Structural Modelling of Damaged Steel Structures

Adam Sobey – ajs502@soton.ac.uk - School of Engineering Sciences
MoD\Lloyd's Register Centre of Excellence in Marine Structures

Motivation

Damaged steel structures have a large structural variability associated with the characteristics, residual strength, corrosion etc., of the ship at the time of damage and also the type of damage, collision or grounding, that has occurred. Even after damage it can be difficult to determine the status of the ship, the size of the damage and the conditions that will be experienced as can be seen in figure 1. The assessment of whether a ship can be sailed to the nearest port, crewed safely or require abandonment can be a difficult decision to make. It is therefore important that tools are created to help analysis of these situations. This research focuses on strength analysis and development of a tool to allow for rapid assessment of damaged marine structures.

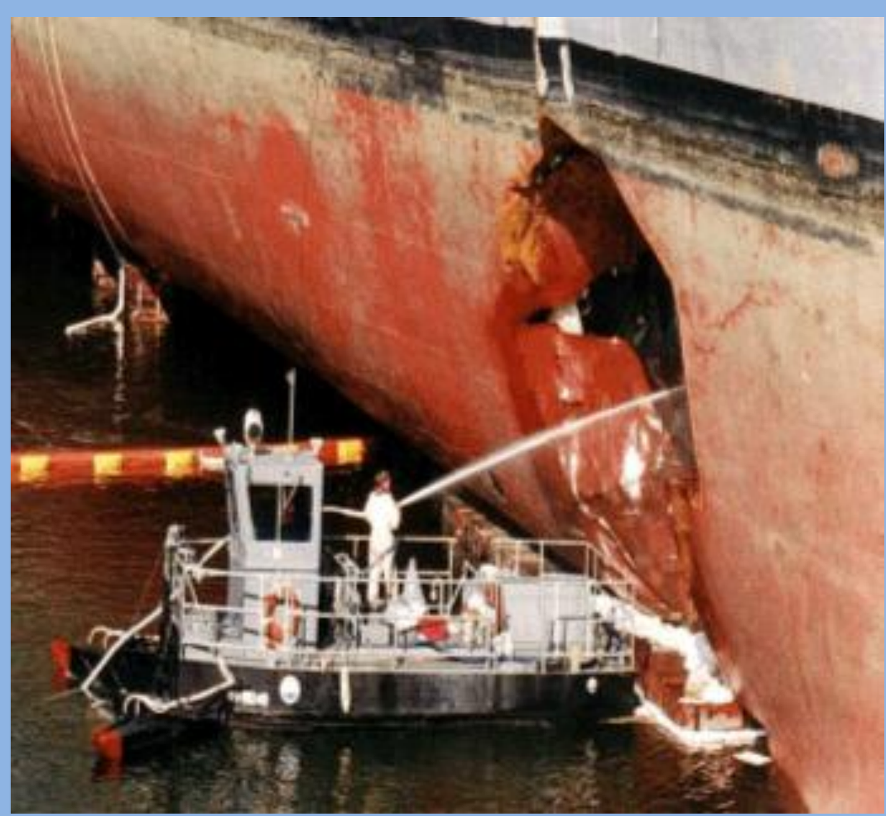


Figure 1: Damage to Ship Hull

Aims and Objectives

The aim of the project is to develop an improved method for damaged ship assessment. This aim will be completed through a number of objectives:

- Determine the applicability of the framework
- Investigate the use of FEA within the framework
- Investigate the use of CFD within the framework
- Validate the modelling of these tools
- Investigate the use of faster tools against experiments or more computationally expensive techniques
- Model damage situation

Methodology

The research has been split into two major themes, hydrodynamics and structural response , each constituting different quantities that must be modelled as shown in Fig. 2. These different quantities will be modelled using CFD and FEA and mapped using Response Surface Methods for speed during emergency response. Stochastic methods are also incorporated to replicate the inherent variability seen within a damage scenario.

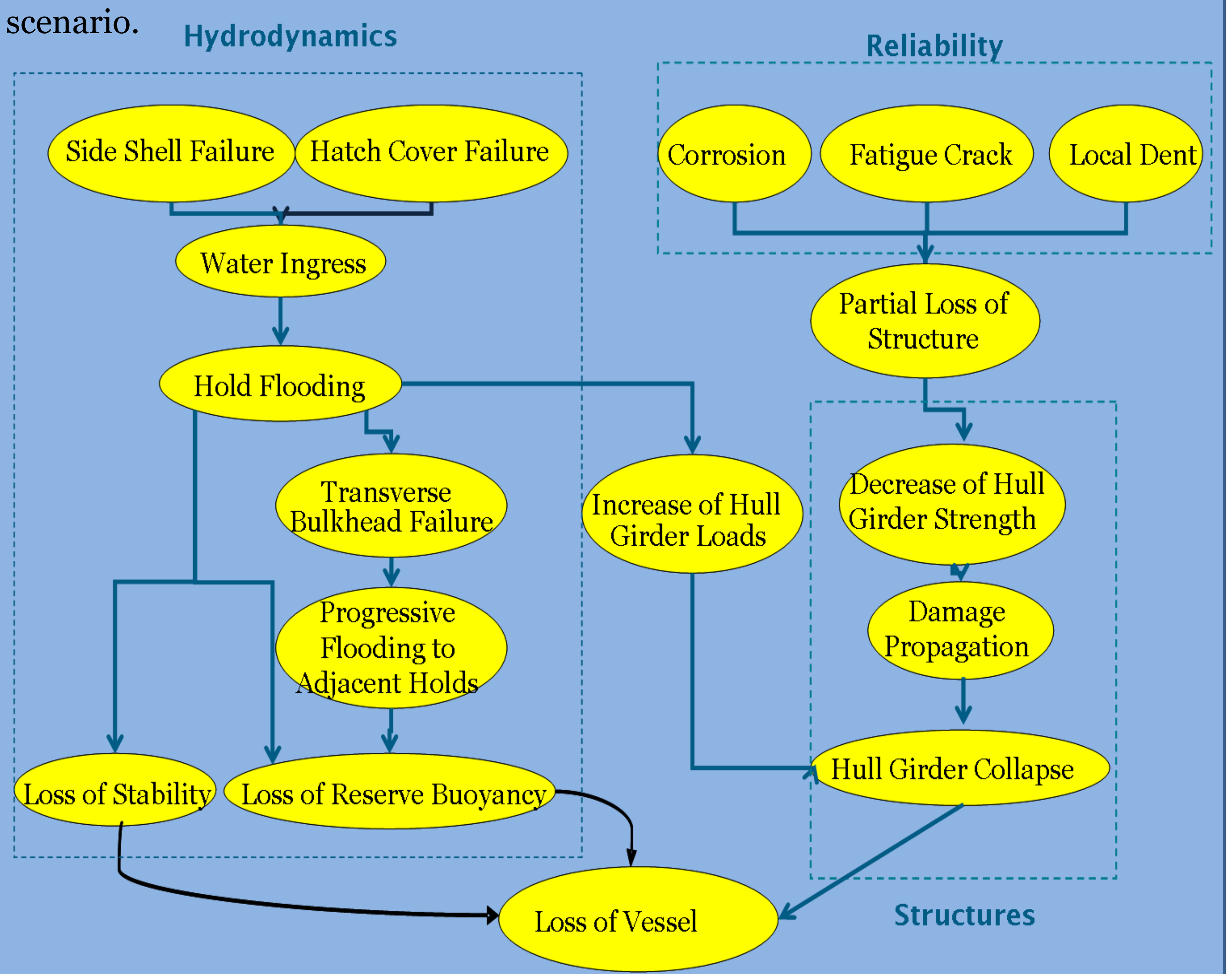
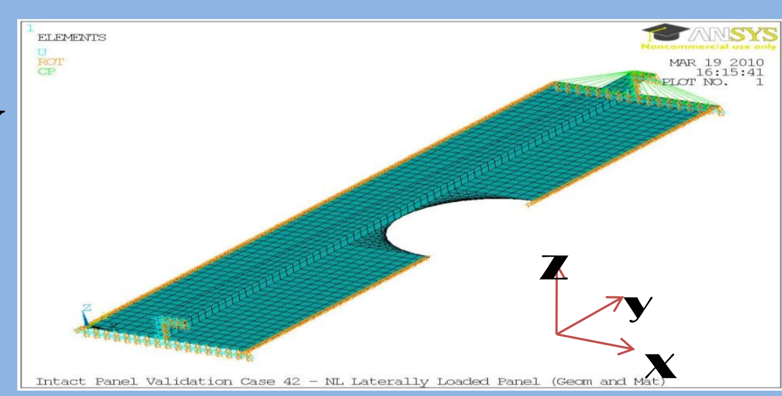


Figure 2: Loss of vessel scenarios based on (Paik & Thayamballi, 1998)

Response Surface Methodology

Response surface methods are becoming an increasingly popular method to allow the use of computationally expensive modelling techniques within computationally expensive analysis techniques to reduce the cost. One of these methods, 'kriging', was first used by geologists to estimate mineral concentrations but is know used in a wide variety of different applications including aerodynamics, structures, and multiobjective problems (Toal et al., 2008).

Sides Constrained in ROTY



Coupled Displacement, constrained in UZ,ROTZ

Constrained in UY,UZ, ROTZ

Fig. 3 FEA model of a damaged plate

A response surface was created to map a model created in Ansys, fig. 3, this was done using a number of different sample points with resulting errors shown in Table 1.

Number of Samples	Error
13	15%
25	8%
50	1%

Table 1 Response Surface Accuracy

Reliability Analysis

The response surface that was created could then be used as part of the structural model for the reliability analysis. This analysis was performed using a Monte Carlo simulation with variables contained in fig. 4. The Monte Carlo method performs a large number of simulations to determine a probability , in this case failure of a panel. This is done by carrying out an analysis on a number of different panels with inputs generated by distributions which match incidences in real life. The failure is determined and the number of times failure occurs over the number of runs is the probability of failure.

Property	Mean	CoV	Distribution
Damage Size	267.7mm	0.5	Normal
Damage Position	170mm	0.5	Normal
Plate Thickness	6mm	0.011	Normal
Axial Load	340152N	0.25	Weibull
Lateral Load	0.035MPa	0.1	Largest Extreme Type I
Young's Modulus	2×10^5	0.02	Normal
Yield Stress	250 N/mm²	0.07	Normal

Fig. 4 Variables for damage ship scenario

Runs	Probability of Failure
10^1	0
10^2	0.020
10^3	0.021
10^4	0.0142
10^5	0.0121
10^6	0.0117
10^7	0.0118

Fig. 5 Convergence of Monte Carlo simulation

The Monte Carlo simulation was run for a number of different run times. Convergence could then be determined as shown in fig. 5. This shows a convergence at 0.012. This indicated that the structure had a high probability of failure as expected for a damaged plate. The analysis, including generation of the points for the response surface method, could be performed within a 24 hr period. This shows that the methodology remains feasible for generation of a tool for damaged ship response during emergency scenarios.

Conclusions

The results show that a response surface of local analysis of a damaged plate can be created with a reasonable cost and a high level of accuracy. This model can then be incorporated with reliability methods to ensure that the stochastic nature of the damage situation can be incorporated within damage modelling.