaged. In these cases damage was positioned along the panel edge so as not to damage the stiffener.

The second arrangement is that of a multi-stiffened panel (figure 3) assessed utilising the same boundary conditions as for the single stiffened panel. For this arrangement, the same intact and damaged cases were run, along with cases to damage the central stiffener.

Assessment of the FEA cases was done to compare the percentage difference between the collapse load for the multiple stiffened panel to a panel constructed in accordance with the progressive collapse analysis assumption of summing the collapse loads of components equivalent to the complete panel. Hence for the intact panel, 3 intact single panels are summed, for a panel with no stiffener damage 2 damaged and 1 intact single panels are summed and for panel with stiffener damage, 2 intact panels are summed.

As shown in the adjoining graphs, the progressive collapse analysis assumptions are generally good for an intact panel, with difference in collapse load less than 10% in all cases.

Percentage difference for the cases with no stiffener damage are generally greater than for the intact cases, though still remains below 12%. However, for the cases where stiffener damage is included, percentage difference increases significantly showing the progressive collapse analysis to be conservative by up to 36%. As can be seen from the results, development of the current analysis methods for damaged vessels are required.

From the response surface created from the damaged discrete plate analysis, a sensitivity analysis was undertaken to assess the sensitivity of the panel to the varied properties. In this assessment it can be seen in the accompanying pie chart that the axial load is the most significant factor in the collapse of the panel, followed by lateral load causing initial deflection and material properties of the panel. The analysis indicated the failure of the panel to be less sensitive to damage size, though this could be due to the relatively large size of the damage in the assessed cases.

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