Assessment of a floating bridge's ability to withstand a ship collision

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Objective

The objective of the thesis is to study the consequences of a ship colliding into a floating bridge. To do this a global model should be established in ABAQUS. The model is used for an analysis of energy levels that develop during the impact, a mesh refinement study and to look at the importance of the heading angle of the ship.

Introduction

A floating bridge rests on pontoons in the water, and are used for water stretches that are so wide or deep that a regular bridge or tunnel won't be able to cross the stretch. The western coast of Norway has many deep and wide fjords that has to be crossed by ferry. The Norwegian Public Roads Administration has an ongoing project called "Ferry free E39" where the ferry connections along E39 is going to be replaced by fixed road connections [2]. One of the risks with a floating bridge is that it is exposed to ship impacts. It is therefore of vital importance that a collision don't penetrate one of the pontoons and cause flooding and buoyancy loss.

Modeling

Ship collisions is mainly dependent on the kinetic energy in the impact, where the kinetic energy mainly is governed by the mass of the ship, including its hydrodynamic added mass and the vessel speed, and is given by [1]:

$$E = \frac{1}{2}(m+a)v^2 \tag{1}$$

A floating bridge can be considered a compliant installation, and the collision energy that has to dissipated as strain energy is given on the form:

$$E_S = \frac{1}{2}(m_s+a_s)v_s^2 \frac{(1-\frac{v_i}{v_s})^2}{1+\frac{m_s+a_s}{m_i+a_i}} \tag{2}$$

where m_s is the ship mass, a_s is the added mass of the ship, v_s is the impact speed, m_i is the mass of the installation, a_i is the added mass of the installation and V_i is the velocity of the installation.

References

[1] Det Norske Veritas: *Design against accidental loads. Recommended Practice DNV-RP-C204*, (2010)

[2] Statens Vegvesen: *Ferjefri E39*, `http://www.vegvesen.no/vegprosjekter/ferjefriE39`, (Accessed 12.12.15)

Acknowledgements

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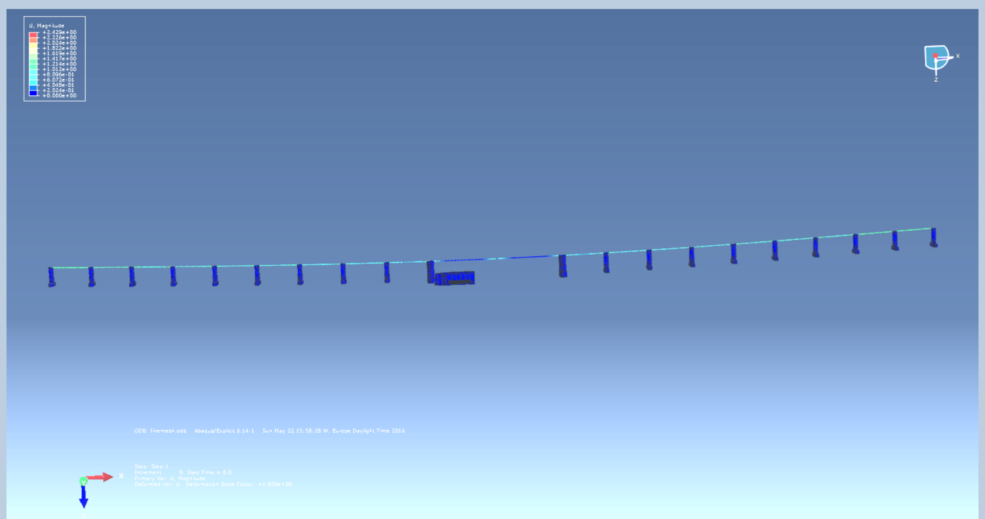
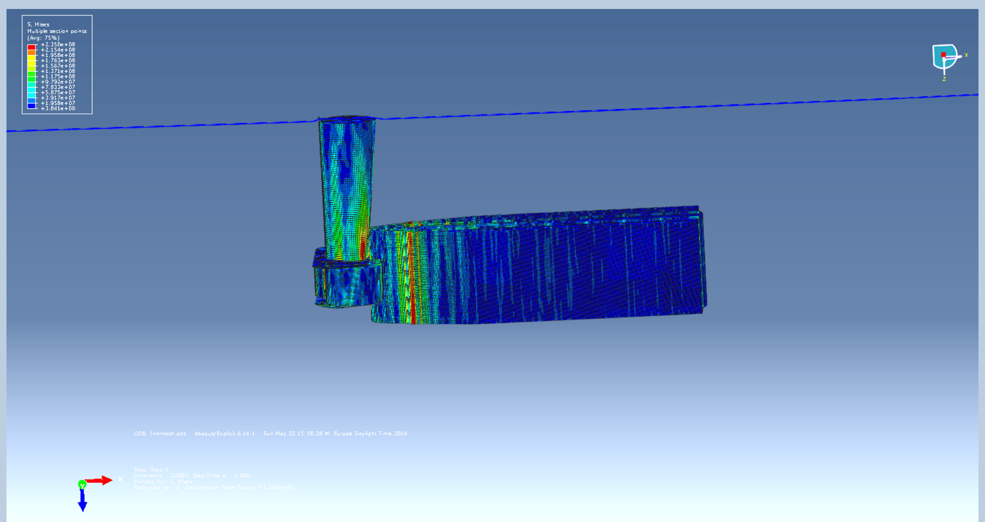
Simulations

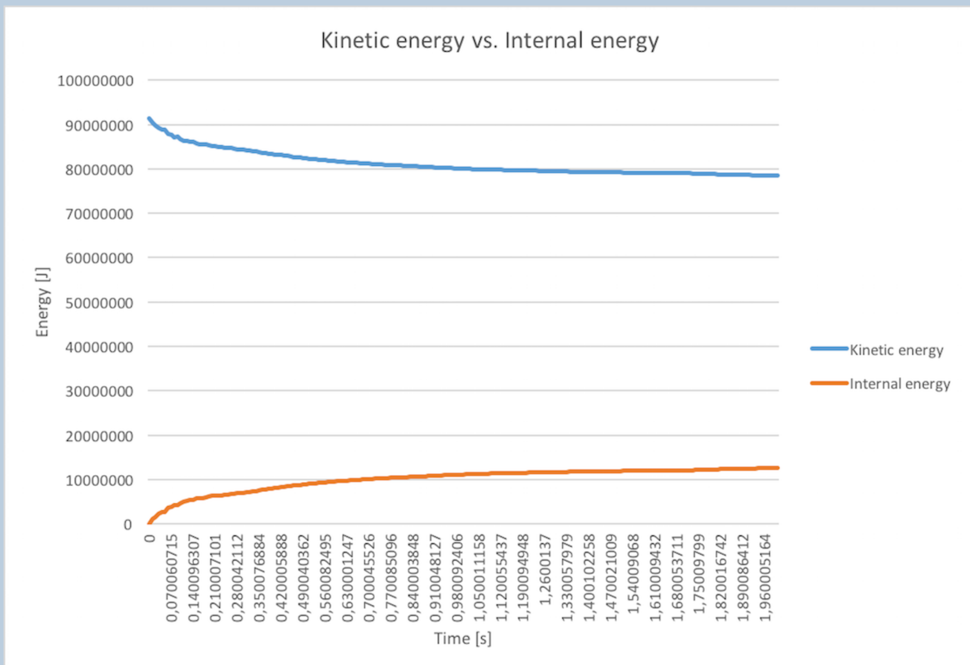
A global model of the bridge has been modeled in the Finite Element Method program, ABAQUS. Since the likeliness of a ship hitting the road is small, this has been modeled as a wire connecting the pontoons. Because of ship traffic in the Norwegian fjords, an opening for the vessels to pass through has been made in the middle of the bridge. As it is the pontoons near the opening that is in the highest risk of experiencing an impact, these have a larger dimension than the rest of the pontoons. The analysis is done by giving added mass to the vessel and the bridge, as well as a velocity to the ship. The velocity of the bridge will be so small in the short impact time, that it is negligible. Further, it can be assumed that plastic deformation will occur, so the materials is modeled to be perfectly plastic. The analysis is then ran with an dynamic explicit time step, which defines the integration method over time. A mesh refinement study has also been conducted, as well as a change in the heading angle for the vessel.

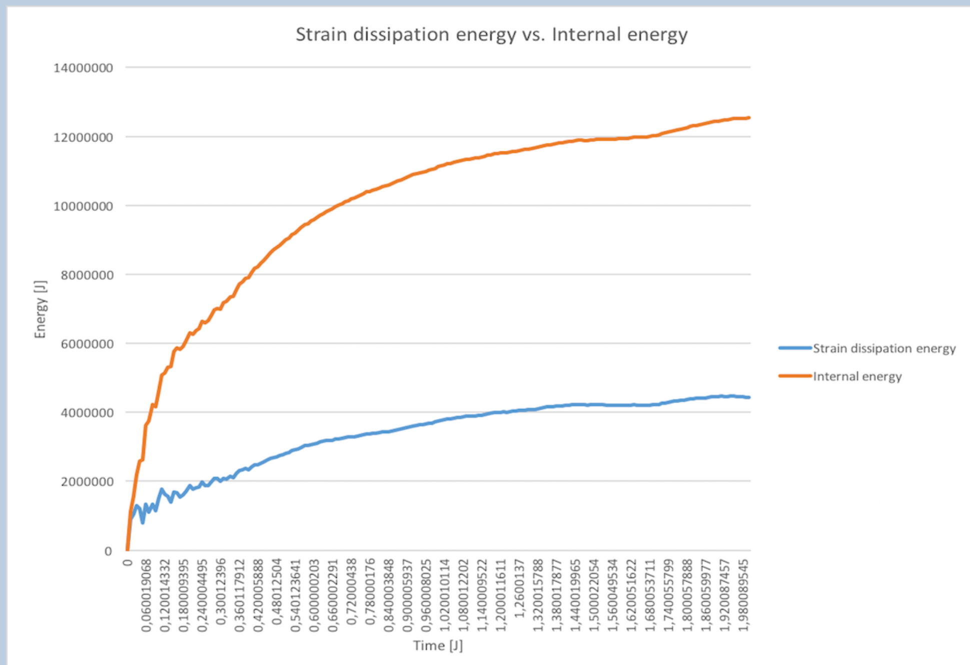




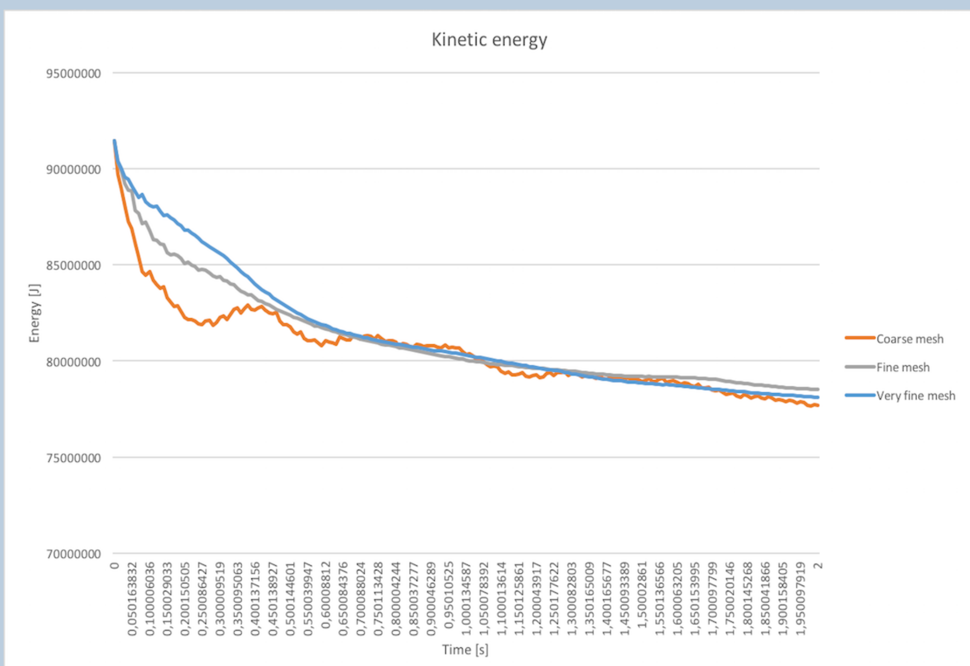
Results

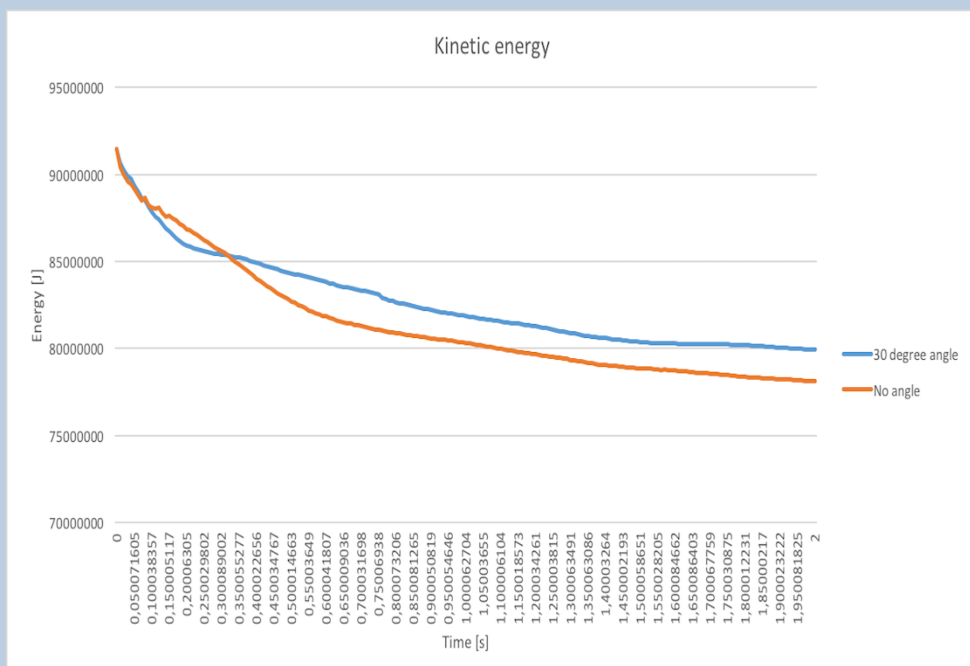
The most important components are of the energy, and how these are distributed among each other during the impact, together with the stresses and displacements that occur. The energy values are exported from ABAQUS to Excel for comparison. By plotting several energies together, some patterns in energy distribution can be seen. Kinetic and internal energies to the left, and internal and strain energy to the right.





From the mesh refinement study, the results in kinetic energy for the different mesh sizes has been plotted together in the graph shown below to the left. On the left is a plot that shows the difference in heading angle for the development of kinetic energy.





Conclusion

From the results, it can be seen that the kinetic energy will decrease, and the internal energy increases with the same amount over time, this means that the kinetic energy from the ship will be absorbed as internal energy in the pontoon and cylinder of the bridge. Since the kinetic energy has to be absorbed as strain energy during deformation, it can be seen that the shape of the strain energy curve is equal to that of the internal energy, but with a smaller value. Further, it can be seen that mesh refinement gives results that become more and more equal with a smaller mesh size. At last it is shown that a different heading angle leads to a lower absorption level of kinetic energy in the pontoon, and will remain as kinetic energy.