MASTER THESIS SPRING'2014 IN MARINE TECHNOLOGY

ANALYTICAL & NUMERICAL ANALYSIS of SHIP/FPSO SIDE STRUCTURES SUBJECTED to EXTREME LOADING WITH EMPHASIS OF ICE ACTIONS

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SCOPES

Transport and exploitation of resources are increasing in the Northern areas. Main challenge for trading is to face ice pressure. IACS including other classification societies are working on to make structural requirements to meet this challenge. This thesis is done focusing on following:

- Review of IACS requirements focusing on comparing the different class w.r.t. strength based on crucial parameter.
- NLFEM analysis of a single frame subjected to Ice loading and compared to IACS requirements.
- Comparing results with simplified capacity model.
- NLFEM for a larger part of side structure of a FPSO.
- Introducing secondary stiffening to the extent of local buckling.

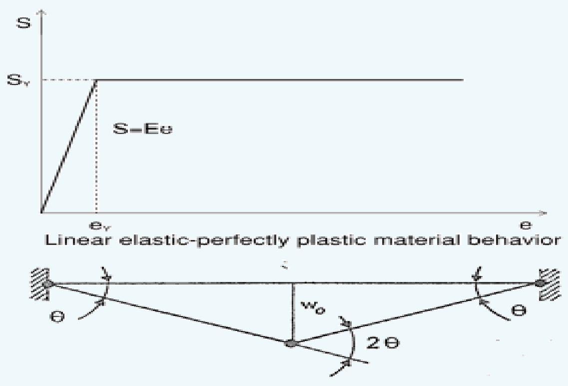
CONTRIBUTIONS

Understanding the backgrounds of IACS requirements were one of the major issue and next how those rules are applied to the structure. The FPSO named 'White Rose Field Husky Oil FPSO' has been assessed based on NLFEM analysis through the thesis.. The following are the main contribution to the existing work:

- Simplified understandings of IACS requirements.
- Assessment of IACS requirements based on FEM analysis.
- Modifying Collapse mechanism for complex structure
- Verifying capacity requirements for a FPSO.
- Introducing a conflict between IACS requirements and DNV requirements.

METHOD & TOOL

In IACS simplified shear plastic collapse mechanisms has been used based on work-energy principle[1]. as design criteria. Method is simplified as it is assumed that mechanism contains shear-bending moment and no effects of membrane and strain hardening effects. During modified collapse mechanism pure bending moment assumed as no shear hinge and no shear-moment interaction.

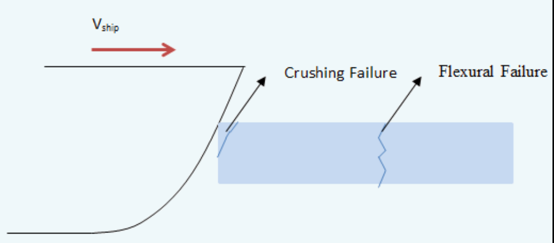


Abaqus, a FEM based engineering simulation program, is used through the analysis as it can solve ranging from simple linear analysis to challenging nonlinear simulations .

REVIEW OF IACS RULES

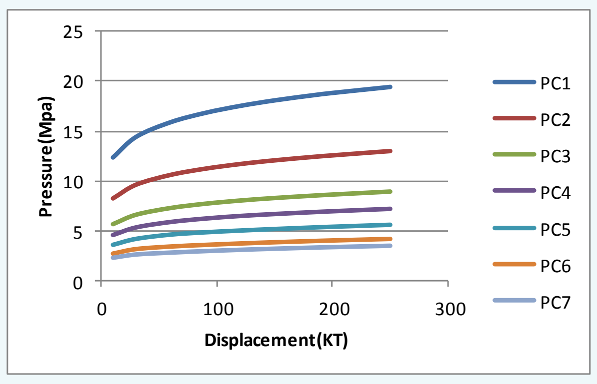
IACS unified rules all are classified into 7 polar class, PC1-PC7 based on strength required for various operational window which indicates different ice condition through a year. In IACS following the ice pressure variance total ship area is divided into many area as shown in above figure. This thesis is done only for the mid-body ice belt area.

Design load is established based on a scenario and it is a glancing collision with an ice edge. Ice force has a relation with nominal contact area between ship and ice and this area then simplified from triangular to an equivalent rectangular **Design Load Patch** with a height of *b* and of width *w.* Ice load is derived by Daley assuming a 'Propov' type of collision and established the load as, $F_n = fa \cdot Po^{.36} \cdot \Delta_{ship}^{.64} \cdot V_{ship}^{1.28}$



Ice load variation is much dependent on ship size because the other parameters on above equation are class dependent.

Pressure varies much as displacement increase for higher polar class and trend of thickness requirement variation are quite same as pressure varies.



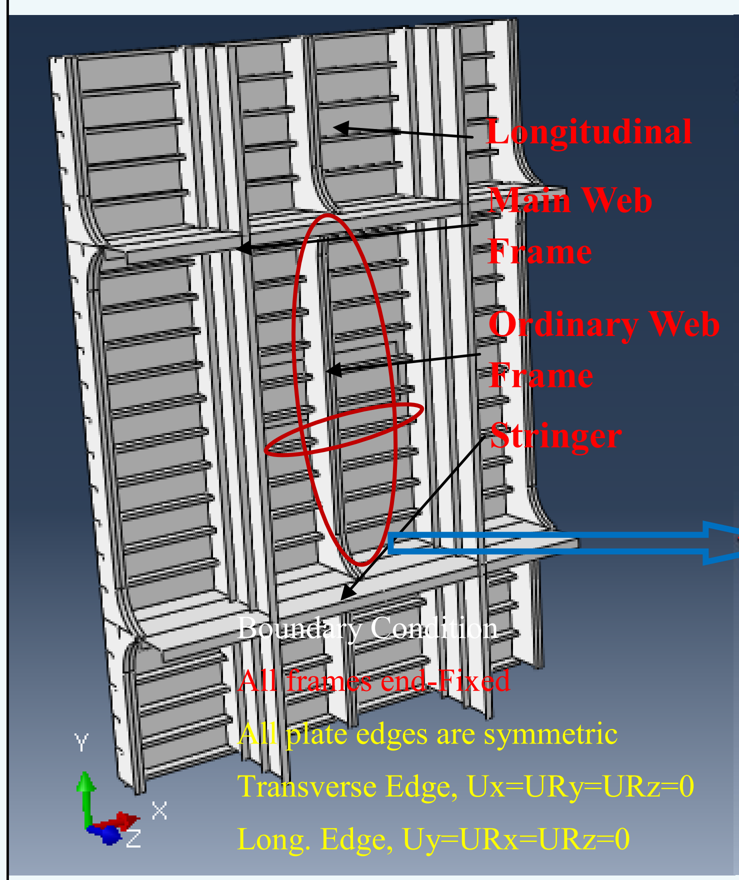
3-hinge capacity for center load patch as IACS considering shear-moment interaction:

$$P_{3h} = \frac{(2-k_w) + k_w\sqrt{1-48Z_{pns}(1-k_w)}}{12Z_{pns}k_w^2+1}\frac{Z_p\sigma_y 4}{[SbL(1-b/2L)]},$$

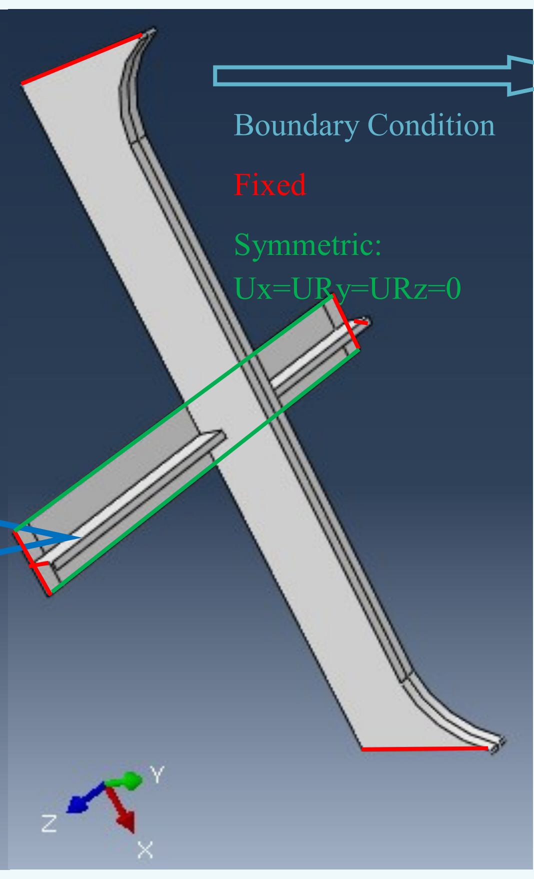
If pure bending is considered instead of shear-moment interaction reduced moment the capacity is simplified as

$$P = \frac{8M_P}{L.b.s.\left(1-\frac{b}{2L}\right)}$$

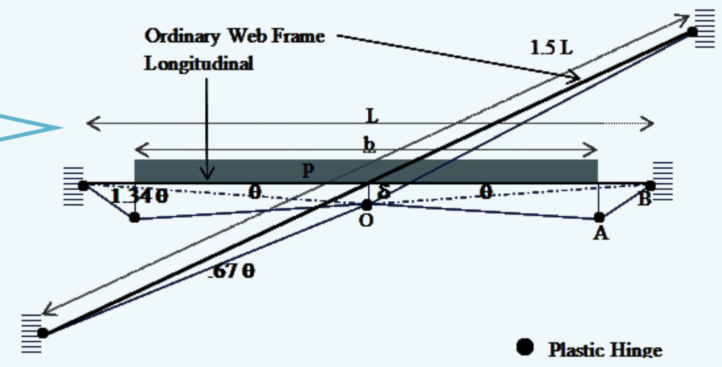
MODELS & RESULTS



Whole Model



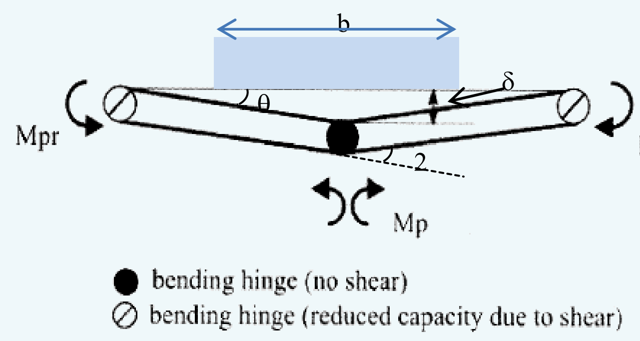
Single Longitudinal Model



Pure Bending Collapse Mechanism Model

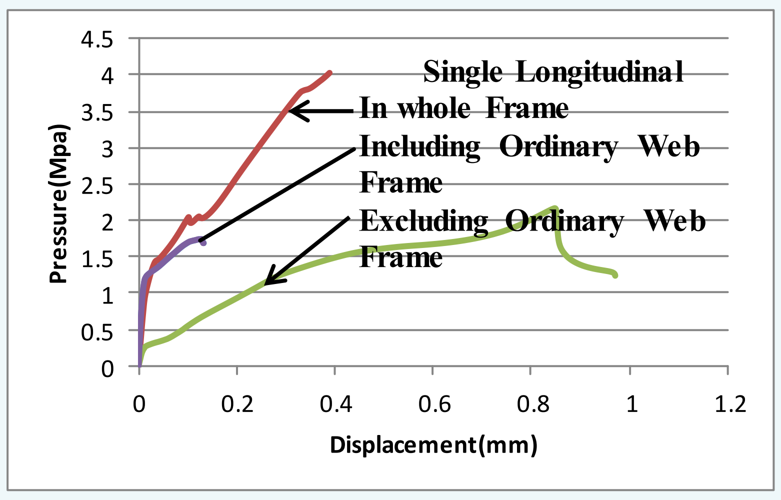
Capacity equation of above model

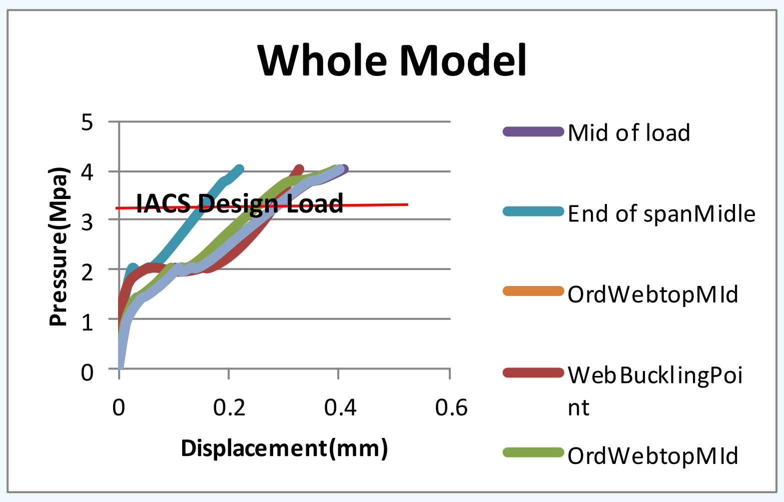
$$P = \frac{2(7.36M_L + 2.68M_W)}{s.\left(bL + \frac{b^2}{2} + \frac{(L-b)^2}{2(b-2L)}\right)}$$



Daley's 3-hinge Collapse Mechanism Model

Capacity of the longitudinal frame, excluding the ordinary frame and calculated as Daley's formula where reduced bending moment has been considered due to shear-bending interaction, is calculated as **0.29 MPa.** If instead of taking reduced plastic moment M_{pr} , pure bending moment is considered for Daley's model, the capacity will be **0.31 MPa** as expected higher value than previous one. Then considering the existence of Ordinary Web Frame and using the simplified model capacity equation given above, the capacity is **2.1 MPa**.





Abaqus analysis shows so close result for single longitudinal frame excluding ordinary web frame. When the web frame is introduced the capacity is approximately **1.6 MPa** which is less than found from simplified collapse mechanism model(2.1 MPa). This happens cause in simplified model it was assumed as pure bending at longitudinal and web end but the moment should be reduced due to shear effect. In whole model the capacity is much higher than both that means this single model is not presenting the actual model. In whole model ordinary web consists of more longitudinal supports rather than one longitudinal as well as plating support. From the whole model analysis, we get local buckling at main web frame though it satisfy the IACS criteria of avoiding local buckling. Also the capacity is checked at many positions in **whole structure and the capacity is not more than 2 MPa which is less than IACS PC 7 ice load 3.3 MPa. In addition, shear area of longitudinal has found half of IACS requirements. That means whether IACS ice load is over estimated or the FPSO is not comply to trade in ice condition.**

REFERENCES

1. IACS. Requirements concerning POLAR CLASS. 2011
2. **Daley, C.G.** Derivation of plastic framing requirements for polar ships
3. **Daley, C.** Backgrounds Notes to Design Ice Loads

FURTHER WORK

As this FPSO is DNV class, so it is necessary to check as it complies with DNV estimated ice load and making comparison with IACS. The bow area is yet to be analyzed. Web capacity after applying secondary stiffening will be done further. It will also be interesting to simulate for whole ship. Ice load characteristics is complex to identify. So more work on ice load estimation could improve the ice load measurement.