NTNU
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ASSESSMENT OF HULL RESPONSE DUE TO IMPACT FROM FALLING OBJECT

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Introduction

Dropped objects or falling loads can be broadly defined as any object dropped from a crane or other lifting equipment, man over board accidents, crane fall and accidental drop of lifeboat. The reported annual frequency of occurrence for dropped objects per vessel or installation in the period 1997 - 2007 was 1.127 for the UK continental shelf (UKCS) alone (Oil & Gas UK, HSE, 2009). This can lead to fatal consequences for human lives and the vessel. Dropped objects on deck, and modelling of the structural response is the main topic in this thesis.

Applicable DNV GL rules and standards for design against accidental limit state (ALS) loads are of interest, mainly methods for dimensioning structural members to resist impact loads.

Crushing resistance of an example deck structure (provided by Wärtsilä Ship Design) is going to assessed using numerical and analytical methods. Material modelling is a challenge, especially concerning the simulation of fracture. Methods for this will be studied and presented.

An LNG fuel tank is placed beneath the deck, and must not be damaged. Improving structural resistance is of interest, and the effect of changing material parameters is in focus.

Background

The resistance of a structure can be quantified by the dissipation of elastic and plastic strain energy. The dissipation of strain energy can be represented by a load (R)-deformation (w) curve (as shown in Figure 1) for both the object and the impacted structure, where the areas under the curves are the dissipated strain energies.

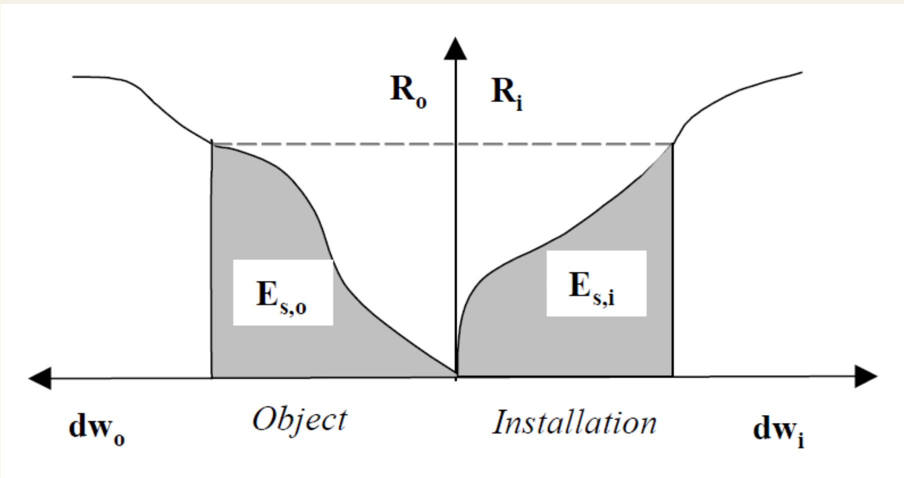

Figure 1: force indentation curves for impacting object and impacted installation (DNV, 2010)

The total dissipated energy can be described analytically by the following equation.

$$E_S = E_{S,I} + E_{S,O} = \int_0^{w_{I,max}} R_I \, dw_I + \int_0^{w_{O,max}} R_O \, dw_O \qquad (1)$$

Most metal alloys fail by ductile fracture when the plastic deformations are too high. The fracture is initiated by microscopic voids that increase in size and then unite and develop a crack. The process from nucleation to fracture is shown in Figure 2.

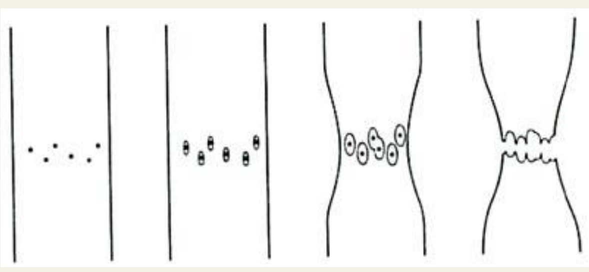

Figure 2: Void nucleation, growth and fracture (Weck, n.d.)

Ductile fracture depends on different factors such as; stress triaxiality, plastic strain, geometry and size, strain rate. Typically a fracture criteria can be defined by a damage variable *D*, where fracture occurs when *D = 1*. This is exemplified by the Cockcroft – Latham fracture criterion.

$$D = \int \frac{\sigma_1}{\sigma_{eq}} \, d\varepsilon_{eq} \qquad (2)$$

, where σ_1 is the maximum principal stress, σ_{eq} is the equivalent von Mises stress and ε_{eq} is the equivalent strain (Törnqvist, 2003).

An empirical model is used in this thesis, where the fracture criterion is based on a critical strain at failure which depends on the characteristic element length used in the finite element analysis.

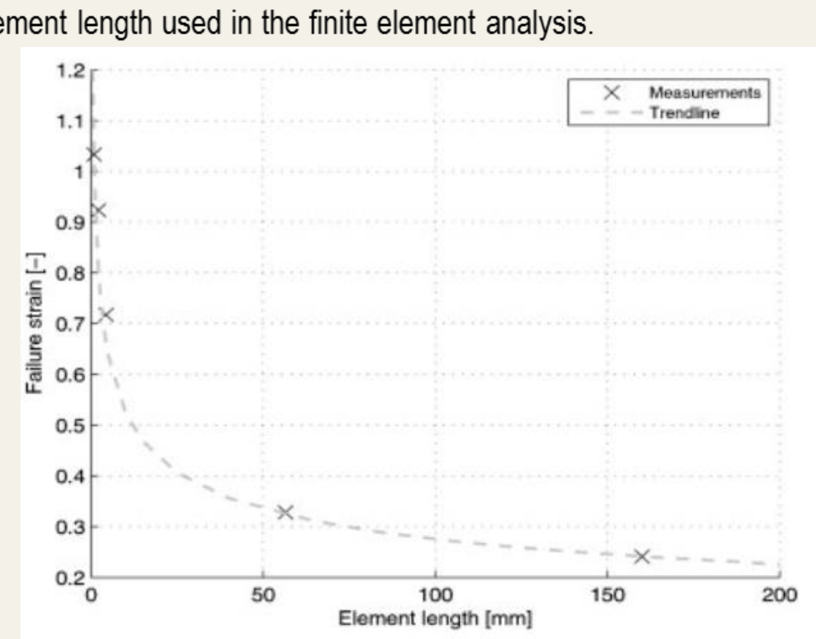

Figure 3: Failure strain vs. element length, NVA steel (Ehlers, 2010)

Numerical Method

Two deck models and container were modelled using Sesam GeniE. The FEM software Abaqus/CAE (Dassault Systémes, 2014) is used for parameter definition. Abaqus/Explicit is used to solve the nonlinear impact problem, where the time integration method used is the explicit central difference method.The model is set up as shown below.

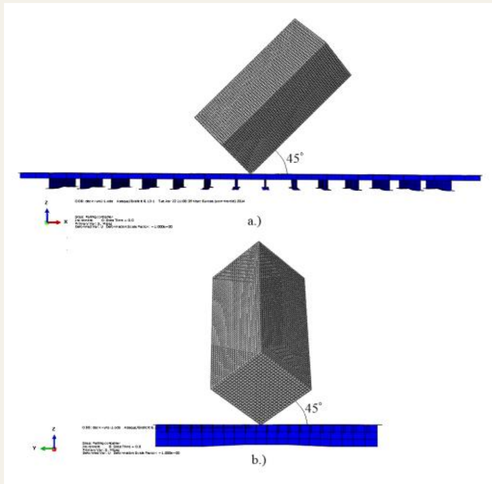

Figure 4: Model configuration

Analytical Method

Analytical methods to analyse the crushing resistance of structural members and quantifying the dissipated energy from impact are also discussed. These types of methods has proven to show accurate results when compared to experiments and numerical results obtained by using NLFEM programs. They are commonly referred to as "energy methods", "plastic methods" or "kinematic methods" and are based on the upper bound theorem. The models vary due to the proposed deformation patterns or folding patterns of the structural members. Simonsen & Ocakli (1999) proposed a model for analysing crushing resistance of web girders, where the folding pattern is shown in Figure 5.

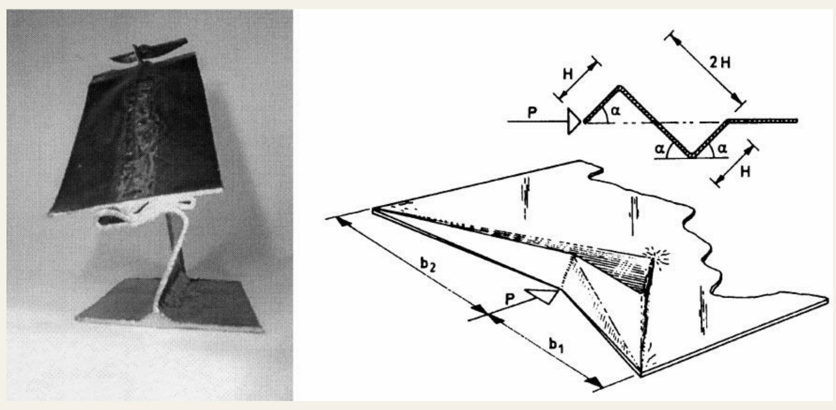

Figure 5: Crushing pattern of web girder propsed by Simonsen & Ocakli (1999)

The instantaneous resistance force is then expressed as,

$$\frac{P(\delta)}{M_0} = \frac{3b}{H\sqrt{1-\left(1-\frac{\delta}{4H}\right)^2}} + \frac{22H}{bt}\delta \qquad (3)$$

Where M_0 is the plastic bending moment capacity, $2b$ is the girder span, δ is the in-plane crushing distance and t is the thickness of the girder.

Results 1: Convergence Test

Name	Characteristic element length [mm]	Fracture strain [-]
Run 1	300	0.21
Run 2	200	0.215
Run 3	100	0.27
Run 4	75	0.30
Run 5	50	0.34
Run 6	32.5	0.4

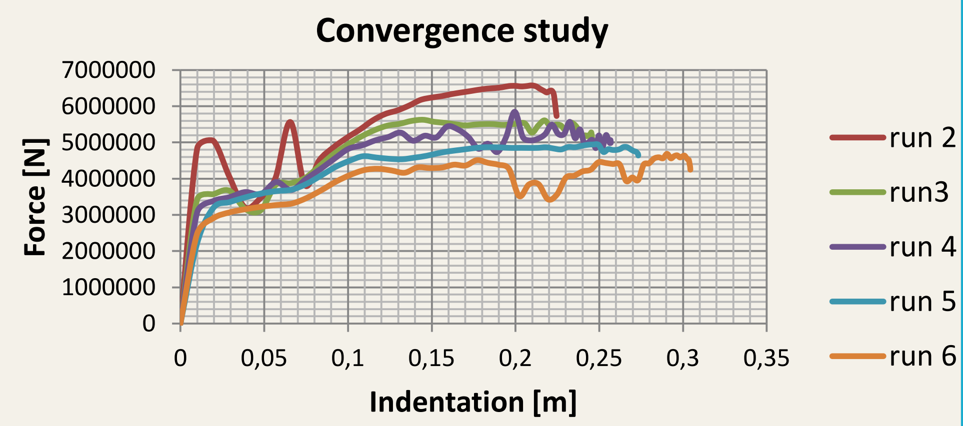

Figure 6: Convergence test results

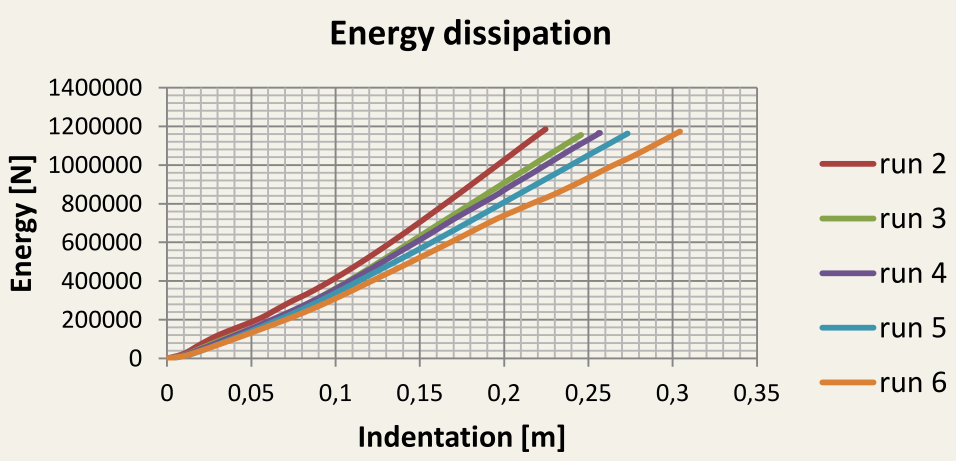

Figure 7: Convergence test results

Results 2: Damage of deck

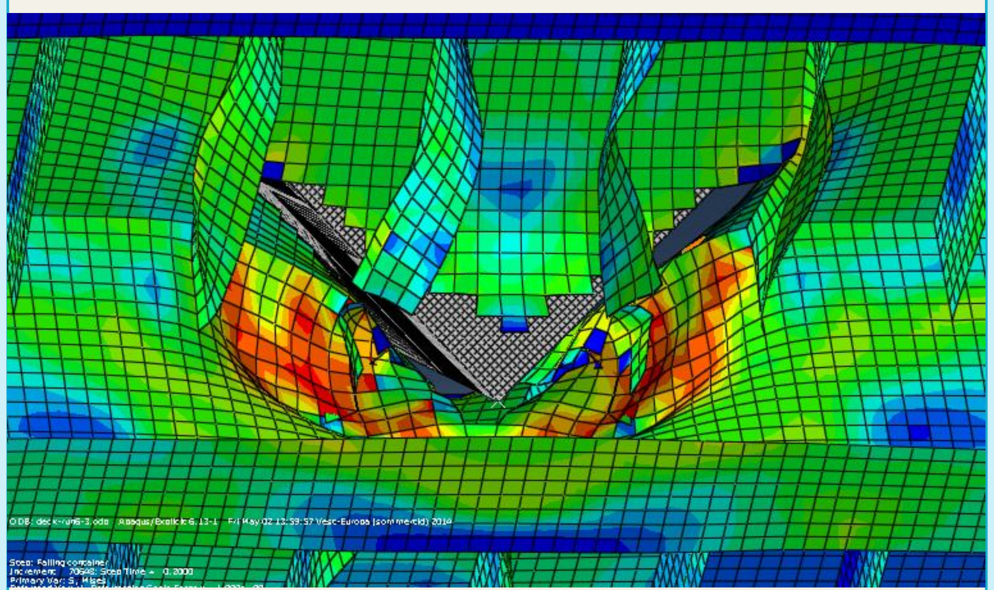

Figure 8: Model configuration

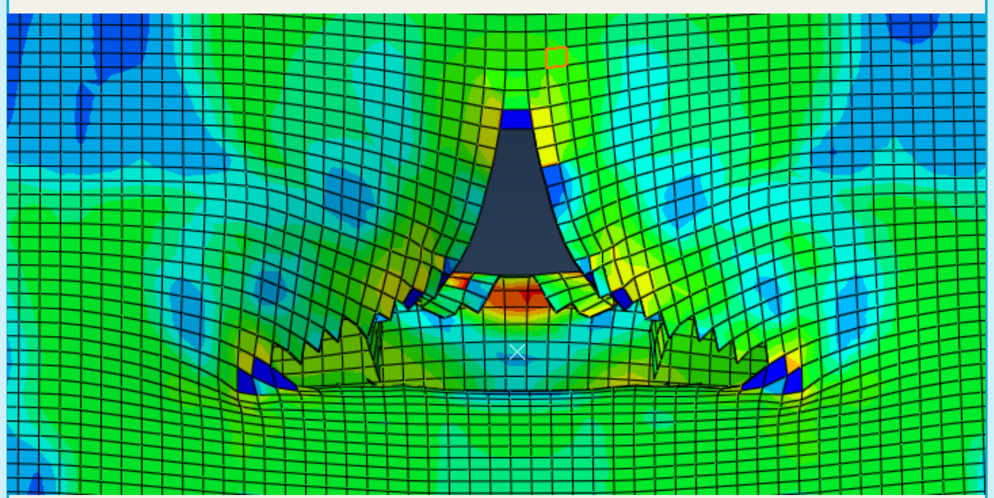

Figure 9: Model configuration

Discussion

Convergence has not yet been satisfyingly achieved. This may be because of faulty material representation. The difference in results for the different mesh sizes are due to the extent of fracture. A closer study into this should be done to find the sources of error. The energy quantification results from Abaqus do however show that the amount of kinetic energy is almost fully absorbed by the deck (when the container is modelled as rigid), and that no significant erroneous energy dissipations occur.

Conclusion

All the needed results have not yet been obtained to gather a conclusion. If intrigued by this topic, it is possible to read the master's thesis when it's finished.

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