Engine foundation re-design due to modification of the shaft line arrangement

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Master Thesis

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(Ing. *Christian Boomas)*.

Including a thrust block in the shaft line

What are the main characteristics of the study case?

Why add a thrust block in the shaft line?

What needs to be taken into account for the support system?

How to adapt the foundation to the thrust block?

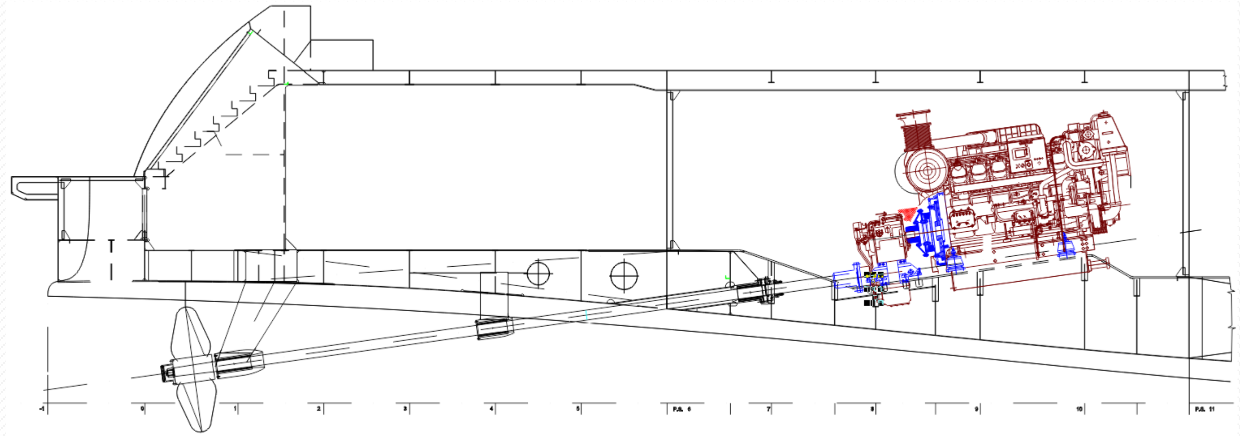
How to compare the proposed modifications?

Which solution should be recommended?

What is the next step?

What are the main characteristics of the study case?

The ship “216”:



Ship **Length**: 46m

Ship velocity (Vw): 16 knots

Engine **Power** (at Vw): 1454 BKW

Engine **RPM** (at Vw): 1830 RPM

Thrust (per shaft): 100kN

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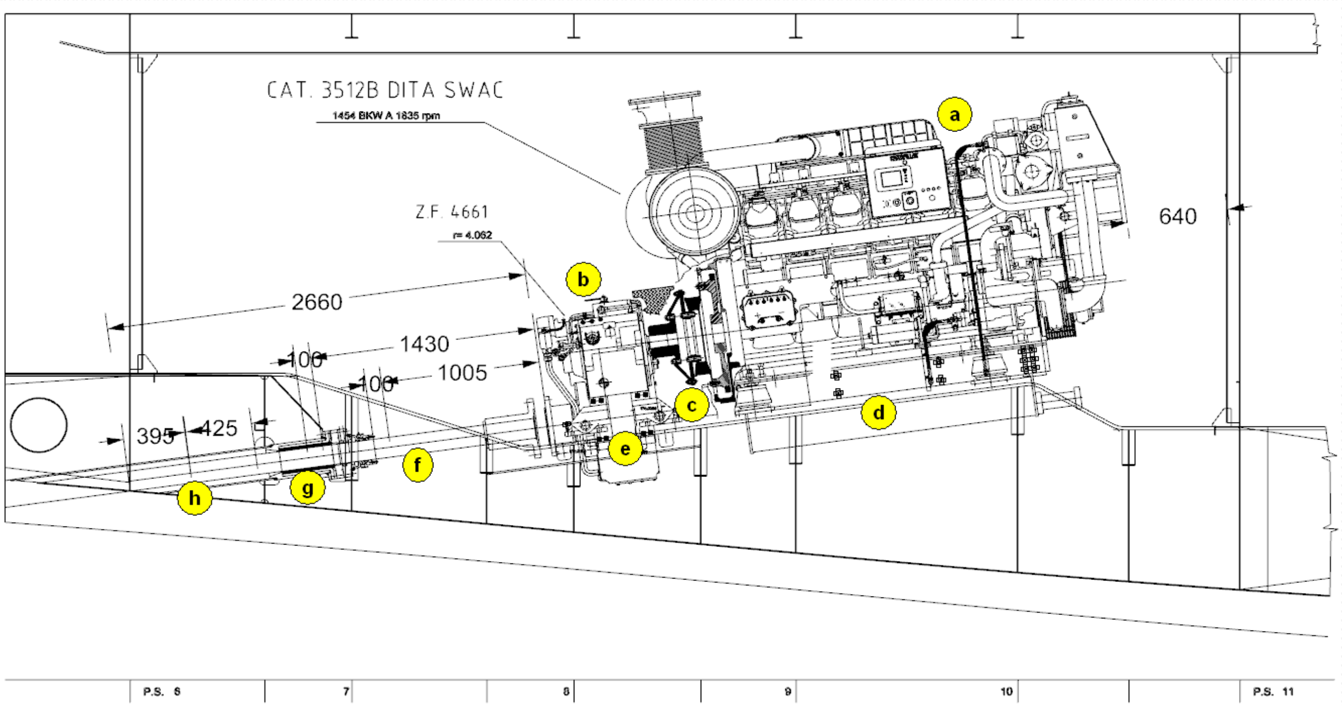
What are the main characteristics of the study case?

Available space and main elements:



a) Engine block
b) Gear box
c) Eng.– GB couple
d) Eng. support
e) GB support
f) Main Shaft
g) Deep sea seal
h) Hull tube

Modification restrictions:

•Engine room ***bulkhead position*** (Sect. 6 and 11);
• ***Shaft inclination*** angle (7,7°);
•***Hull tube*** longitudinal location(intersection with frame 6).

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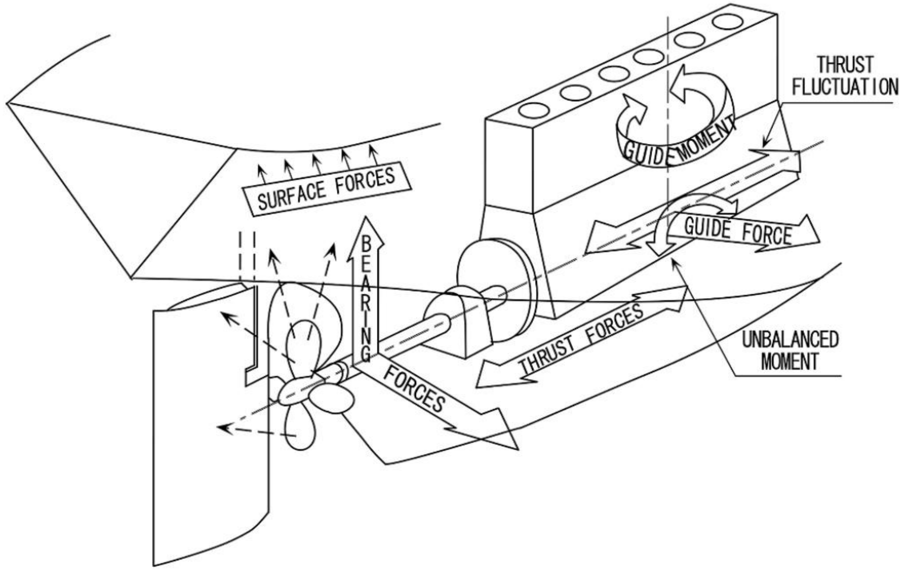
Why add a TB in the shaft line?

Main engine excitations



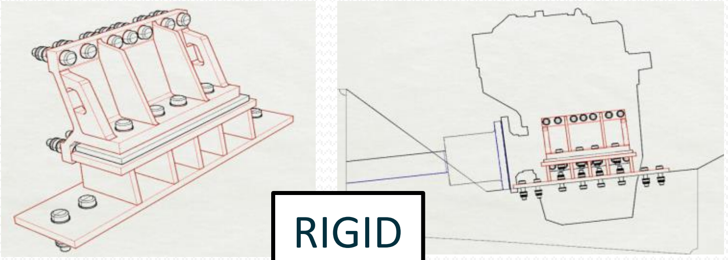
Take the form of:

- •unbalanced moments,
- •guide forces and moments

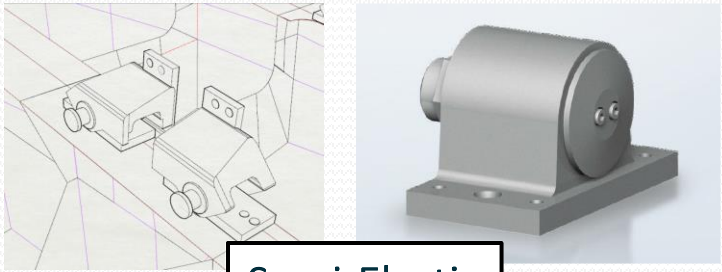
At the:

- •engine revolution frequency,
- •the cylinders firing frequency and inherent harmonics.

GB support system



RIGID



Semi-Elastic

•Are transferred to the foundation

•Induce **hull girder vibration** or **superstructure vibration**.

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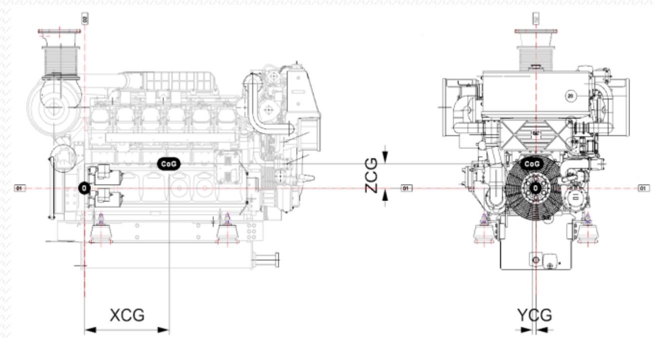
Applied loads

Engine's Weight:

$$W_{eng}\,[kN] = W_{eng\,dry}[kN].(1{,}35)$$

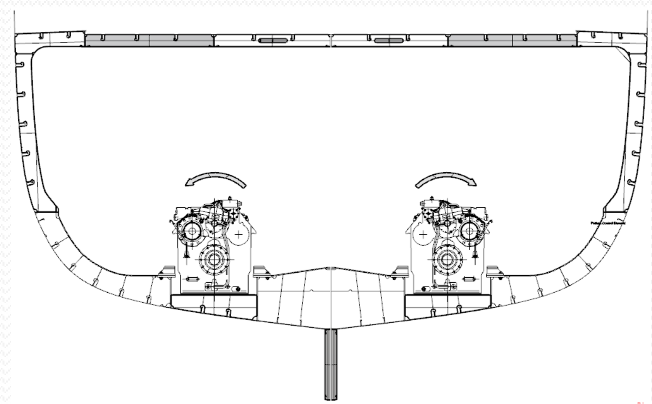
$$W_{eng}\,[kN] = 88{,}24\;kN$$



Gear box Torque:

$$T_{GB}\,[kNm] = \frac{P_{eng}[kW] * 9{,}55}{\omega_{eng\,nom}\quad [RPM]} \cdot \frac{1}{1/r}$$

$$T_{GB} = 7{,}57kN.\,4{,}062 = 30{,}73\;kNm$$



Shaft's thrust:

$$\frac{P_{effective}}{2} = P_{engine}\,.\,\eta$$

$$T = \frac{2.\,v}{P_{effective}} = 168\;kN$$

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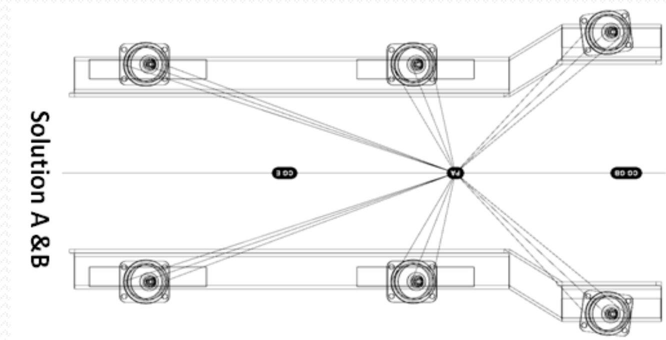
What needs to be taken into account for the support system?

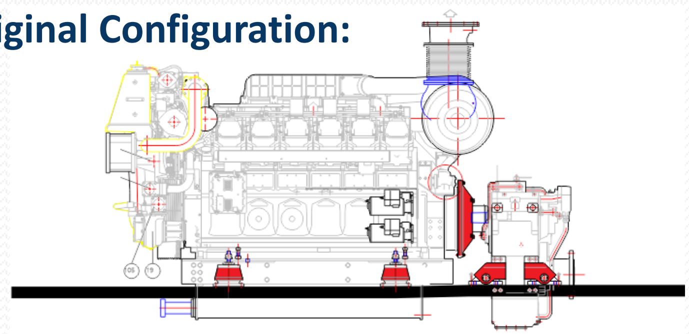
Mounting configuration

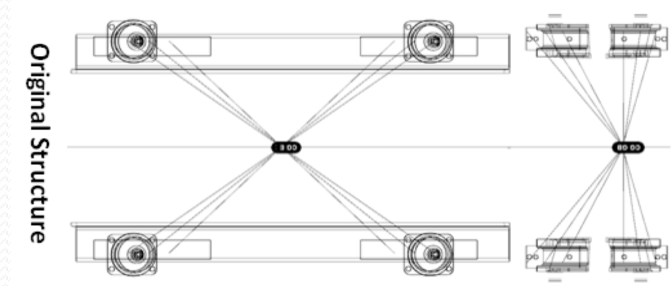
Rubber Design's proposal:

- Engine weight and gear box torque on the ***same support.***
- Engine block moves as ***one body.***



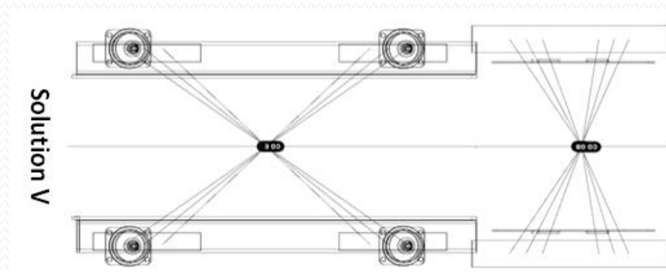
Original Configuration:





Vulkan Italy's proposal:

- Engine and gear box ***independent supports***.
- ***Traction resistant*** gear box support.
- ***Relative motion*** between Eng. and GB.



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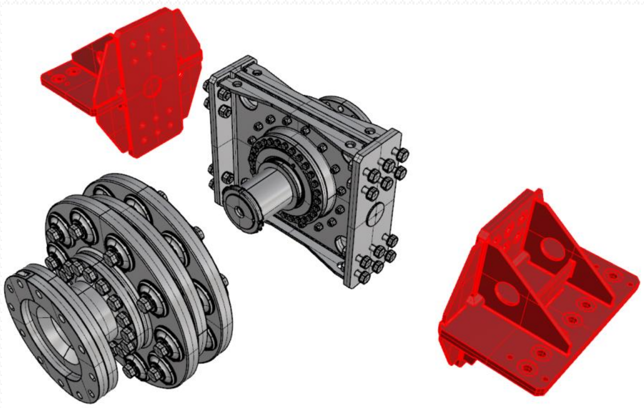
How to adapt the foundation to the thrust block?

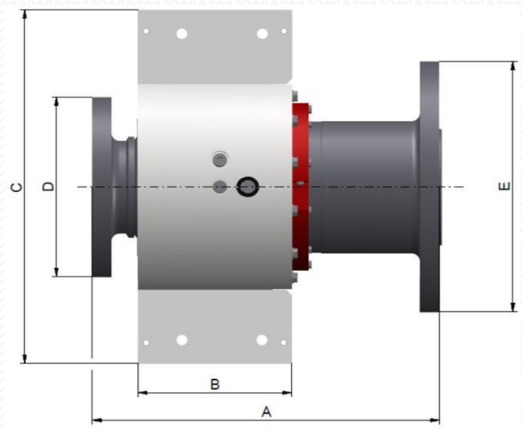
Proposed Thrust blocks

Vulkan Italy



Selected based on:	
Shaft Torque	Shaft Thrust
Support	
Flexible	Long. Flange (A) Trans. Flange (B)
TB-GB coupling	
Propiflex -T (compact)	Double Marine Coupling
Block Length (mm):	
735	1250 (A) 1720(B)

Rubber Design



Single marine coupling

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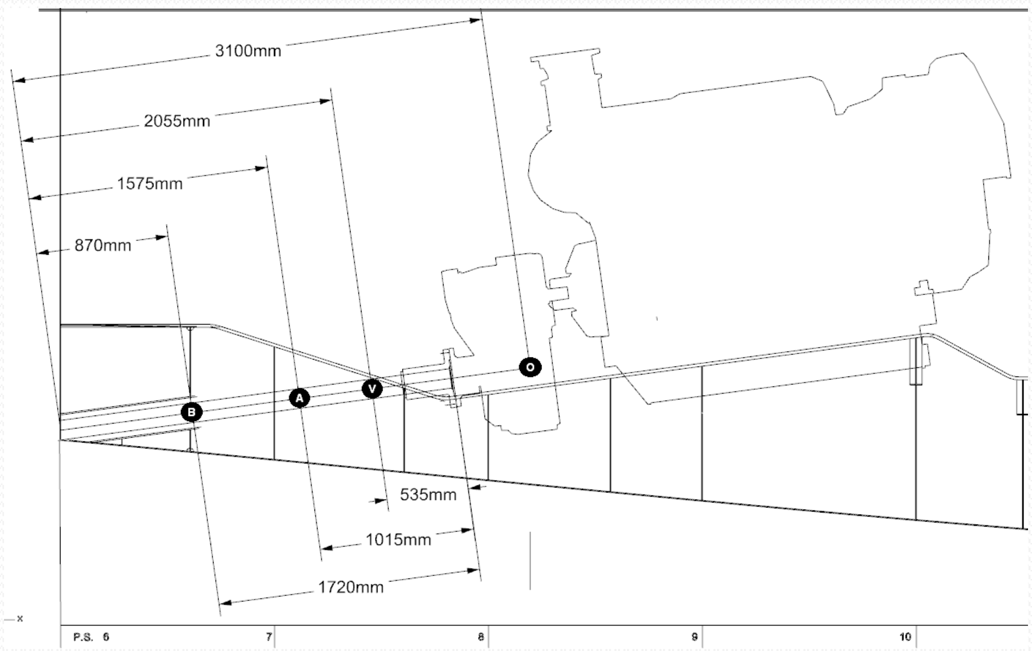
How to adapt the foundation to the thrust block?

Load application differences:



Structural modification conditions:

1- Is it possible?

2- Is there a less invasive option?

3- Can it be built?

Distance from the TB to the GB's Flange (mm)	
Original ("O");	0
Rubber Design ("A");	535
Rubber Design ("B");	1015
Vulkan Solution ("V").	1720

Support system	
Original ("O");	Gear box
Rubber Design ("A");	Keelson Flanges
Rubber Design ("B");	Transversal plate
Vulkan Solution ("V").	Keelson flanges or web

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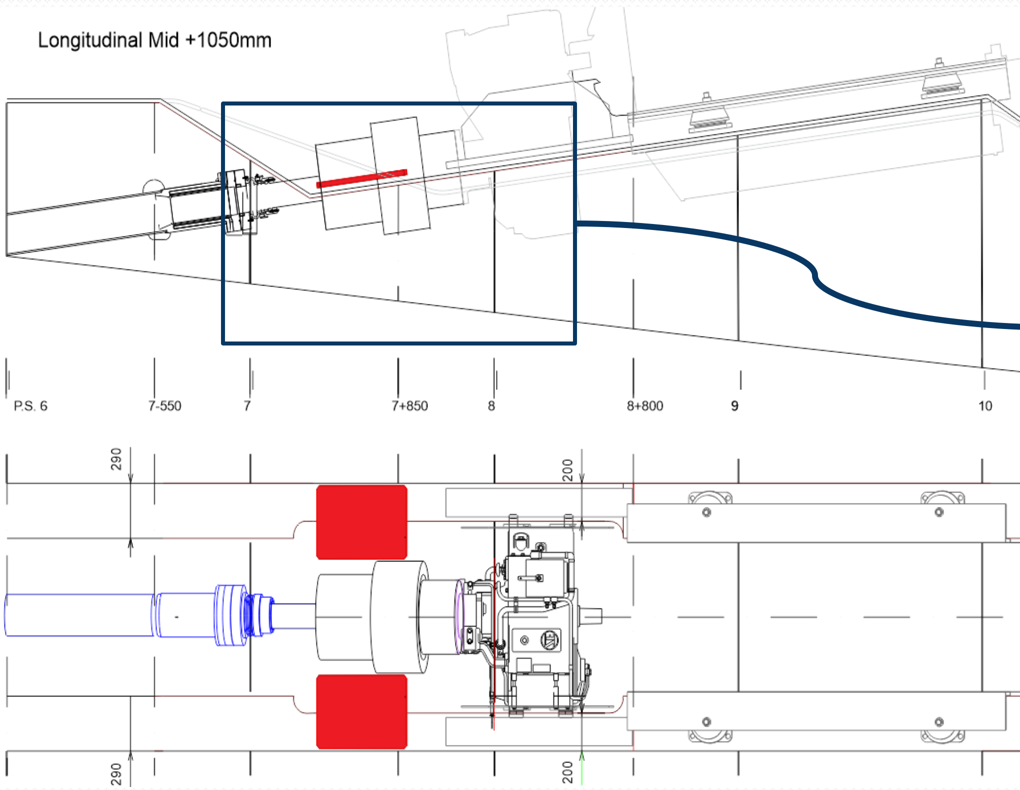
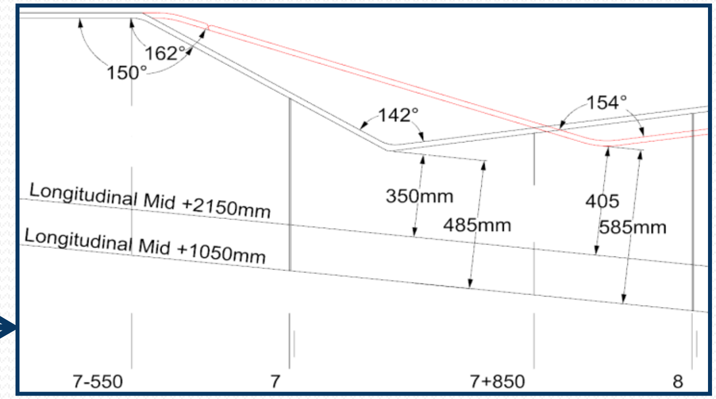
How to adapt the foundation to the thrust block?

Vulkan's TB:
Proposed Solution V





Minimum change:

• *Locate the TB, GB and engine supports on the* ***same seating flange****.*

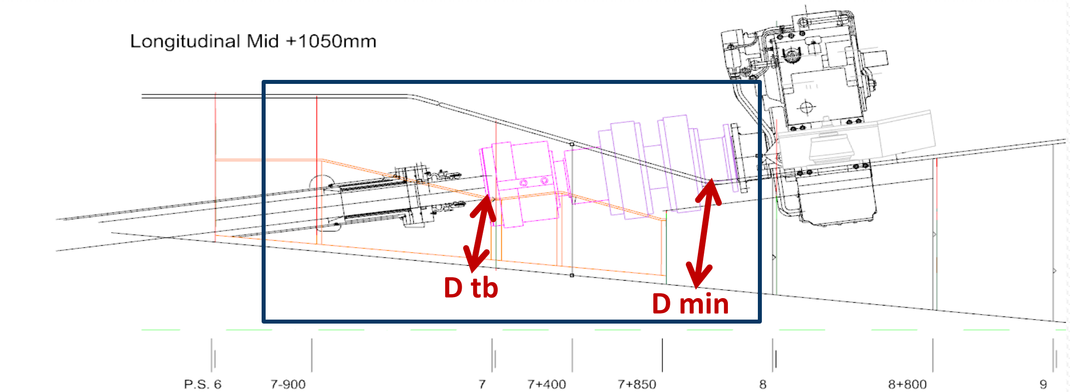
Worst case scenario:

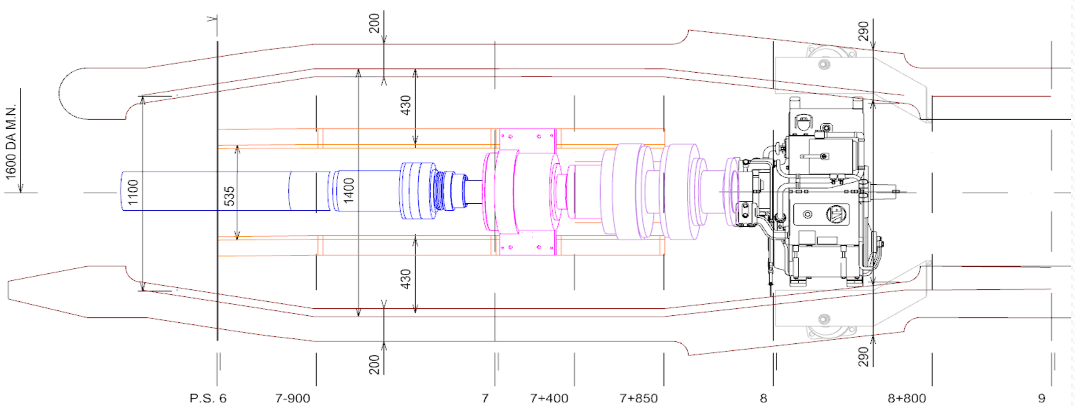
• *Reduction of the* ***web height****.*

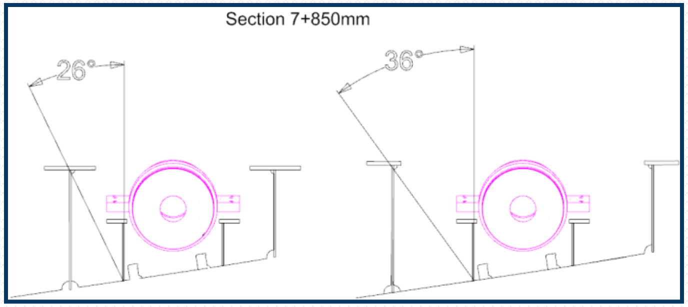
•*Reduction of* ***transition angles****.*

How to adapt the foundation to the thrust block?

Rubber Design's TB:
Proposed Solution A







Performed modifications:

- *Addition of **internal stiffeners** supports;*
- *Increase **keelsons separation**;*
- *Modify **keelson flanges**;*
- *Transversal **frame addition** (at 7+400mm);*
- *Transversal **frame displacement** (from 7-550mm to 7-900mm).*

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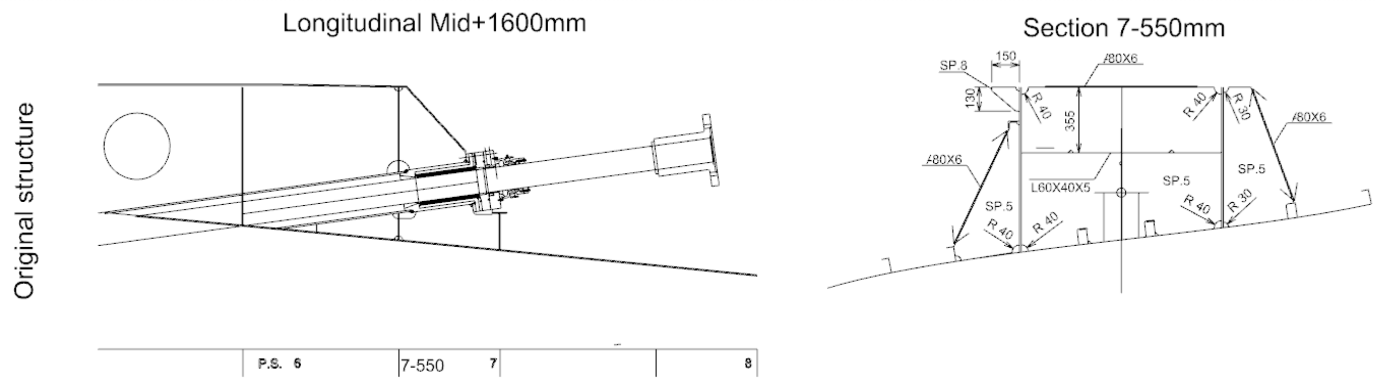
How to adapt the foundation to the thrust block?

Rubber Design’s TB:
Proposed Solution B

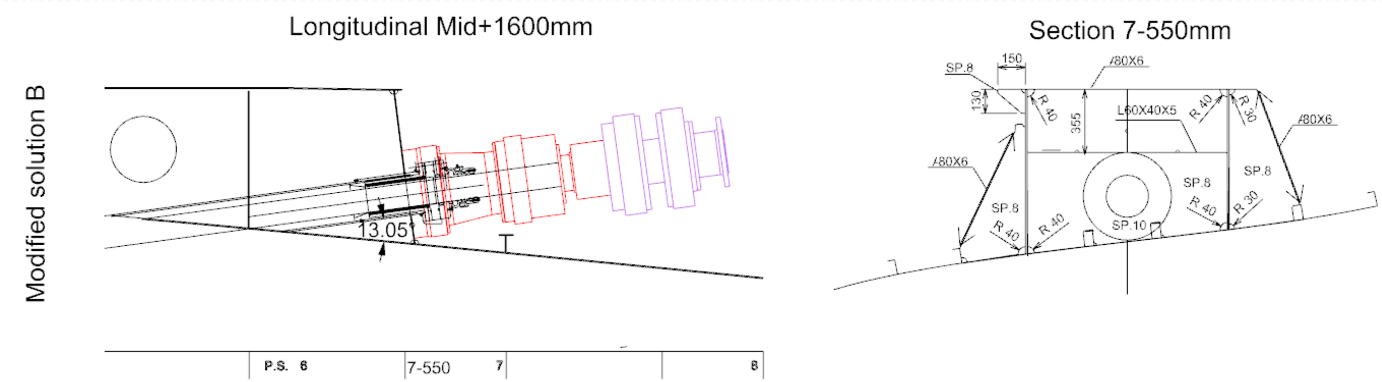
Insufficient space

- ***Below bolting flange.***

With 13° shaft hull angle, the TB should be displaced 500mm for a 112 mm gap.



- ***Around deep sea seal:***



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FEM analysis

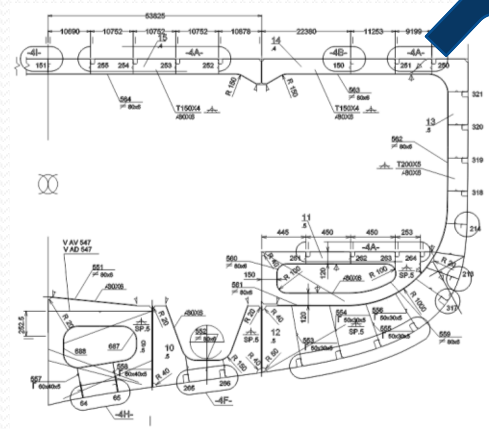
Representation from 2D plans:

•**Stiffeners** : Section's shape, direction and length.

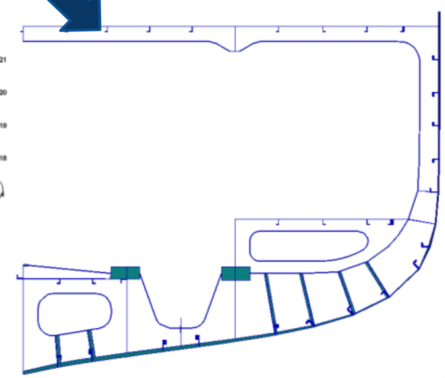
Beam elements: Axial, torsional and bi-directional shear and bending stiffness.

•**Plates** : Shape between stiffeners and thickness.

Shell element: In-plane stiffness, out-of-plane bending stiffness



2D Plan



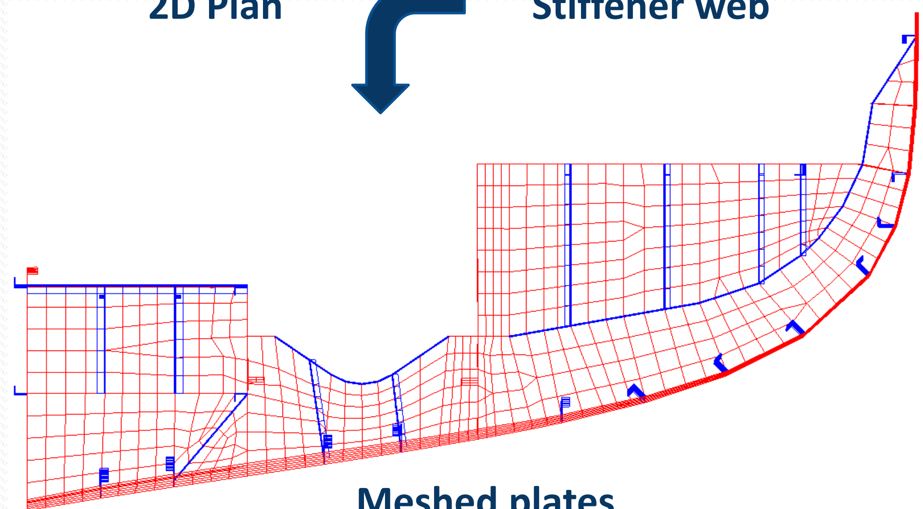
Stiffener web

Meshed plates:

•Adapted to the position of the stiffeners;

•Allows to follow the stress flow direction;

•Dandified at high variation stress points.



Meshed plates

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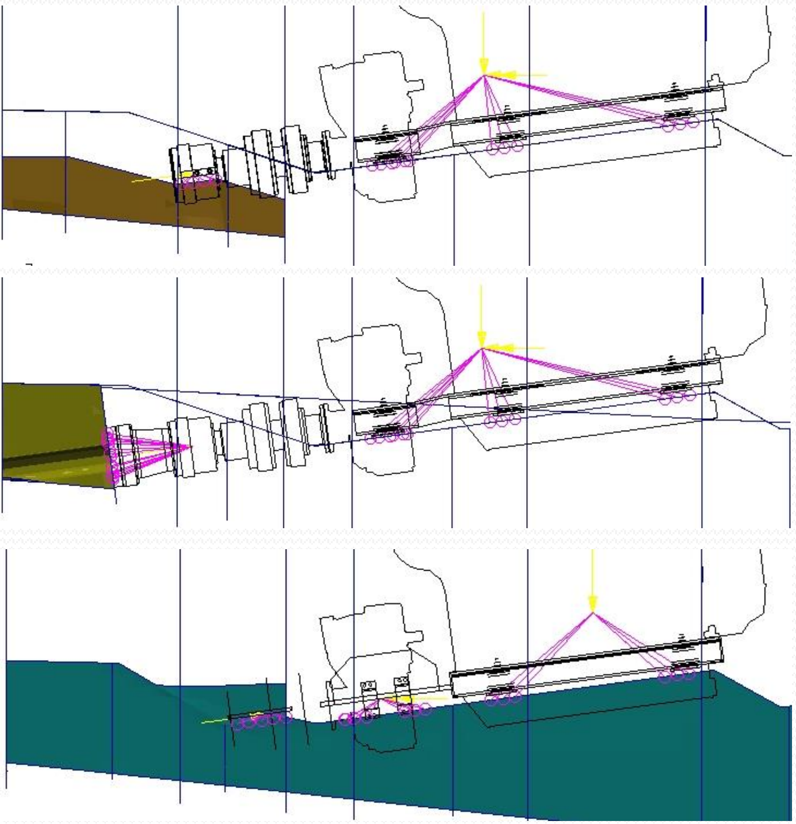
How to compare the proposed modifications?

FEM analysis

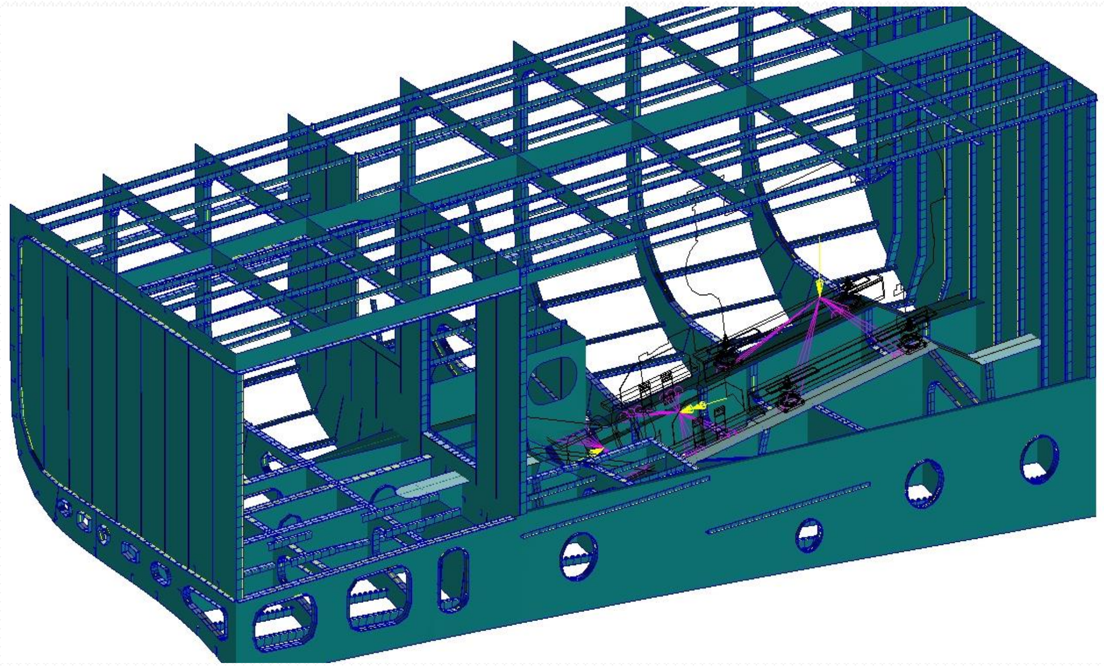
Load Representation:

Rod elements (MPC): Axial stiffness.



4 complete FEM models:

- **Original** configuration;
- RD's Modified **Solution A**;
- RD's Modified **Solution B** and
- Vulkan's Modified **Solution V**.



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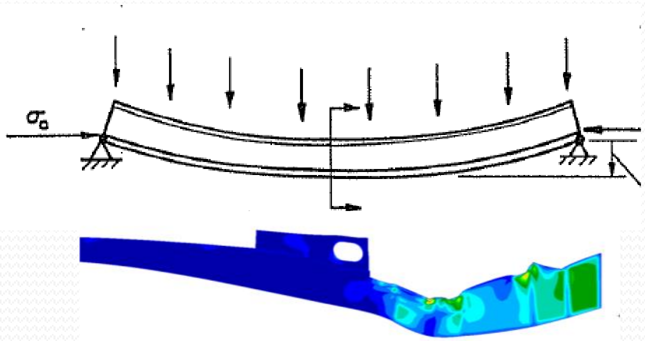
How to compare the proposed modifications?

Structural strength

Combined load approach (O.F. Hughes)



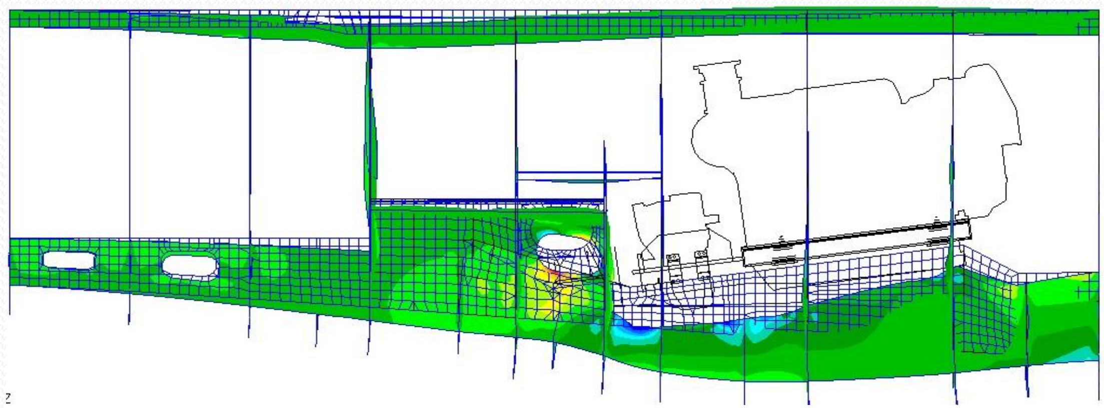
Stiffened plate = *keelson*, under

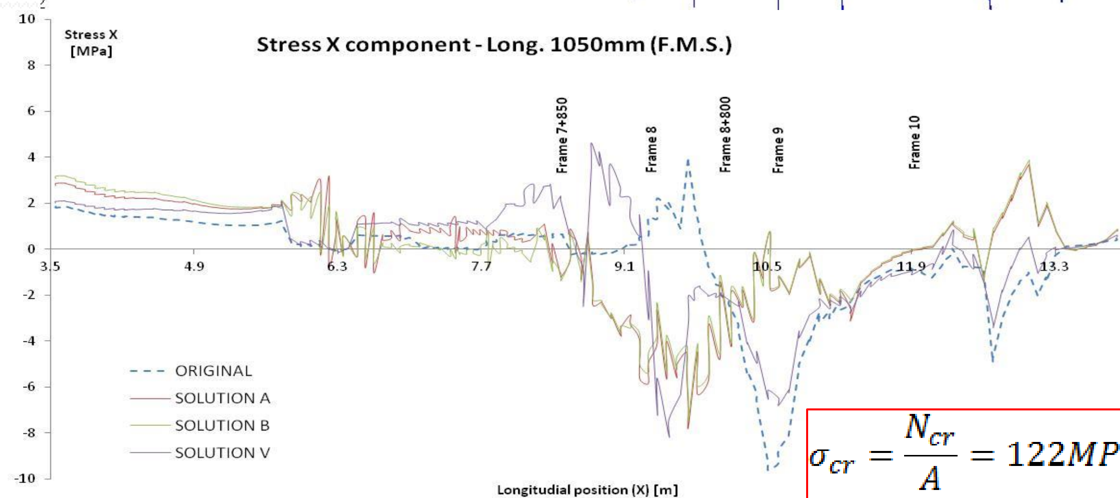
- In-plane compression = *thrust load*
- Lateral load (negative bending) = *weight + torque*.

Collapse mode I:

- Compressible yield close to the flange,
- Buckling or tripping.

Longitudinal Stress (X) along the keelson:



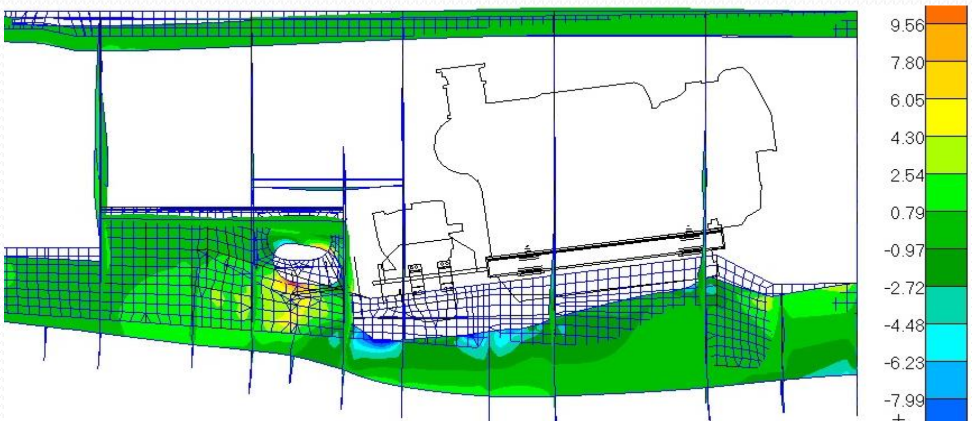


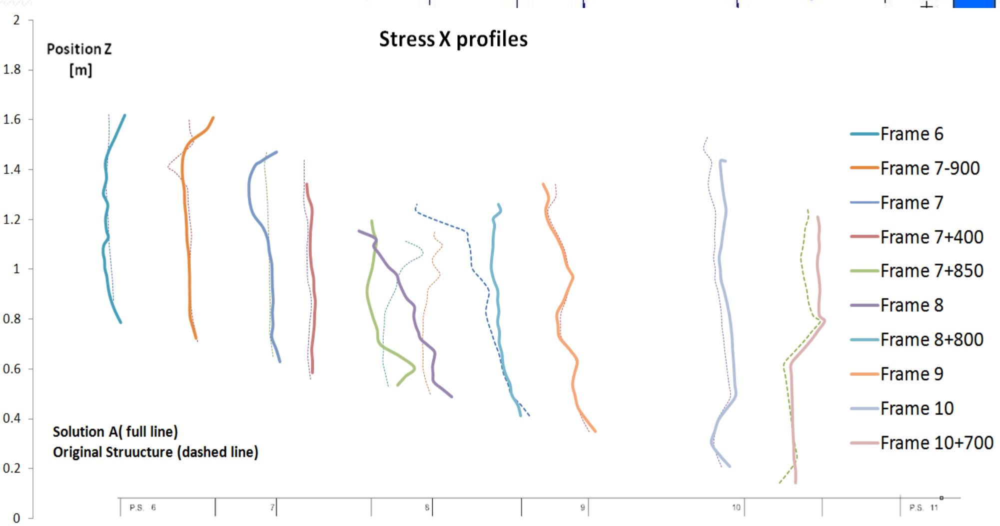
$$\sigma_{cr} = \frac{N_{cr}}{A} = 122MPa$$

How to compare the proposed modifications?

Structural strength

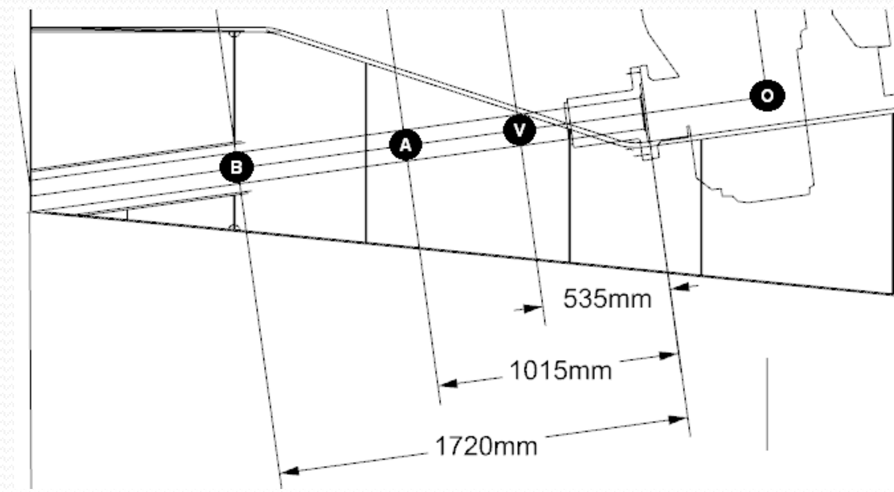
Longitudinal Stress (X) Profiles





Conclusion:

- The minimum section increases with the length of the compressed keelson.
- Depends on the position of the TB with respect to the minimum web height.



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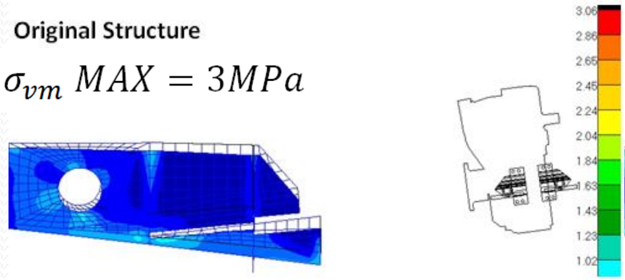
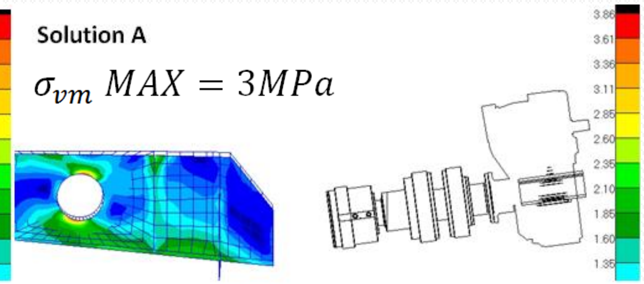
How to compare the proposed modifications?

Structural behavior

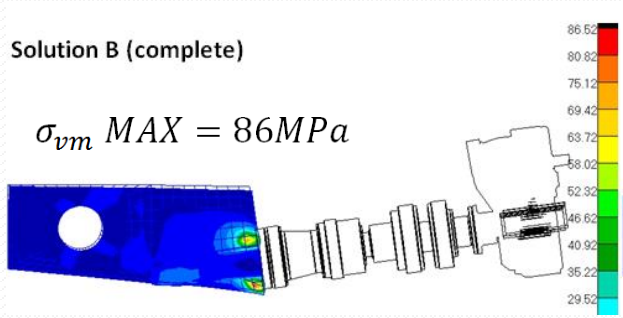
Combined stress distribution along the “Shaft “keelson.

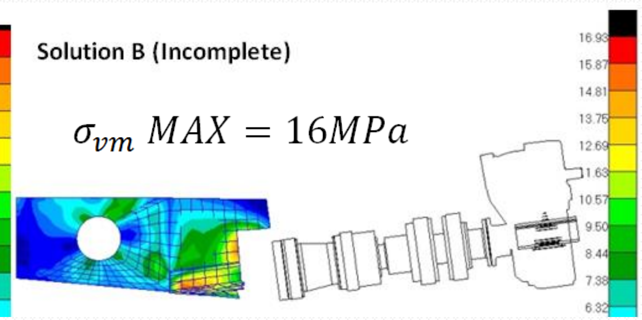




Solution B

- **Concentrated stress** at the secondary supporting structures.
- **Traction** on the keelson above the shaft.
- Concentrated stress is **not transmitted** to the engine foundation.





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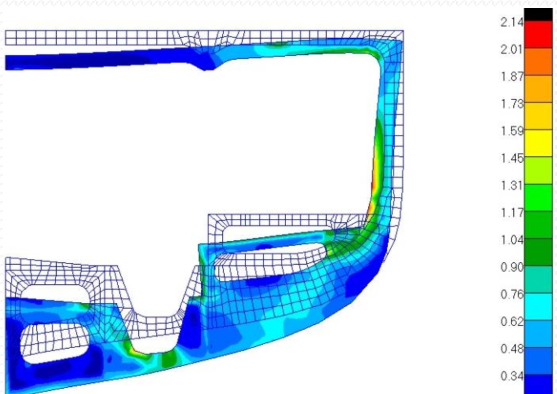
How to compare the proposed modifications?

Which solution should be recommended?

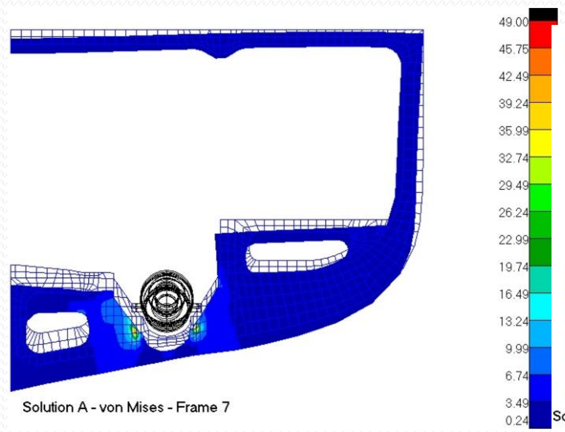
What is the next step?

Which solution should be recommended?

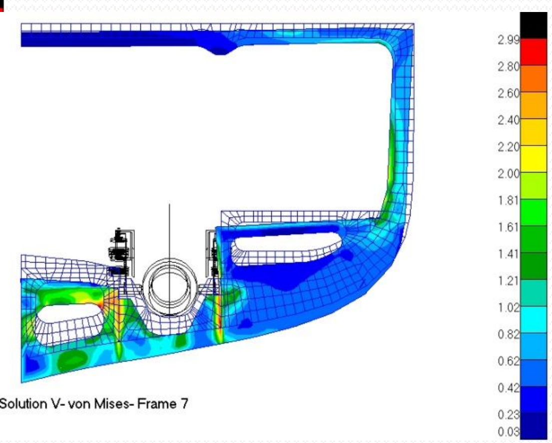
Ship 216	Structural Medications	Structural strength	Structural behavior
Solution “A”	Invasive	Sufficient	Stress concentrated on secondary and to the foundation keelson.
Solution “B”	Not possible	Slightly worst	Traction on the “shaft” keelson. Foundation keelson isolated from thrust.
Solution “V”	Simple	Slightly better	Load applied on the foundation keelsons. Tension over minimum web height.



Original Structure- von Mises - Frame 7



Solution A - von Mises - Frame 7



Solution V- von Mises- Frame 7

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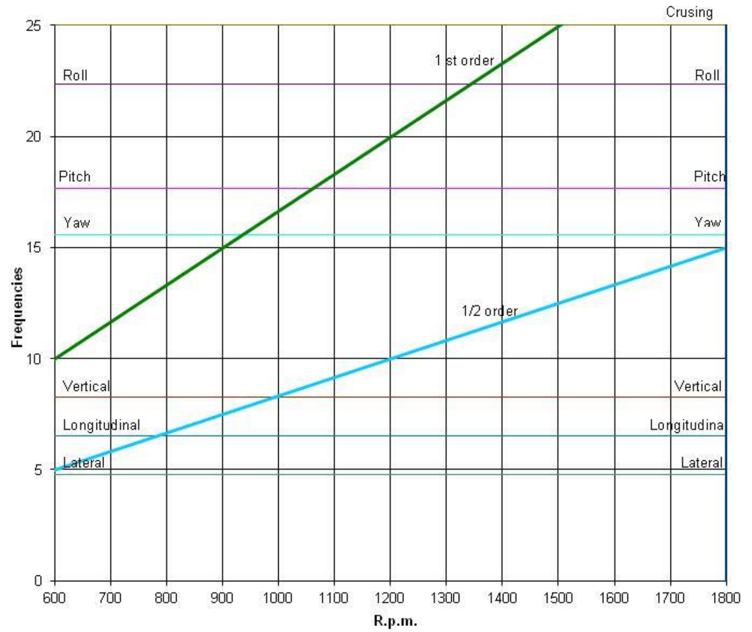
Integrated dynamic analysis of the support system

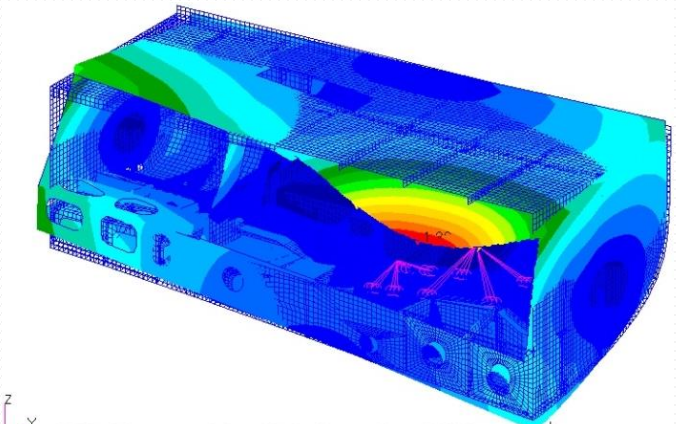
System:

Engine + Elastic Support + Foundation



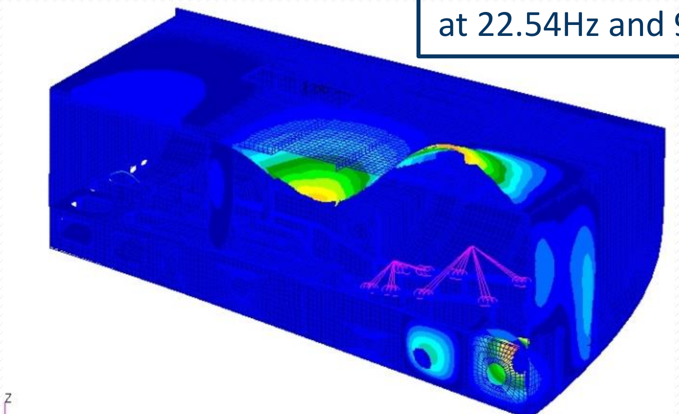
Design the support system *taking into account the interaction of the engine with the actual foundation structure.*

Reduce transmissibility and vibration!!



Original Strucuture- Eigen Mode Shape - Freq: 9.88Hz

Natural mode shapes at 22.54Hz and 9.88Hz



Original Strucuture- Eigen Mode Shape - Freq: 22.54Hz

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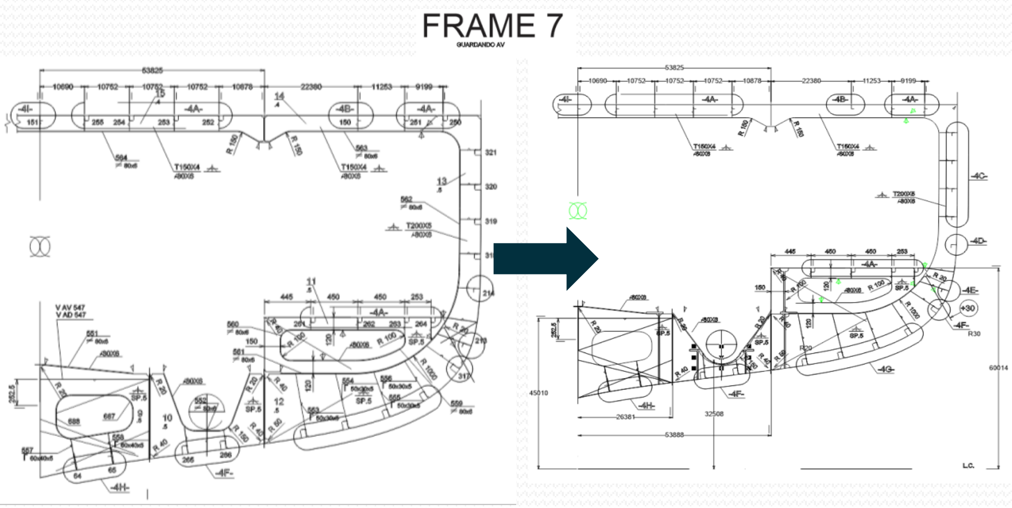
What is the next step?

Final design plans

Construction plans



•Perform detail design plans of the performed structural modifications.

•Classification society requirements.

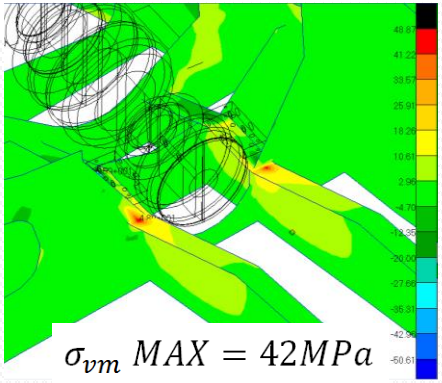
Fatigue Analysis

•Final secondary structures added to support the thrust blocks.

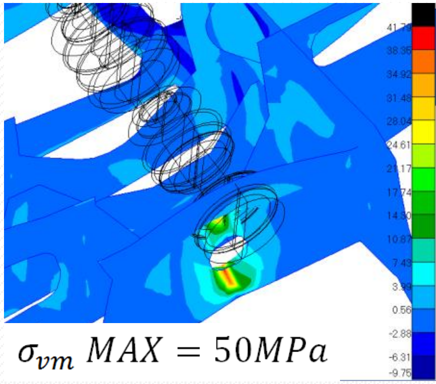
•Refined mesh.

•Applied load frequency.

Solution A



Solution B



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