Ship Collision With Floating Offshore Wind Turbine

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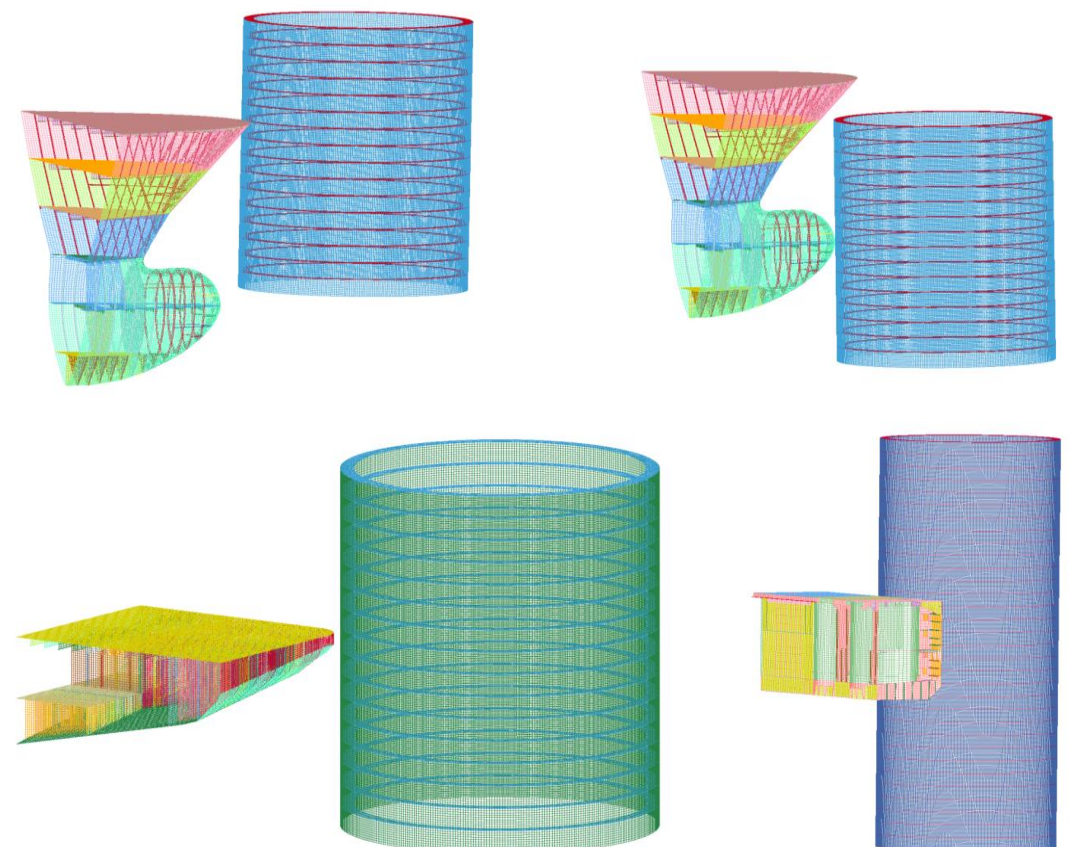Supervisor: Professor Jørgen Amdahl, Associate Professor Zhaolong Yu

Problem

Assessment of the structural resistance of offshore wind turbines has typically been placed on accidental events such as impacts from larger drifting vessels. Recently, focus has also been put on more frequent incidents during what is considered normal operations, which has to be considered in the ULS (Ultimate Limit State) instead of in the ALS (Accidental Limit State). ULS checks usually assume elastic behavior, which is difficult to achieve with ship collisions as small damages in the form of dents are likely. Therefore, it is important to know if these damages are critical, or if the damaged structures can comply with the ULS criteria otherwise.

Introduction

In the fight against climate change, several organizations are working on ways to reduce greenhouse gases and find new renewable energy sources. At the Glasgow Climate Conference over 200 countries signed a pact to keep the goal of limiting the global temperatures from rising more than 1.5 degrees Celsius alive [1]. This requires actions across sectors, including increasing the renewable energy share to 32% [2]. The European Commission believes that offshore wind represents a significant opportunity[3], and, according to the International Energy Agency, the offshore wind market had a growth of almost 30% per year between 2010 and 2018, due to rapidly maturing technology [4]. Currently, floating wind farm concepts are receiving a lot of attention [5]. Floating wind farms are less sensitive to water depth and seabed conditions, compared to bottom-fixed structures. This allows for the installation of several turbines without the same constraints regarding space and planning, with the sites having a higher wind energy potential [6]. The service and supply vessels operating on and around the turbines may accidentally collide with the turbines. In addition, wind farms may be located close to areas with high ship traffic density, which means that there is also a possibility of collision between larger merchant vessels and turbines [7]. To date, research regarding collisions between ships and wind farms is mainly limited to impacts between vessels and bottom-fixed structures. This is because bottom-fixed wind farms have been operational for years, while currently there are few commercial FOWTs. To capture more clean energy, the number of FOWTs is going to increase, and therefore investigating impacts between vessels and floating structures is relevant [5].

Simulation Models

The collision analyses are made up of several models. There is one model for the tower section and models representing the bow, side, and stern corner of the vessel colliding with the tower section. with the column section which are all described in this section. The tower section diameter is 12 meters, with a thickness of 25 mm and stiffener spacing of 1 m. The vessel models are based on a typical modern supply vessel with a displacement of 7500 tons. The collision is simulated using the nonlinear finite element software LS-DYNA. The tower section has a constant speed of 5 m/s
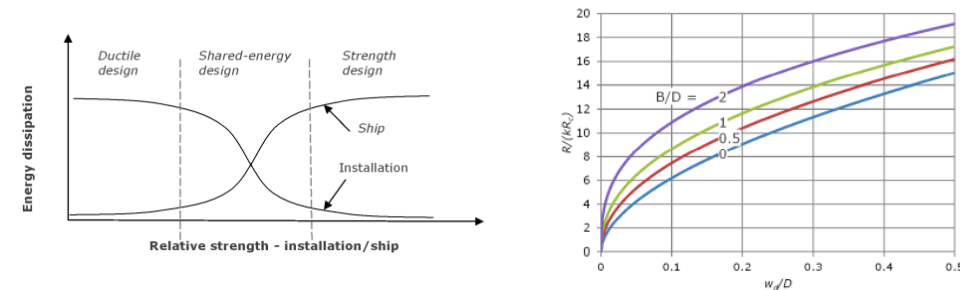
Theory

The collision energy to be dissipated as strain energy by the structures may be taken as

$$E_s = \frac{1}{2}(m_s + a_s)v_s^2 \frac{\left(1 + \frac{v_i}{v_s}\right)^2}{1 + \frac{m_s + a_s}{m_i + a_i}}$$

Where m, a, and v are the mass, added mass, and velocity respectively, and the subscripts i and s represent the installation and ship respectively. The design principles regarding the distribution of strain energy can be distinguished between

- Strength design
- Ductility design
- Shared-energy design

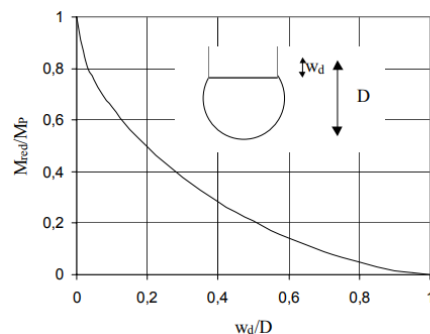Which describes the amount of energy dissipated by each structure [7].

The resistance to indentation of an unstiffened tubular member may be taken from the figure above. Where w_d is the indentation, B is the width of the contact area and D is the diameter of the tubular member. The resistance is based on plastic analysis and developed on non-dimensional form [7].

Conventional buckling theory is generally only valid for idealized structures. However, two main effects may have a damaging effect on the real buckling load of the cylinder
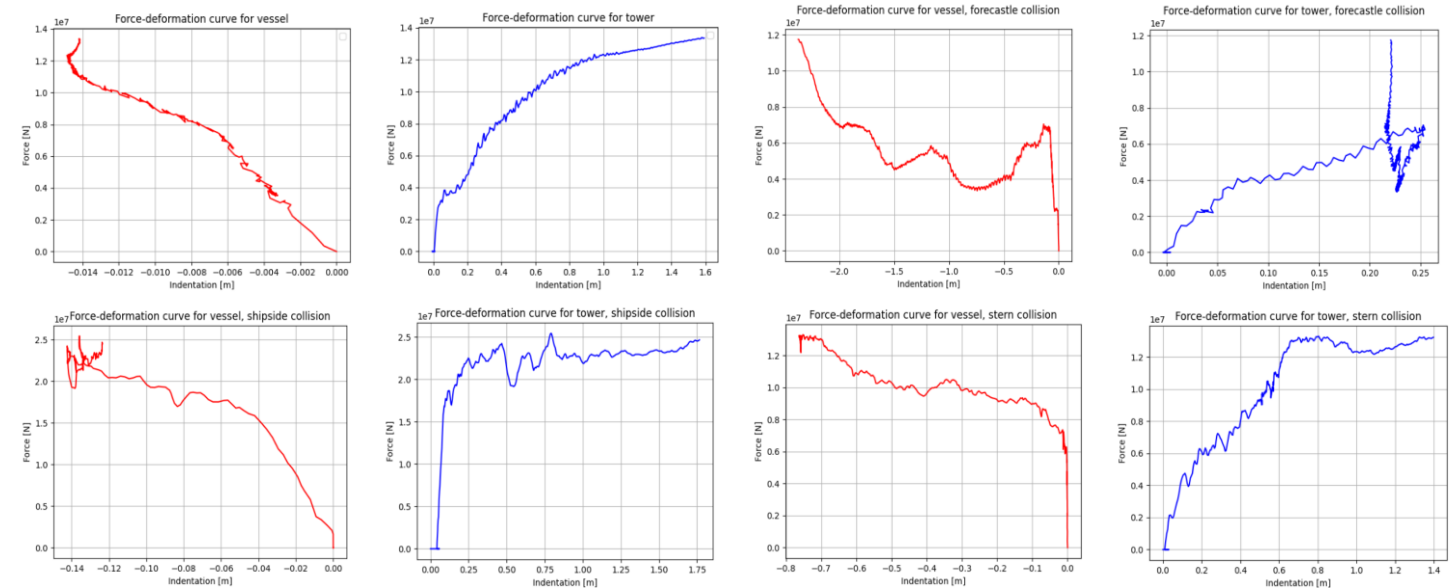
- Material imperfections
- Shape imperfections

The reduction of moment capacity due to indentations can be seen in the figure below [7].
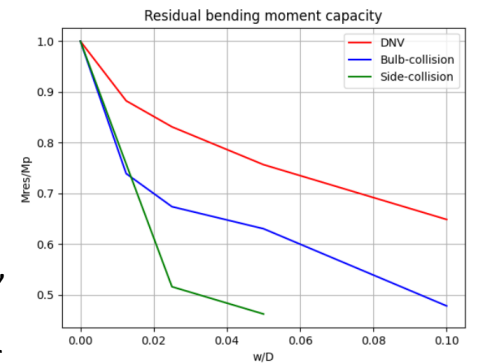

Results

The results show that the collision between the bulb of the vessel and the tower, and the side of the vessel and the tower create only small deformations in the vessel, meaning that the tower dissipates the majority of the collision energy. As for the other two collision, with the forecastle and the stern corner, the dissipation is shared between the two structures.

As for the residual bending moment capacity, the figure to the right shows that the current analytical model proposed by DNV underestimates the effect of indentations compared to the results from this analysis. One of the reasons for this is that the moment capacity of the undamaged tower section is significantly larger than what is expected from the DNV model, meaning that even though the capacity reduction is larger, the residual strength of the tower may in some cases still be larger than what is expected from the proposed models.

Conclusion

Proposed models for assessment of denting resistance in tubular members investigated in this thesis seem to be conservative and underestimate the resistance. This may be due to the significant changes that have happened to the towers and vessel since they were developed. Regarding residual strength, proposed models underestimate the effect of indentation on the capacity of the tower.

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