Sacheendra Naik

6th EMship cycle: October 2015 – February 2017

Master Thesis

Fatigue strength Comparative study of knuckle joints in LNG carrier by different approaches of classification society's rules

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Szczecin, February 2017

WESTCON GROUP

- Office in SZCZECIN
- Ship build and repair
- Supervisor :Alfred Jazukiewicz

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1. INTRODUCTION

- shipping in sea routes of North Sea, North Atlantic is much more challenging.

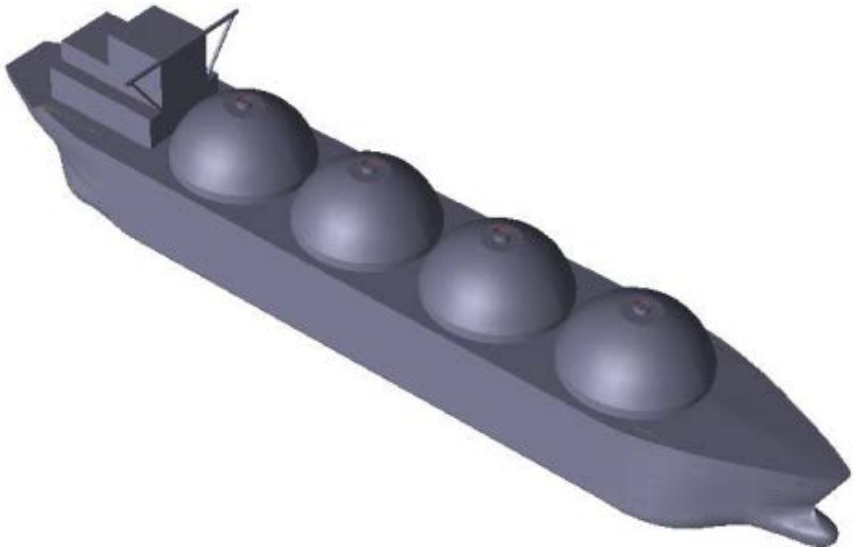
Why focus on fatigue?

- Most common hull damage
- Some of the area is inaccessible for inspection and repair
- LNG vessels often designed for extended life time

1. INTRODUCTION

2. OBJECTIVE

- **Comparative study on the fatigue strength of hopper knuckle joints**



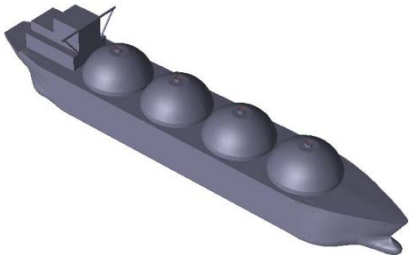
- Hydrodynamic Analysis
- Structural analysis

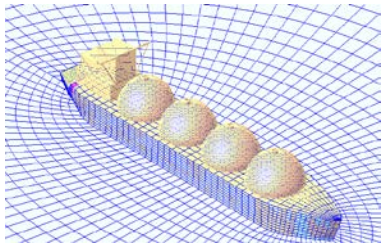
Parameters	Technical data
Length Overall	289.5m
Length between perpendiculars	277.0m
Breadth moulded	49.0m
Depth moulded	27.0m
Design draught	11.9m
Speed	16knots

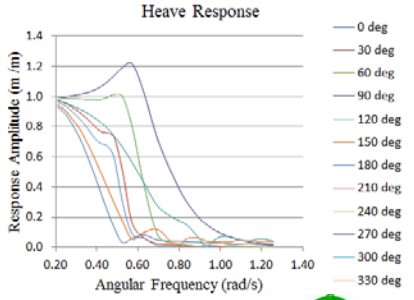
3. METHODOLOGY

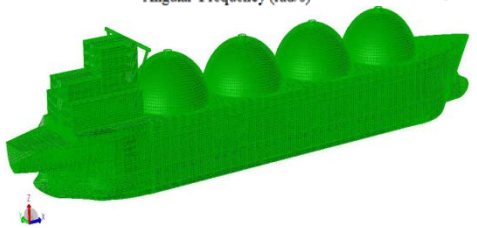
SESAM suite

- Global Structural model → GeniE →
- Hydrodynamic analysis model → Hydro D / Wasim →
- Global Motion Response Post process → Postresp →
- Structural analysis Global and local → Sestra →
- Fatigue analysis → Stofat

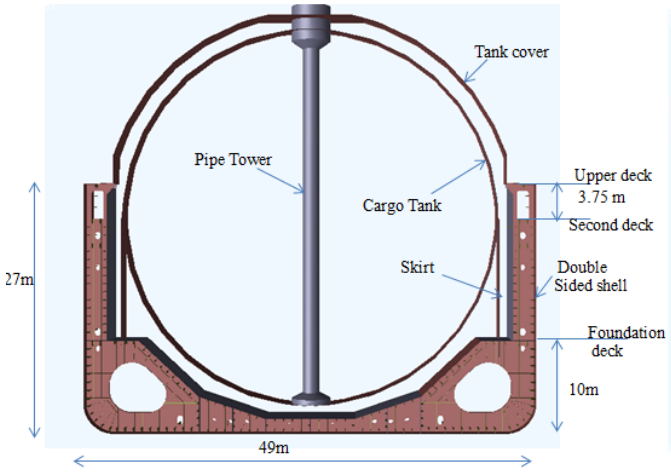


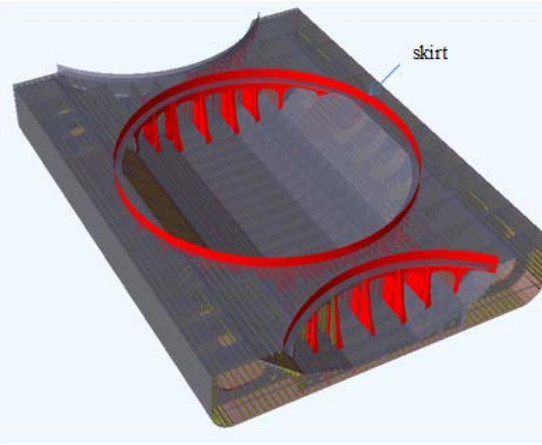




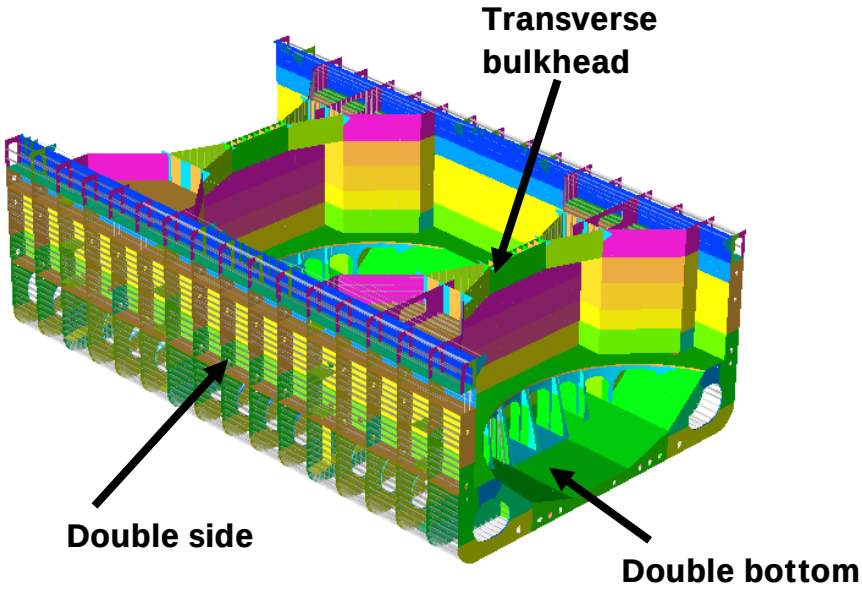


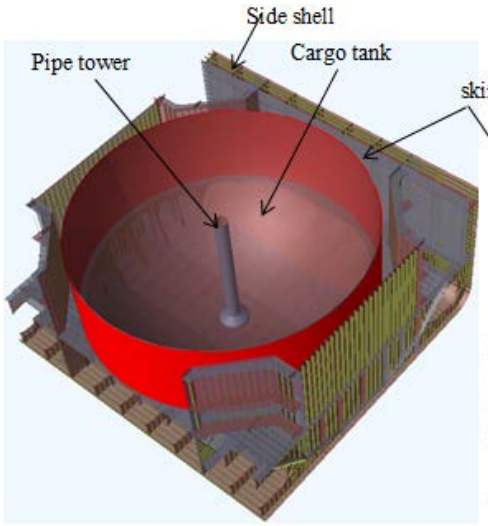
- **Global structural model – combination of beam and shell elements**

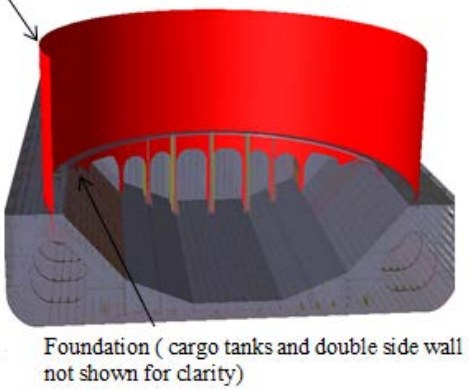




- **Double sided & double bottom hull**

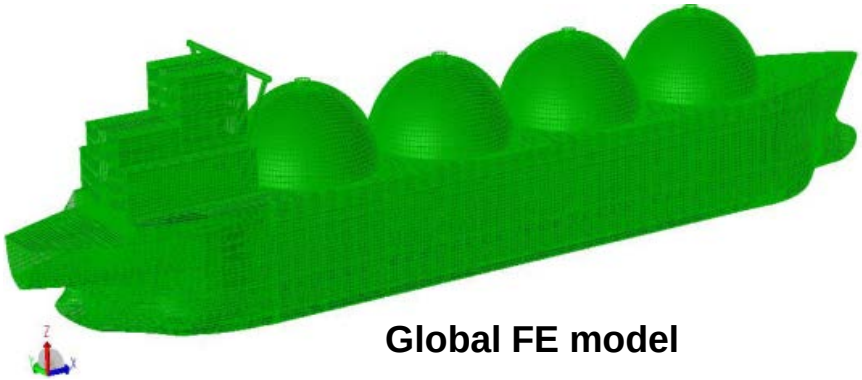






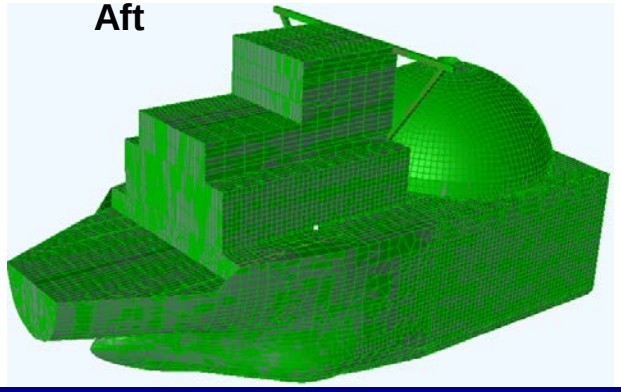
- **4 node shell element and 2 node beam element -Global model**

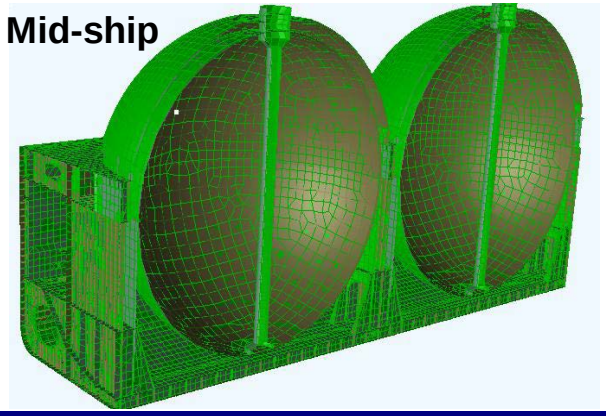
- **To reduce computational time---Coarse mesh 1m**

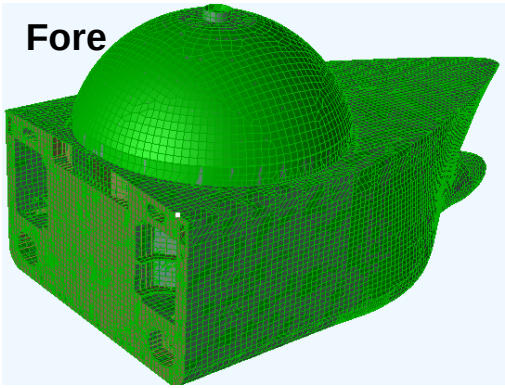


Global FE model

- **The spherical tanks and skirts are modelled sufficiently accurate**



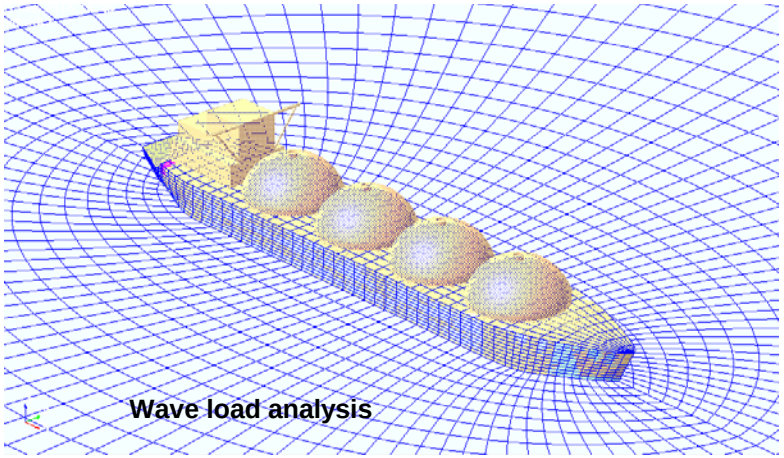




4. ANALYSIS OVERVIEW :Hydrodynamics Analysis

- Global FE model transferred to Hydrodynamic analysis

→ Ensures same mass model in Structural & Hydrodynamic analysis

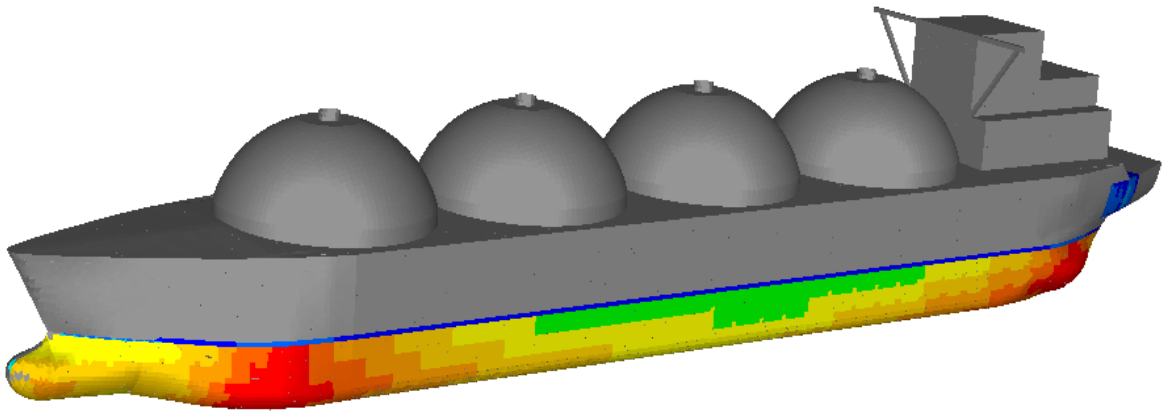


Wave load analysis

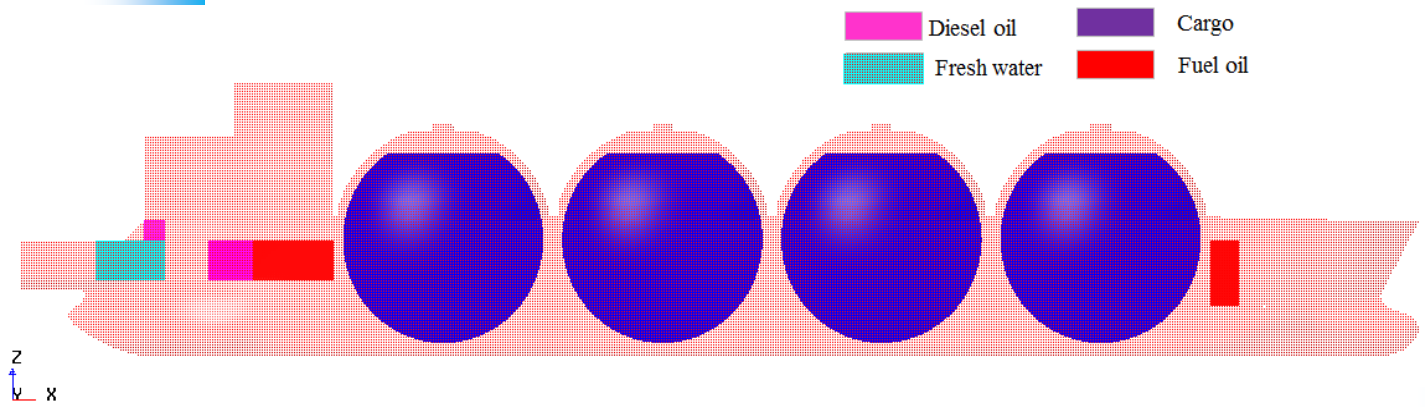
Direct wave load and response analysis

Automatic transfer of dynamic internal/external pressures and inertia loads

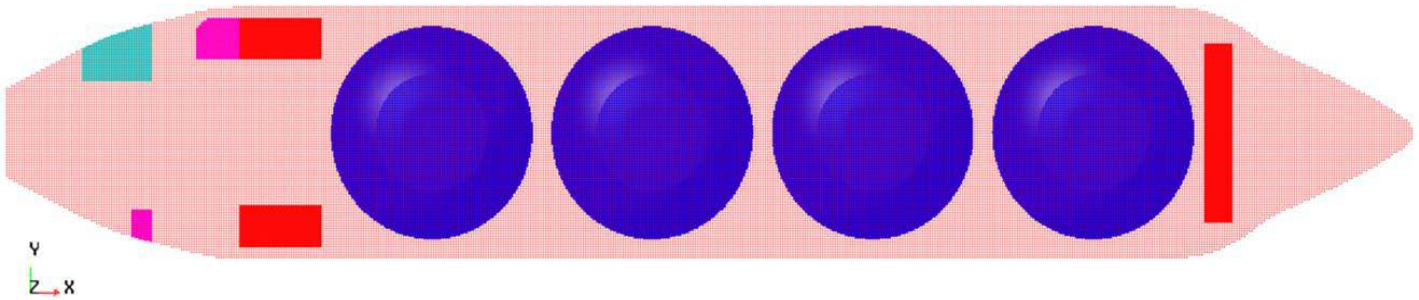
Pressure distribution



Full load case

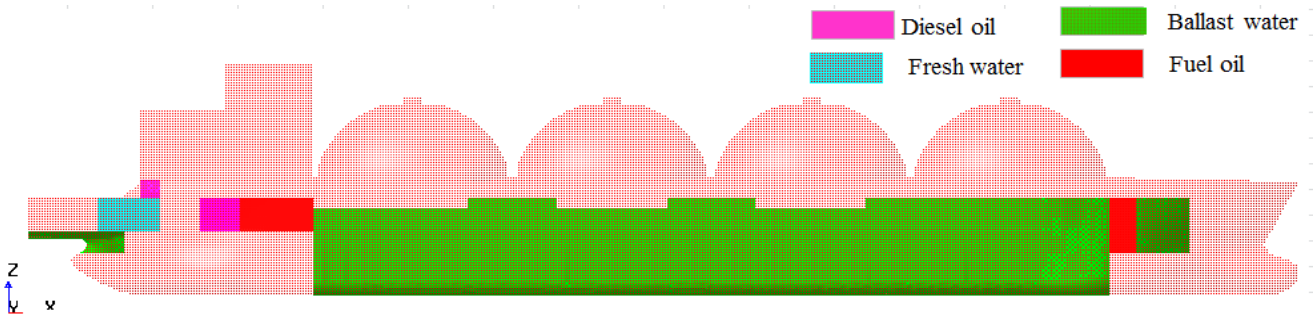


Draught 11.9m

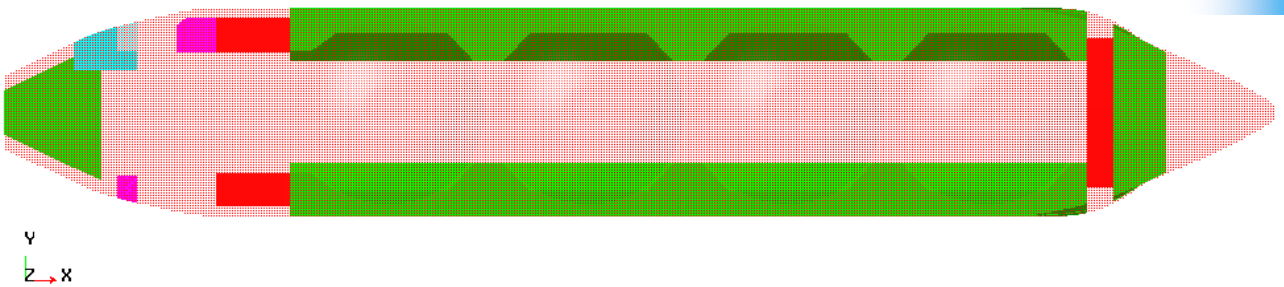


Property	Value	Units
Mass	1.088E+08	kg
Buoyancy Volume	1.362E+05	m^3
Centre of Buoyancy in coordinate (x,y,z)	(142.4,0,6.08)	m
Centre of Gravity in coordinate (x,y,z)	(149.7, 0.19, 21.27)	m
Radius of Gyration (x,y,z)	(11.49, 64.09, 64.31)	m

Ballast load case



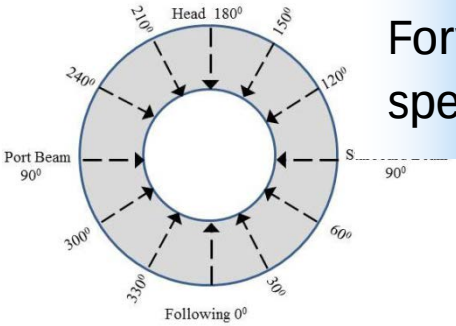
Draught 6m



Property	Value	Units
Mass	1.015E+08	kg
Buoyancy Volume	6.3701E+04	m^3
Centre of Buoyancy in coordinate (x,y,z)	(143.5,0,3.09)	m
Centre of Gravity in coordinate (x,y,z)	(144.7, 0.433, 15.65)	m
Radius of Gyration (x,y,z)	(25.5, 92.19, 92.22)	m

4. ANALYSIS OVERVIEW :Hydrodynamics Analysis

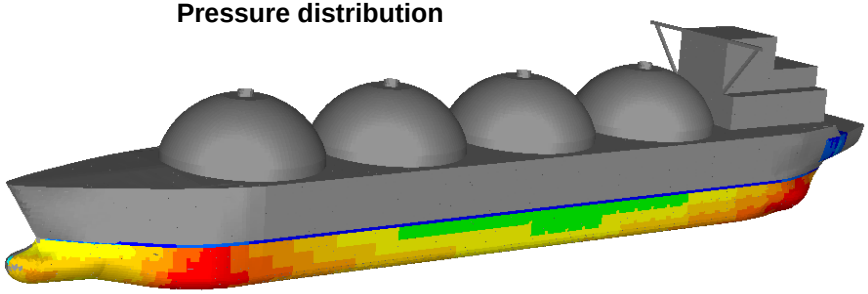
Wave period (s)	5.0	5.25	5.5	5.75	6.0	6.25	6.5	6.75	7.0	7.5	8.0	9.0	10.0	11.0
	12.0	13.0	14.0	15.0	16.0	17.0	18.0	20.0	24.0	26.0	30.0			



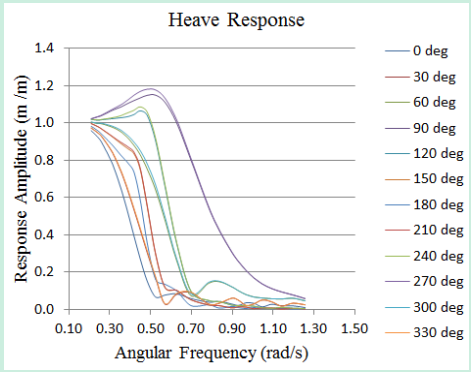
Forward speed= (2/3)design speed

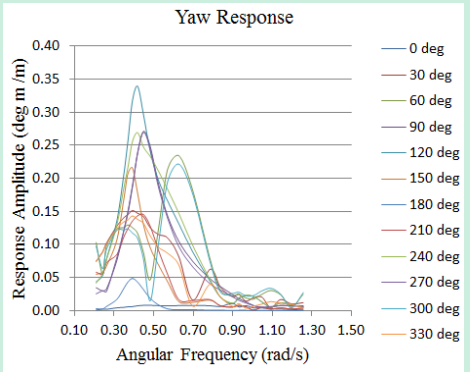
Hydrodynamic analysis with 1m wave amplitude is performed in frequency domain

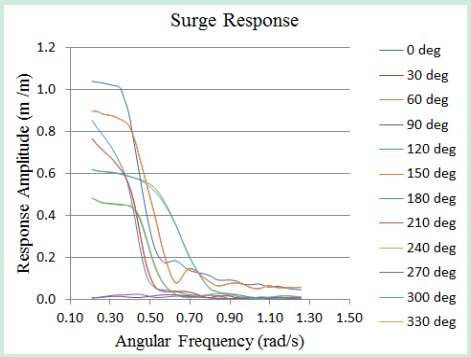
Pressure distribution

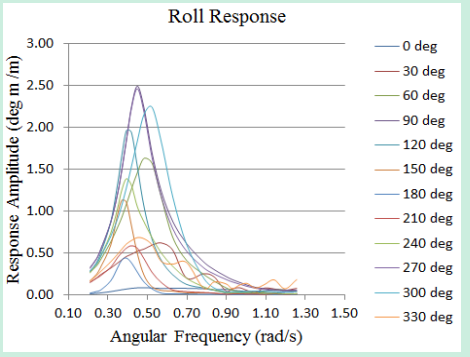


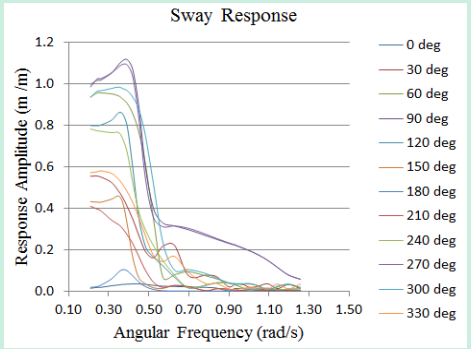
Pressure transferred to the structural FE model

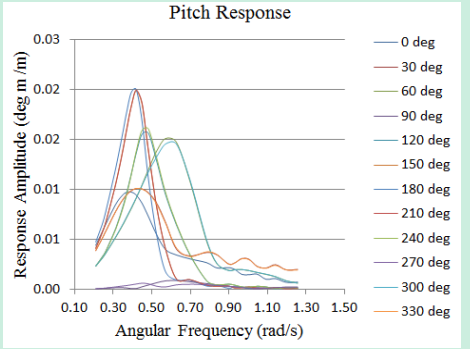








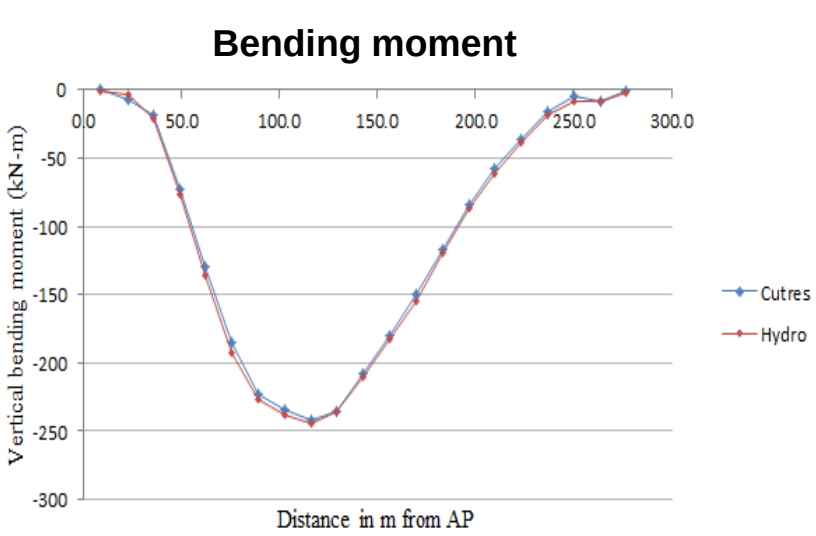


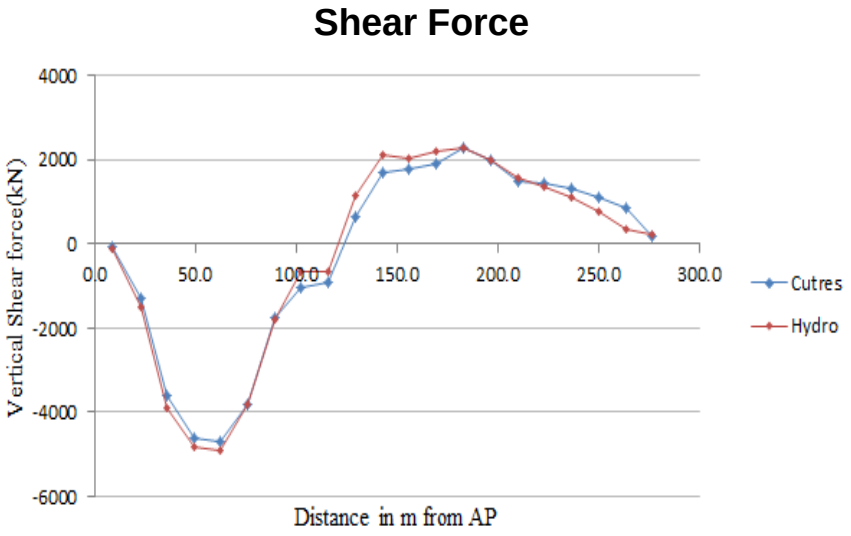


➢**Transfer of Hydrodynamic loads to FE model ----12 wave directions and 25 wave periods results in 300 complex load cases**

➢ 2 Analyses –Ballast and Full load cases run separately

➢ Check of inaccuracy in load transfer from hydrodynamics analysis to structural FE model → The main source of error in spectral fatigue analysis

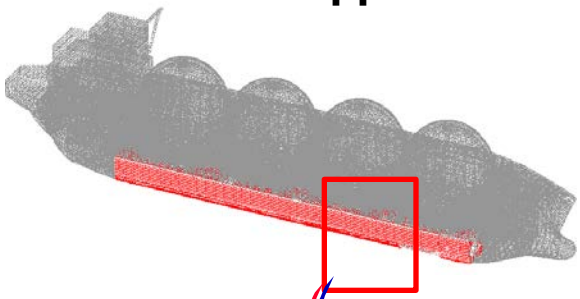


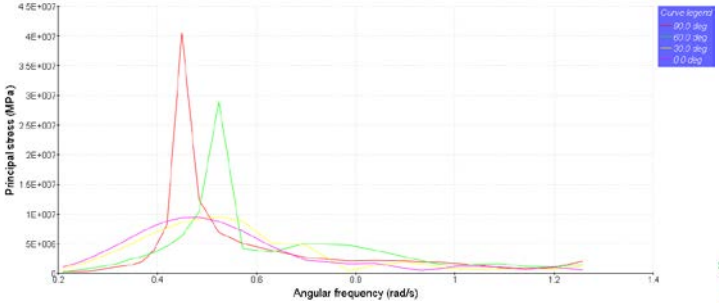


➢ **Fatigue critical locations screening in hopper knuckle**

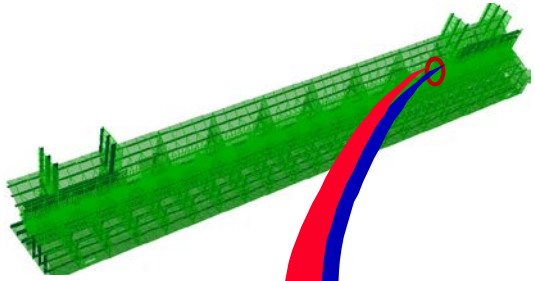
Criteria

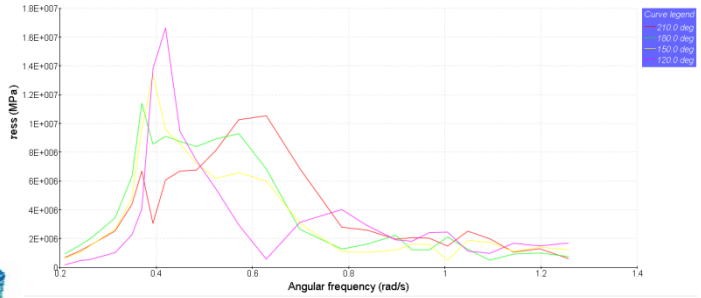
Maximum principal stress



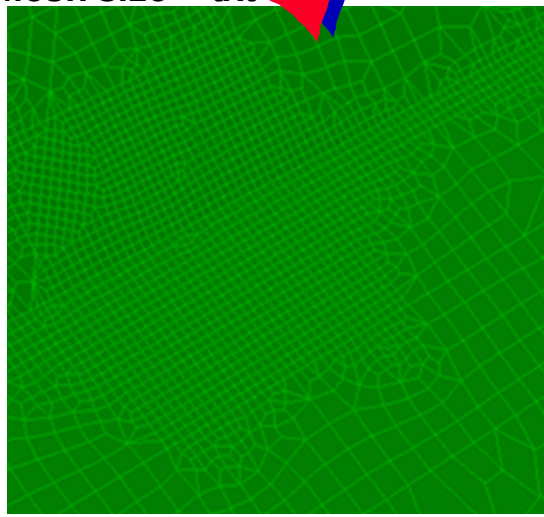


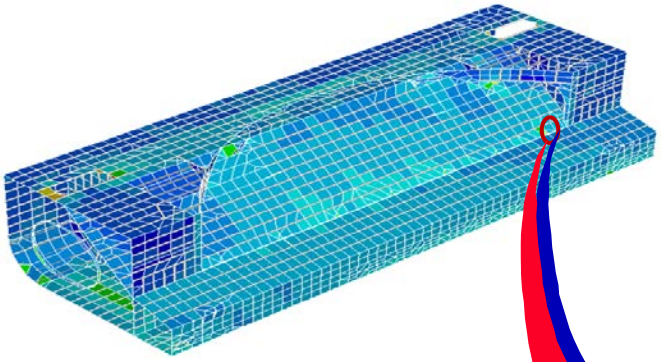
Sub model



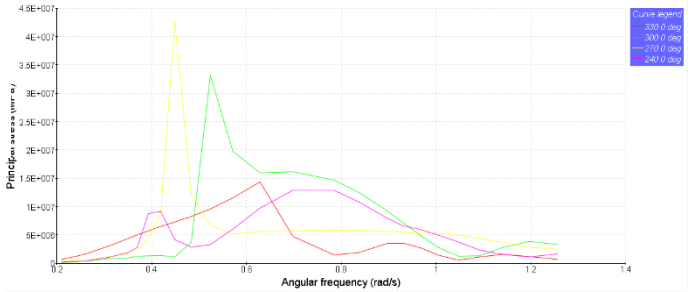


Mesh size - txt





Maximum principal stress



Stress transfer for Maximum principal stress

4. ANALYSIS OVERVIEW : Spectral Fatigue Analysis

- Short term response

  - Wave climate North Atlantic
  - Pierson-Moskowitz wave spectrum
  - cosine power 2 as a wave spreading function

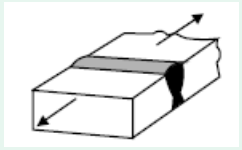
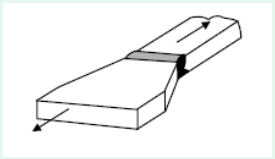
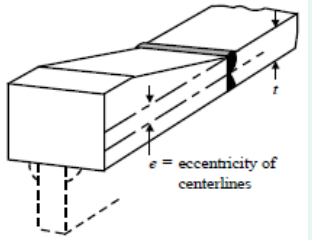
- Long term response

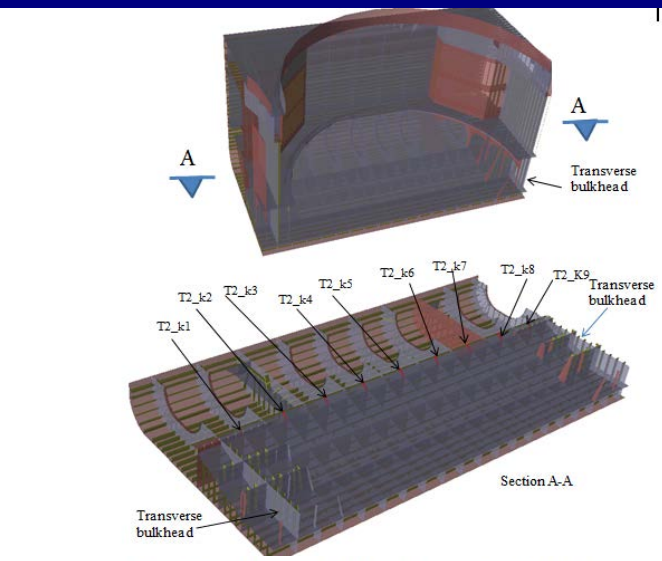
  - Wave scatter
  - 2 parameter Weibull distribution

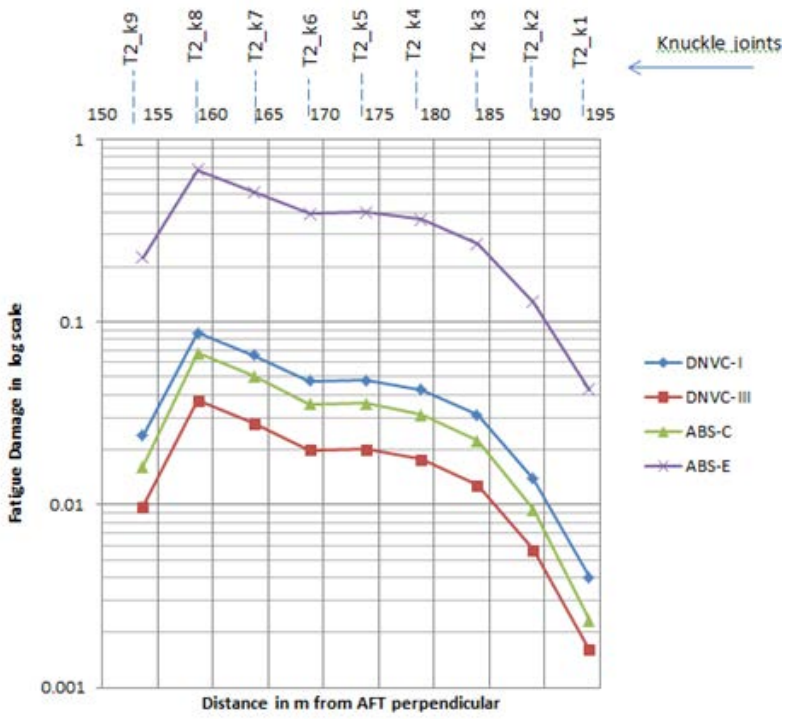
Fraction of time at sea **85 per cent of its total design life of 40 years**

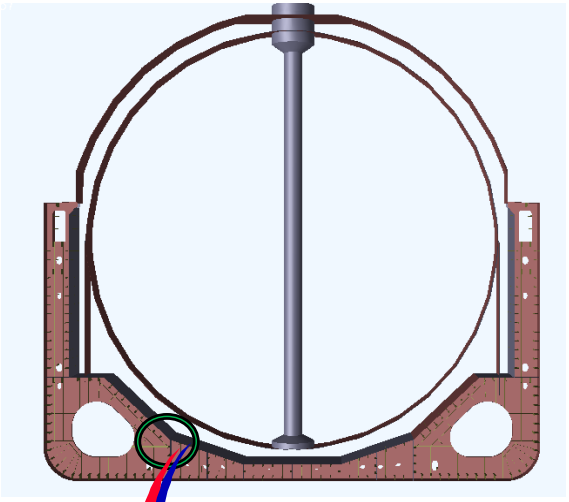
Vessel type	Tankers
Full Loaded conditions	0.50
Ballast conditions	0.50

4. ANALYSIS OVERVIEW : Spectral Fatigue Analysis

SN-Curve	Requirements	Stress limit at 10^7 cycles (MPa)	Construction detail
DNVC-III	Rolled plates	106.97	-----
DNVC-I	Welds made in flat position in shop. Weld run-off pieces to be used and subsequently removed. Plate edges to be ground flush in direction of stress.	52.63	
ABS C	With the weld overfill dressed flush with the surface and with the weld proved free from significant defects by non-destructive examination. The significance of defects should be determined with the aid of specialist advice and/or by the use of fracture mechanics analysis. The NDT technique must be selected with a view to ensuring the detection of such significant defects.	78.16	
ABS E	The corners of the cross-section of the stressed element at the weld toes should be dressed to a smooth profile.	47	

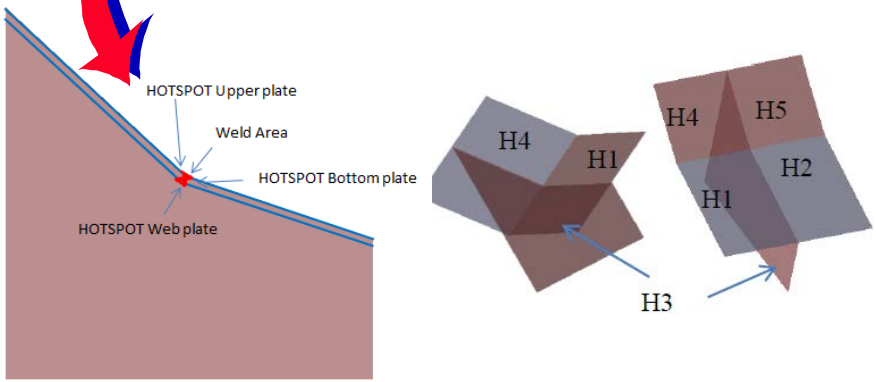




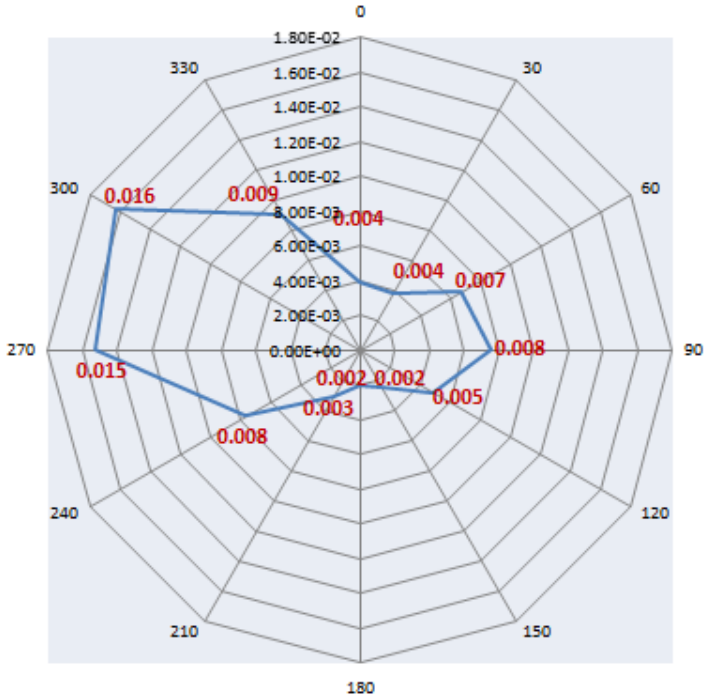


Fatigue Damage for various S-N Curve

S-N Curve	H1	H2	H3	H4	H5
DNVC-I	0.0826	0.0377	0.0317	0.0651	0.0456
DNVC-III	0.0352	0.0156	0.0131	0.0274	0.0190
ABS-C	0.0640	0.0271	0.0229	0.0490	0.0336
ABS-E	0.6435	0.3271	0.2731	0.5299	0.3804



Hotspot positions for lower hopper knuckle



Polar Plot of Total Fatigue Damage

5. CONCLUSIONS

- Ballast load case contributes around 85 to 90 % to the total fatigue damage. The contribution from full load case is around 10 to 15 % depending on the location of knuckle joints.

- The majority of the total damage is scattered between 240^0 to 330^0 wave headings which correspond to 50% of the total damage.

- The bent knuckle joint from rolled plate shows better fatigue life in comparison with welded joint. Fatigue life of bent knuckle plate is 7 times higher than welded knuckle joint confirming to ABS-E curve requirements.

- The weld preparation quality and inspection category have a direct consequence on the fatigue life . Higher weld quality and stringent inspection type results in increased fatigue life.

7. RECOMMENDATIONS & FUTURE SCOPE OF WORK

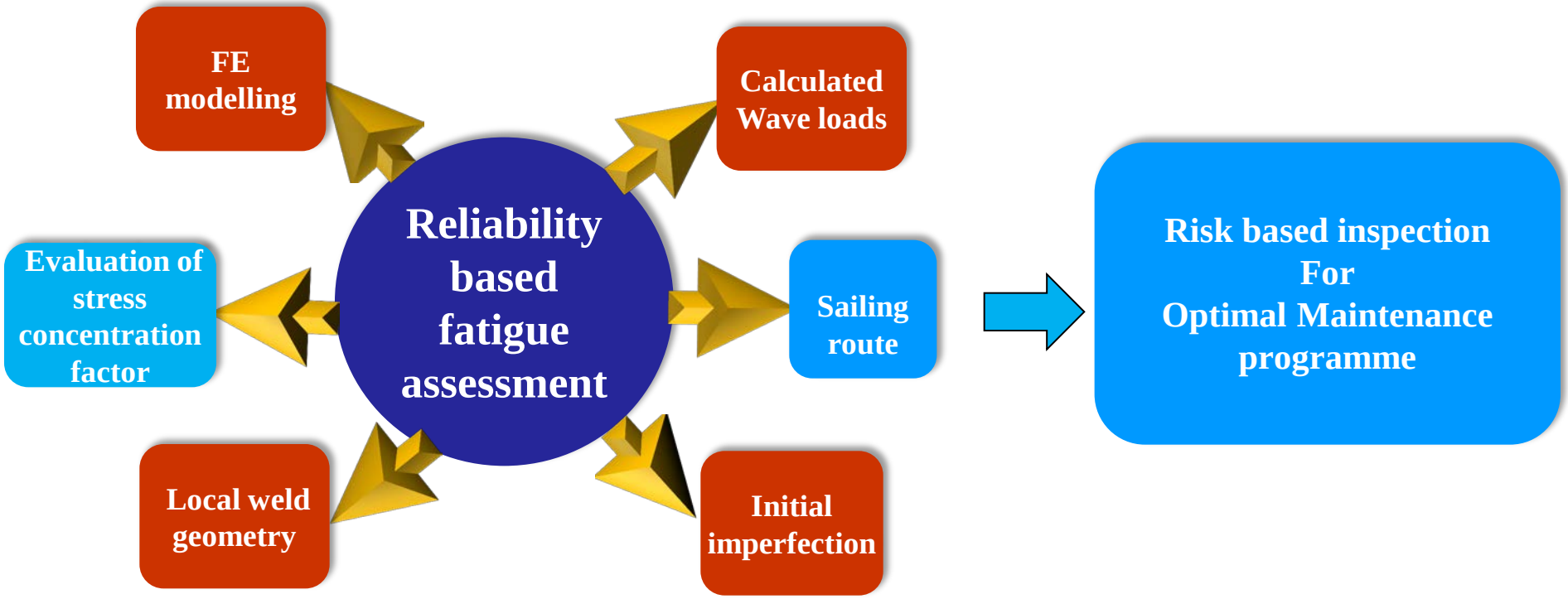
- Time-consuming computational procedures.

  During Preliminary design stage

  Equivalent design wave (EDW) method may be used for fatigue screening

- The effect of the weld can be considered . ⇒ Further increases fatigue damage.

- Variables involved in the fatigue design subjected to significant uncertainty.



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Thank you!

http://www.wildoceanfilm.com/marketing/images/photos/marinelife/Big%20Ship.jpg