Université de Liège

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Zachodniopomorski Uniwersytet Technologiczny w Szczecinie

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EMship Advanced Design

Structural design of self-unloading mining ship and unsteady flow computations over its vertical riser

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Company supervisor: Prof. Tomasz Abramowski

Szczecin, 30 th January 2013

EMship Advanced Design

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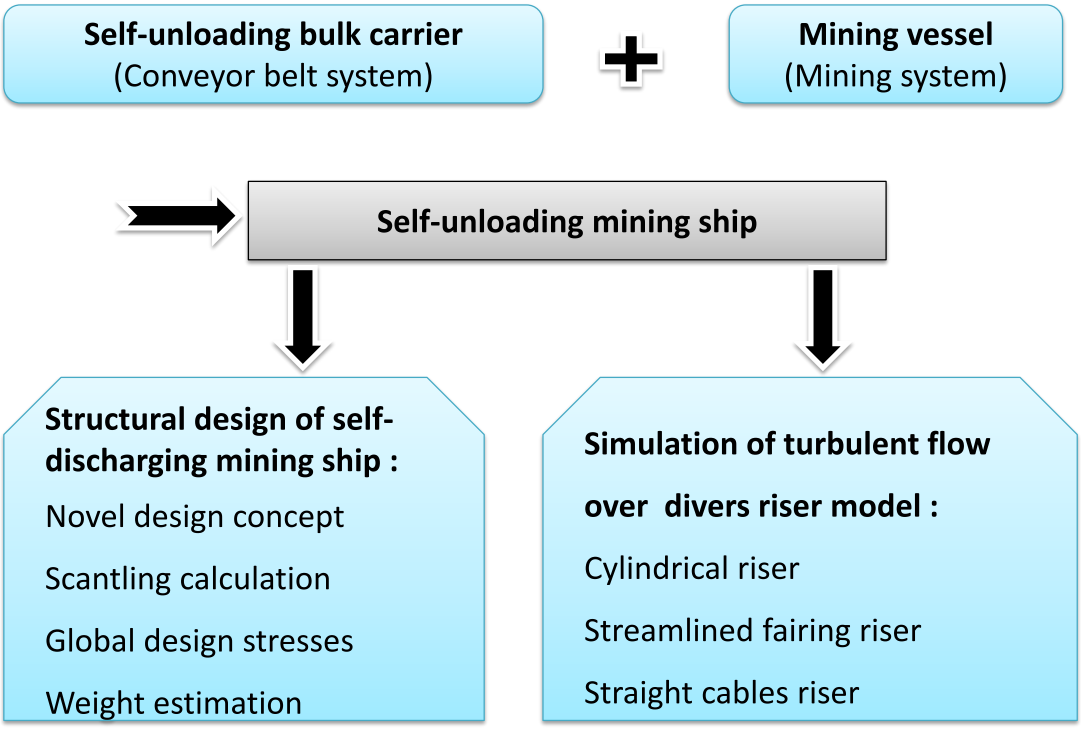

Self-unloading bulk carrier
(Conveyor belt system)

\+

Mining vessel
(Mining system)

Self-unloading mining ship

Structural design of self-discharging mining ship :

- Novel design concept
- Scantling calculation
- Global design stresses
- Weight estimation

Simulation of turbulent flow over divers riser model :

- Cylindrical riser
- Streamlined fairing riser
- Straight cables riser

Self-unloaders

- Enable to discharge without shore-based unloading equipment.
- Rapid discharging rate , reduced infrastructure and labor requirements.
- Bulk cargo handling option is an effective and competitive solution that helps keep costs down and minimize environmental impacts.
- Self-unloaders provide ideal solution for shipping and handling commodities

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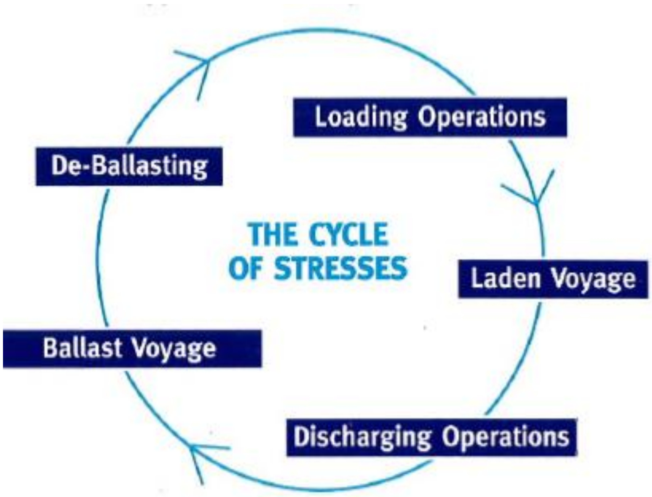
Self-unloading bulk carrier 'Kvitnes'

The De Beers diamond mining vessel ‘Peace in Africa’

Typical bulker operation

‘Careful cargo handling helps maintain bulk carrier safety –

bad practice lowers safety margins and increases risk ‘ (IACS)



THE CYCLE OF STRESSES

Loading Operations

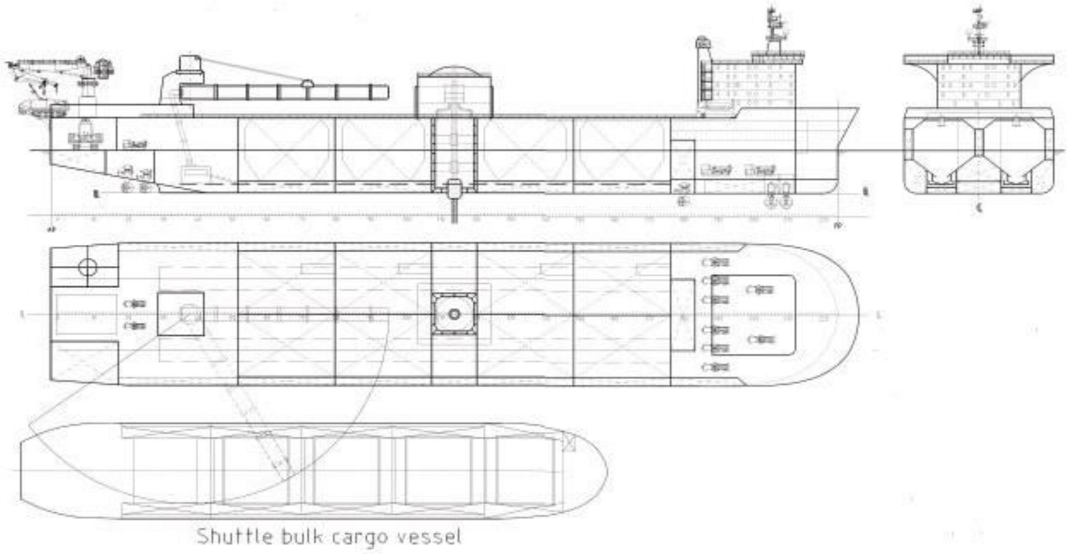
Laden Voyage

Discharging Operations

Ballast Voyage

De-Ballasting

Initial proposal for general arrangement of Self-unloading mining ship



☐ Main characteristics of the designed mining ship

Item	Magnitude	Unit
Length between perpendiculars L_{bp}	227	[m]
Rule length ,L	220.19	[m]
Breadth moulded ,B	43.2	[m]
Depth moulded, D	22.8	[m]
Draught moulded ,T	12.9	[m]
Block coefficient, C_b	0.845	[m]
Min.design draught at AP	8	[m]
Min.design draught at FP	8	[m]
Waterplane area coefficient ,C_{wp}	0.950	-
Area of the waterplane	9352	[m^2]
Maximum service speed, V	15	[knots]

Design consept of Self-unloading mining ship

Principal characteristics:

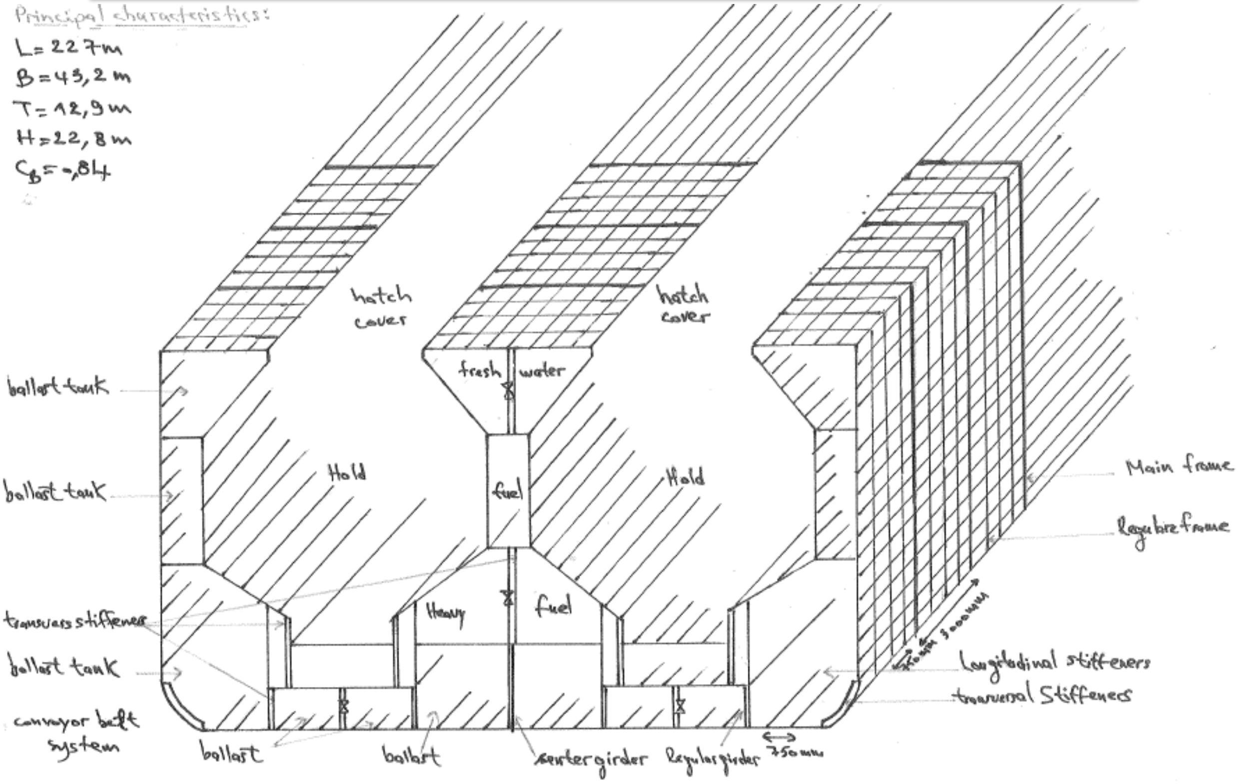
L = 227 m

B = 43,2 m

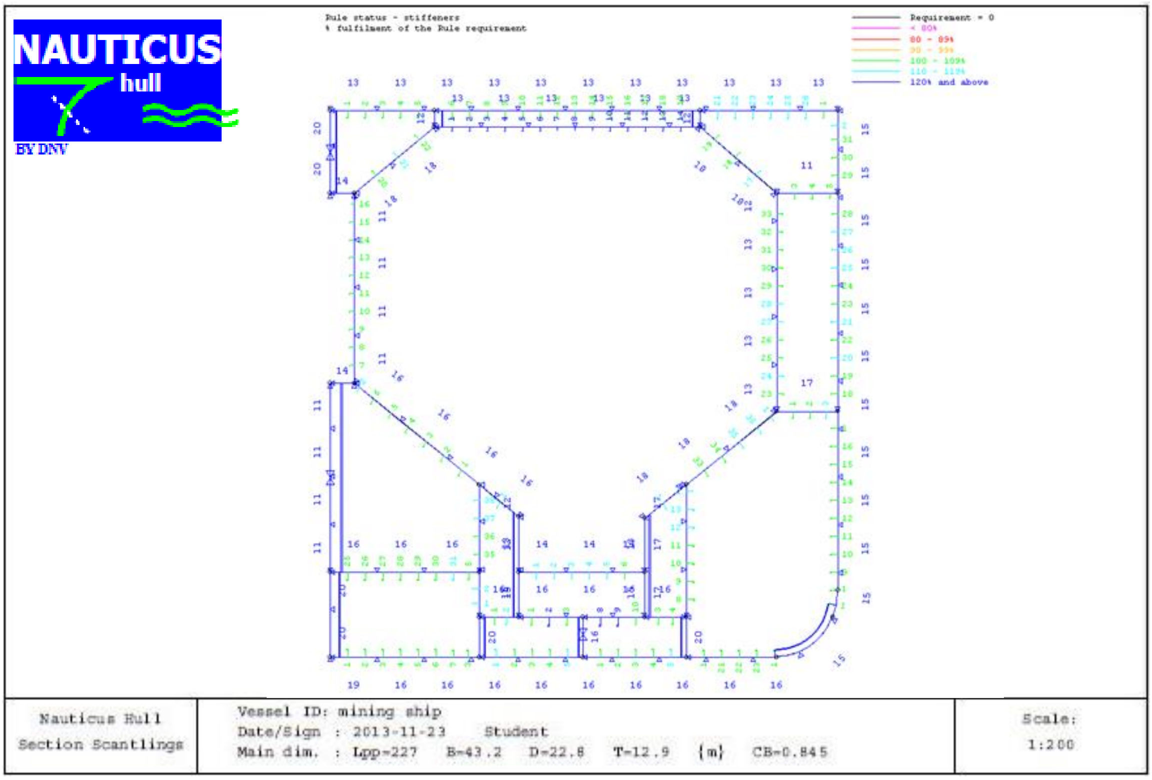
T = 12,9 m

H = 22,8 m

C_B = 0,84



Structural design concept using Nauticus hull package



Rule status - stiffeners
% fulfilment of the Rule requirement

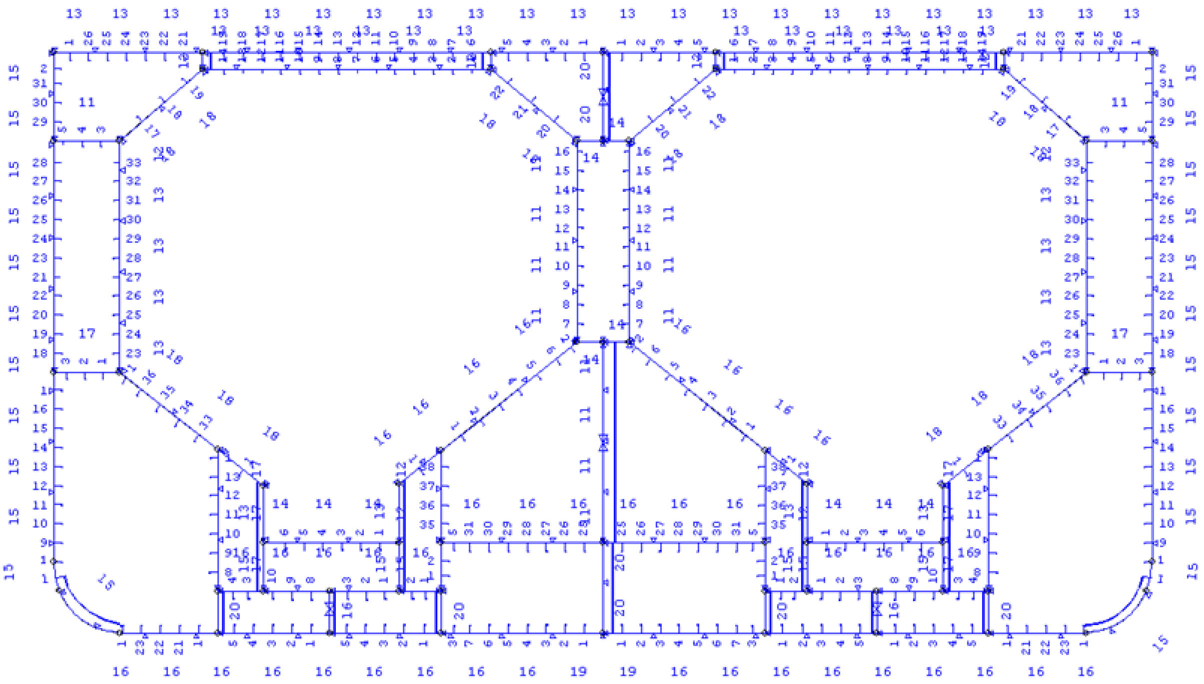
—	Requirement = 0
—	< 80%
—	80 - 89%
—	90 - 99%
—	100 - 109%
—	110 - 119%
—	120% and above

Nautics Hull Section Scantlings	Vessel ID: mining ship Date/Sign : 2013-11-23 Student Main dim. : Lpp=227 B=43.2 D=22.8 T=12.9 {m} CB=0.845	Scale: 1:200

❑ Main particulars and structural data of the ship hull

Material	NV-NS denotes normal strength structural steel			
Yield stress [Mpa]	235			
Items [mm]	Magnitudes for different panels			
	Deck	Shell	Bottom	Bulkheads
Plate thickness	13	15	16	11/20
Web frames				
Span (main frames)	3000	3000	3000	
Thickness (t)	13	15	16	
spacing(regulars frames)	750	750	750	
Longitudinal Stiffeners HPbulb profil				
Web thickness (t)	13	11/12	12/13	10/12
Web depth (h)	300	280/320	320/340	200 /340
Spacing (S)	750	750	750	750
Transversal Stiffeners Flat bar profil				
Web thickness (t)	14	13	12/20	11/14
Web depth (h)	340	320	232/500	240/340
Span	3450	2995	1669	670/2318
Cut out breadth (b)	200/600			

Detailed scantling of the cross section (105 m AP)

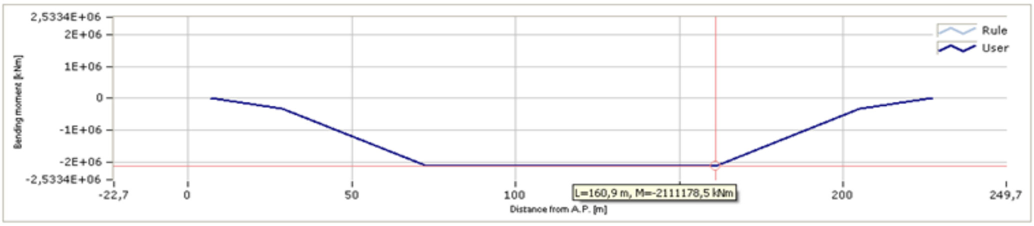


❑ Comparison between input and design bending moment

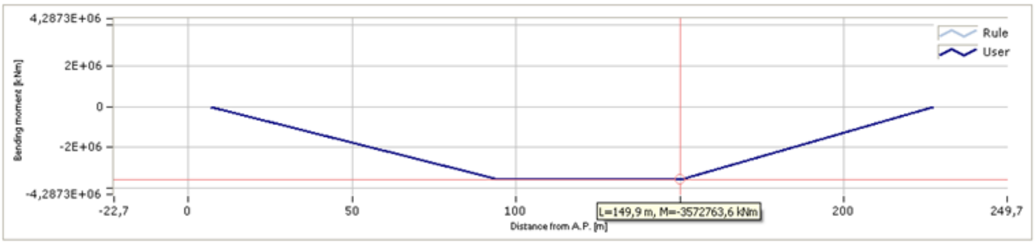
Frame 140 (105 m from AP)	Sagging (kNm)	Hogging (kNm)
Still water bending moments standard according to rules, M_S	2111178	2308789
Design still water bending moments, M_S (input)	2262340	2474100
Design wave bending moments, M_W (input)	3828575	3616815
Design wave bending moments, M_W for buckling check input	3983033	3616815
Horizontal wave bending moment according to rules, M_{WH}	1744383	

Bending moment distribution

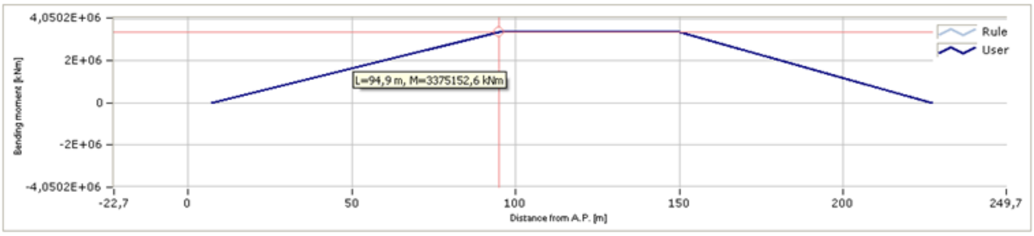
- Still water bending moment (Sagging)



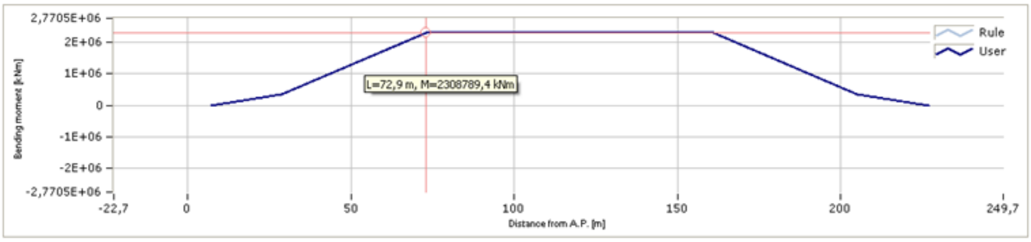
- Still water bending moment (Hogging)



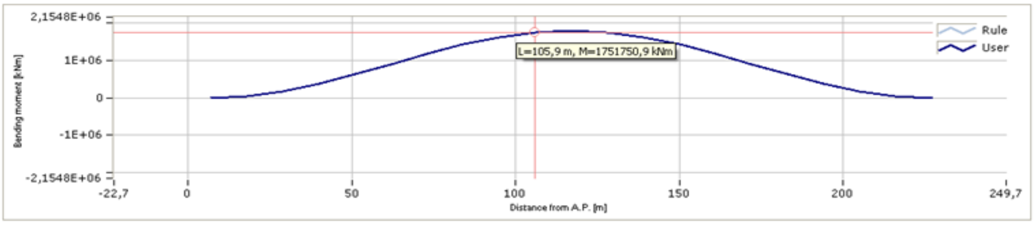
- Wave bending moment (Sagging)



- Wave bending moment (Hogging)

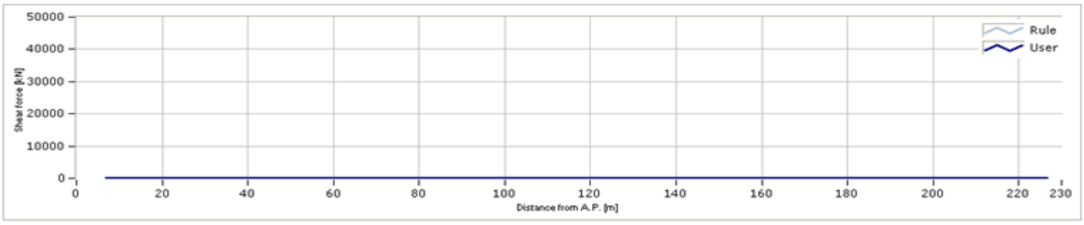


- Wave horizontal bending moment

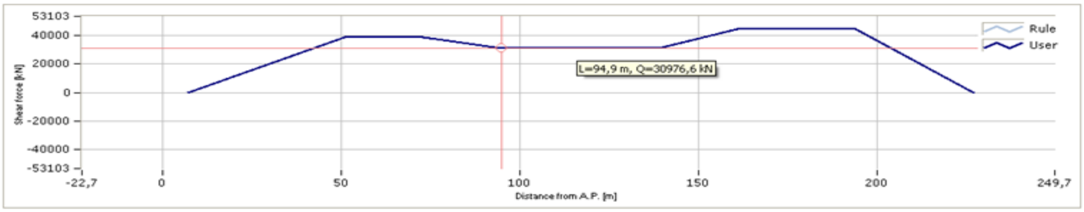


Shear force distribution

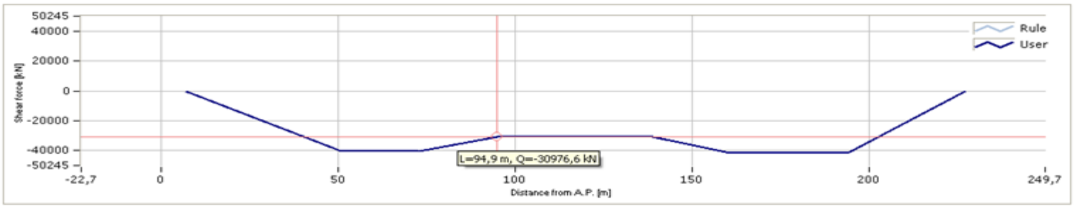
- Still water shear force



- Wave shear force (Sagging)



- Wave shear force (Hogging)

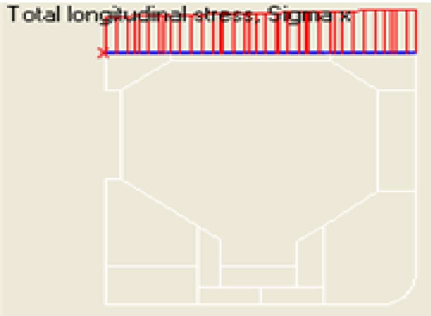


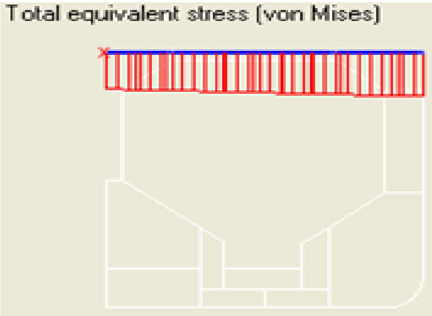
Global design stresses

❑ **Longitudinal and equivalent (Von Mises) stress distribution for different panels**

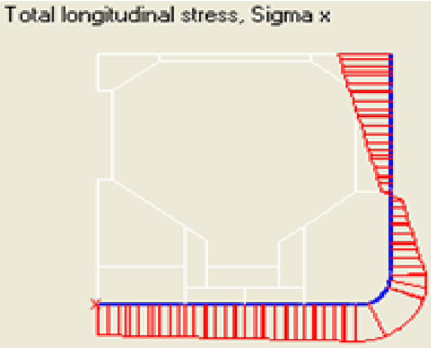
Sagging

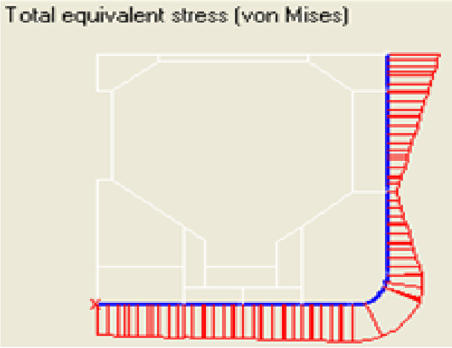
Deck





Outer shell





EMship
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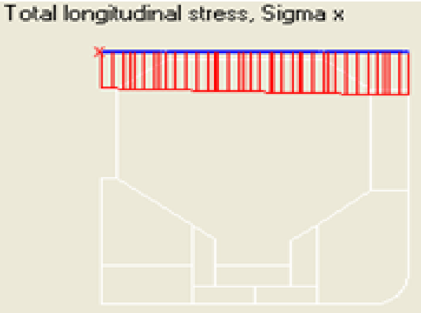
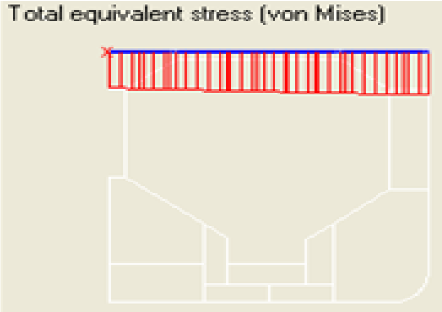
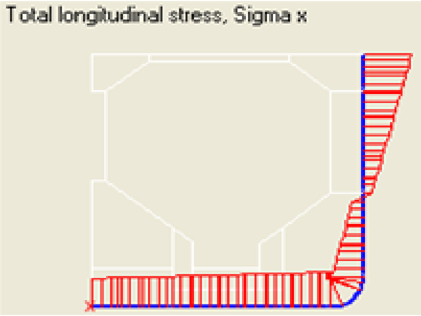
Hogging

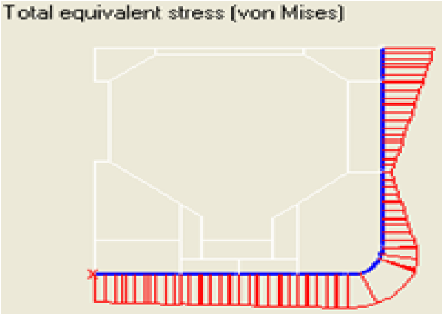
Deck





Outer shell





❑ Buckling check

Stress areas :

- ➢ Deck panel supporting the mining lifting system in the mid ship
- ➢ The crane and the boom in the aft part ship
- ➢ Bottom supporting the riser system
- ➢ Inner bottom along the conveyor belts system
- ➢ Cargo holds bottom ,hatchway corners and bulkheads

	Deck		Side		Bottom		bulkhead	
Stress values	Applied stress	Buckling strength	Applied stress	Buckling strength	Applied stress	Buckling strength	Applied stress	Buckling strength
Plates	160	173	134.6	188.5	120	191.4	121.1	173.4
Longitudinal Stiffeners	150	200	70	207	121	211	86	178
Transversal stiffeners	160	235	160	235	160	235	160	235

❑ Global results of the scantling

Item	Magnitude	Unit
Moment of inertia about the horz. neutral axis, Ih	499.45	[m^4]
Moment of inertia about the vert. neutral axis, Iv	1266.91	[m^4]
Section modulus, bottom (z = 0 mm)	48.93	[m^3]
Section modulus, deck line (z = 22800 mm)	39.66	[m^3]
Section modulus, at side (y = 21600 mm)	58.65	[m^3]
Height from base line to the neutral axis	10.21	[m]
First moment of the area above the neutral axis, s	26.36	[m^3]
I/s	18.95	[m]

❑ Weight estimation (Frame 120 to 160)

- ➢ Reduced weight of hull structures designed for a very large bulk carrier plays an important role as the economic efficiency is the most significant aspect .

Item	Computation	magnitude	Unite
Area of plates	A_{plates}	10.64	[m^2]
Area of longitudinal members	A_{Long}	3.2	[m^2]
Area of transvers stiffeners	A_T = Σ (web height . thickness)	0.63	[m^2]
Total area	A_{Total}	14.43	[m^2]
Lenght of bloc	L_{Bloc}= Nr frames . Frame spacing	30	[m]
Volume of the bloc	$V_{total\ block=}\ L_{Bloc} \cdot A_{Total}$	432.9	[m^3]
Density of steel NS	$\rho_{\ NS\ steel}$	7.850	[t/m^3]
Total weight of the bloc	$W= \rho_{steel} \cdot V_{total\ block}$	3398.265	[tones]

Simulation of turbulent flow over mining riser

❑ Characteristics of the cylindrical mining riser

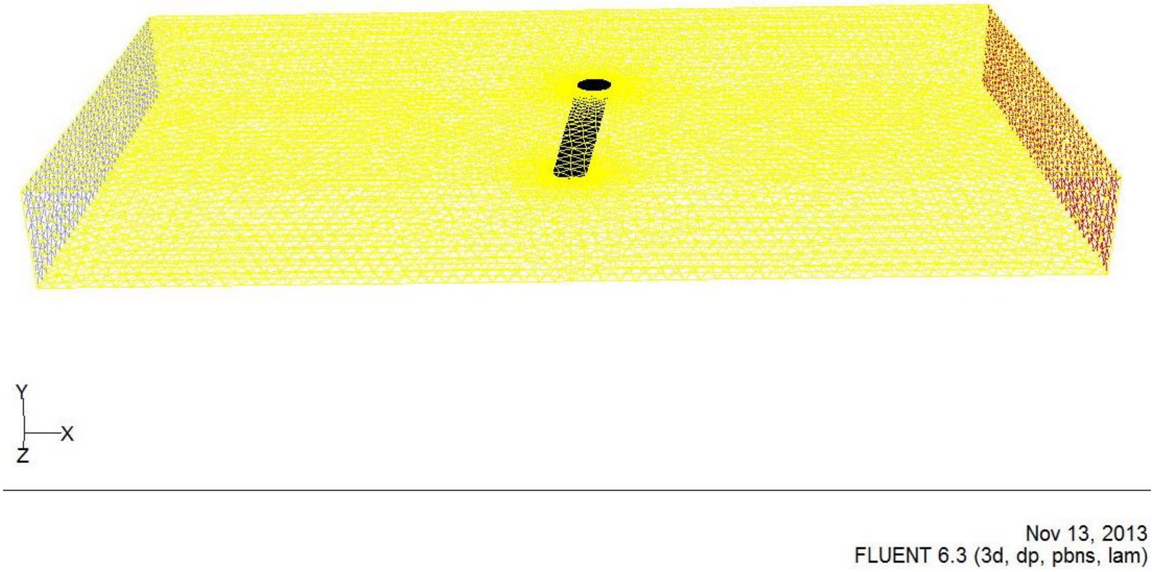
Item	Magnitude	Units
External diameter (D_0)	0.7	[m]
Inner diameter(D_i)	0.4	[m]
Wall thickness (t)	0.15	[m]
Riser length (L)	5000	[m]
Elasticity (E)	206.82×10^9	[N/m^2]

❑ Control parameters of the simulation

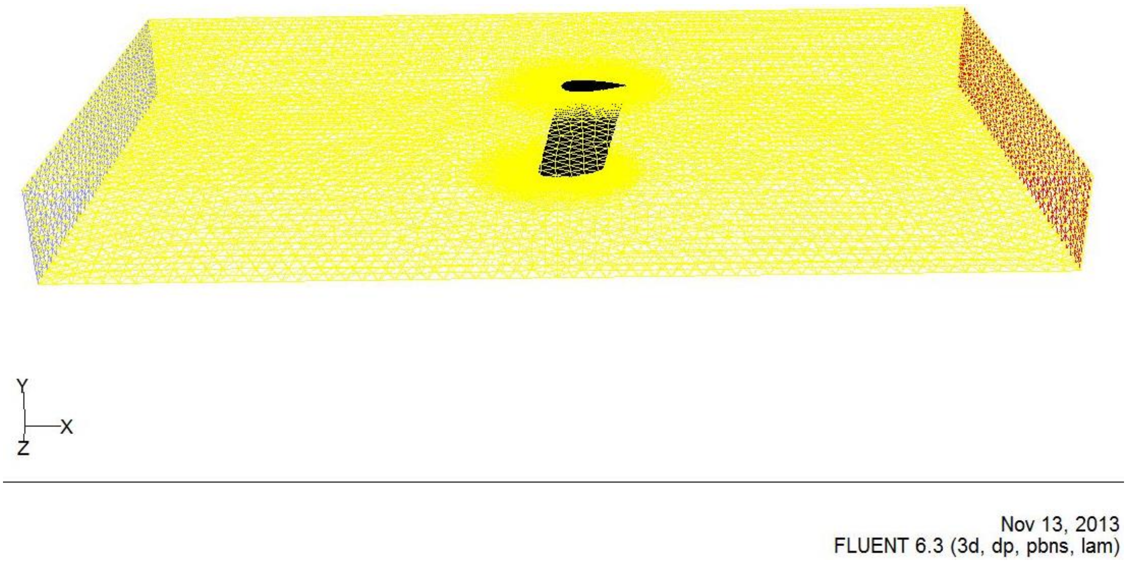
Input data	Magnitude	Units
Temperature (T)	288	[K]
Sar water density(ρ)	1025	[kg/m^3]
Dynamic vescosity (μ)	0.001003	[kg/s m]
Riser diameter (D)	0.7	[m]
Lenght of riser section (L)	2	[m]
Strouhal number (St =f D/U)	0.2	-
Riser inclination	70	degree
Weted Area for cylindrical riser	4.396	[m^2]
Weted Area for streamlined fairing riser	5.652	[m^2]
Weted Area for straight cables model riser	6.908	[m^2]

3D computational domains for three riser model

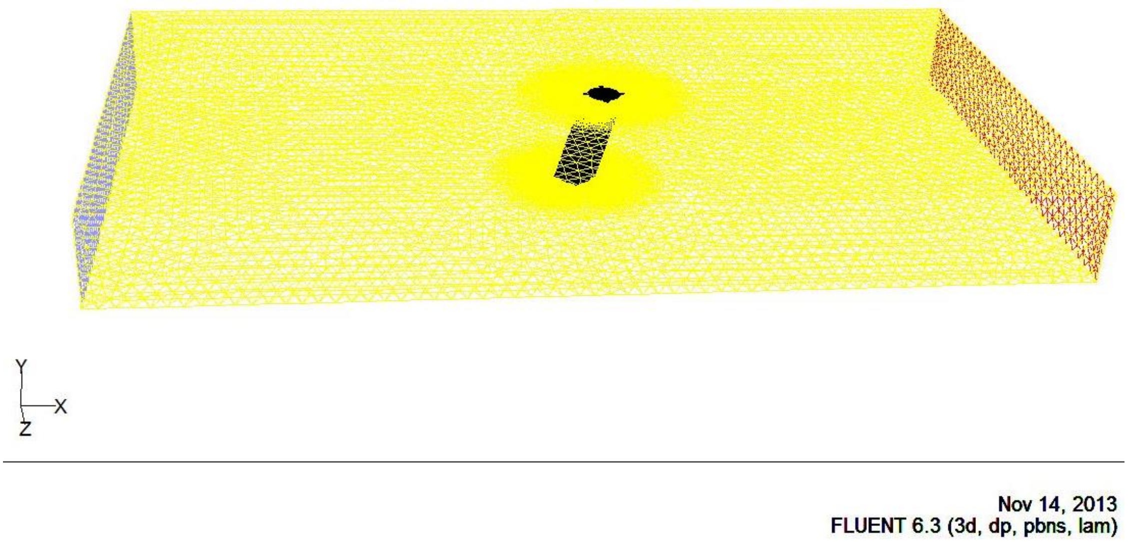
- **Computational domain for cylindrical riser**



- **Computational domain for streamlined riser**

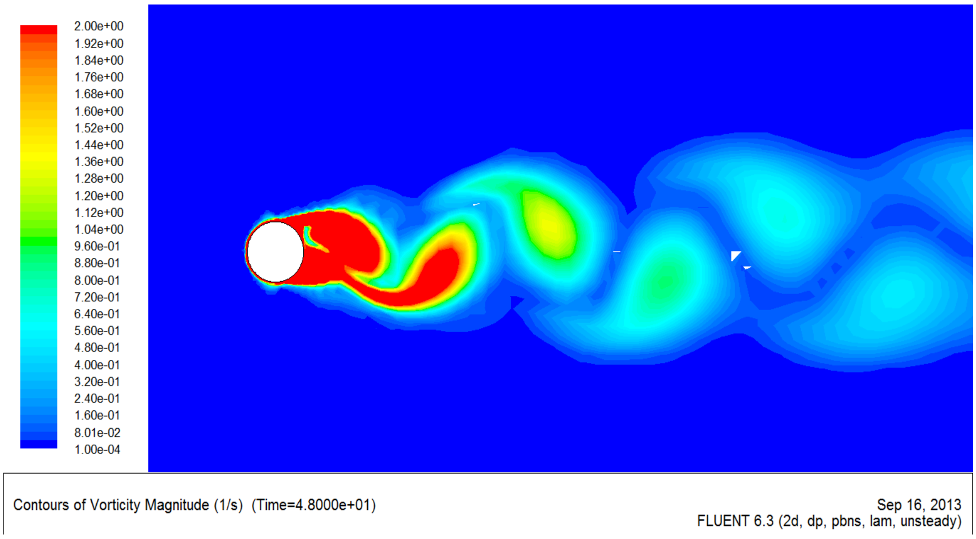


- Computational domain for straight cables riser

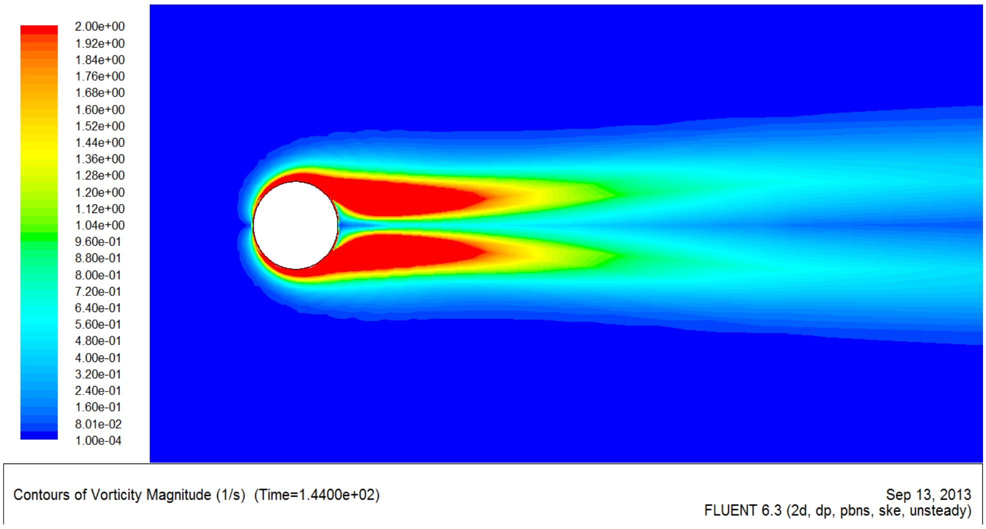


RESULTS ANALYSIS

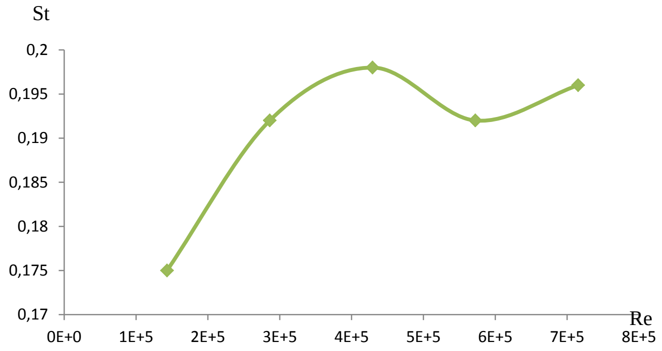
☐ Vorticity contours for 2D laminar flow over a cylinder



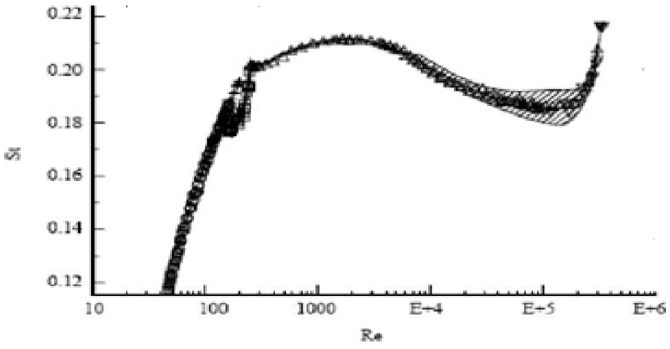
☐ Vorticity contours for 2D turbulent flow past a cylinder



✓ Validation of Strouhal number as a function of Re



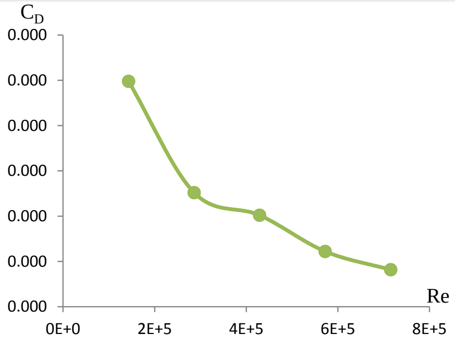
Numerical result of Strouhal number as a function of Re



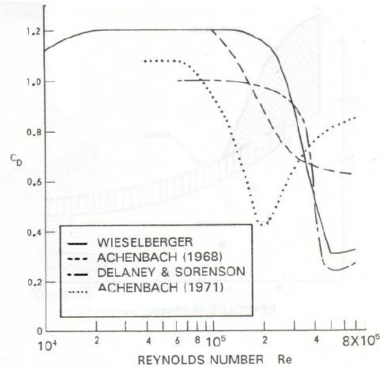
Experimental result of Strouhal number as a function of Re

❑ Simulation of 3D flow past cylindrical, streamlined fairing & straight cable riser

✓ Validation of drag coefficient in function of Re for cylindrical riser

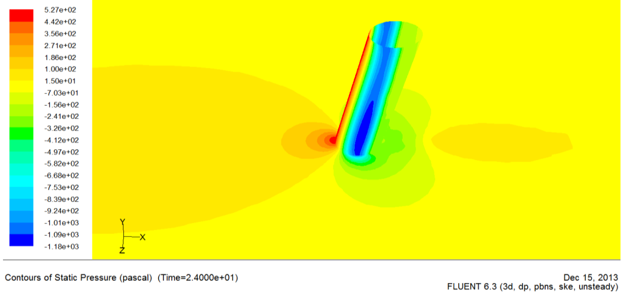


Numerical result of cylinder drag coefficient as a function of Re



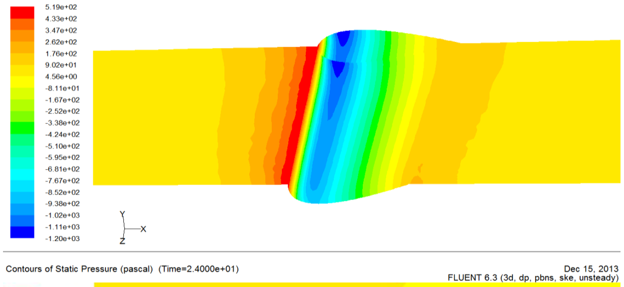
Experimmental result of cylinder drag coefficient as a function of Re [Wieselberger (1921)]

- **Pressure contours**



Contours of Static Pressure (pascal) (Time=2.4000e+01)

Dec 15, 2013
FLUENT 6.3 (3d, dp, pbns, ske, unsteady)



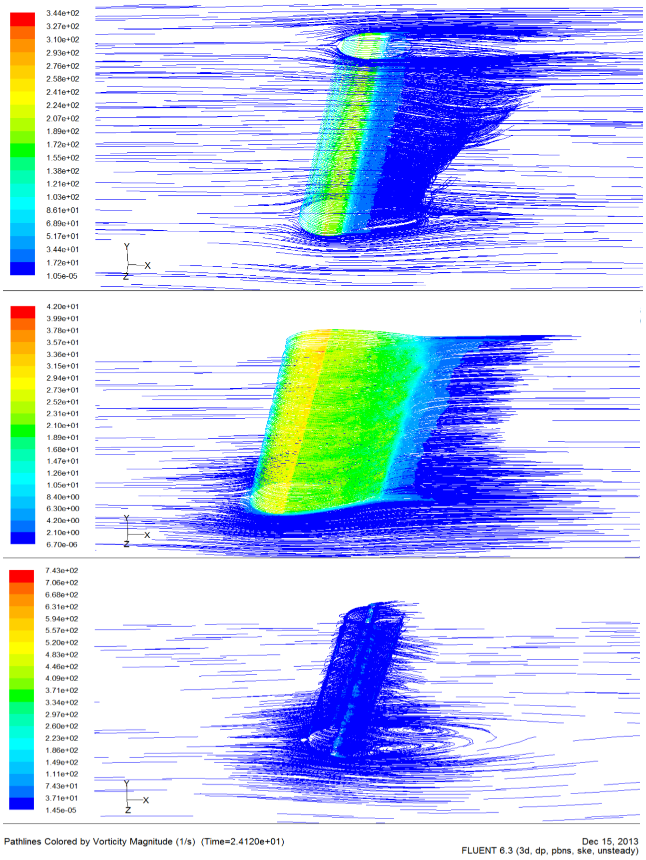
Contours of Static Pressure (pascal) (Time=2.4000e+01)

Dec 15, 2013
FLUENT 6.3 (3d, dp, pbns, ske, unsteady)

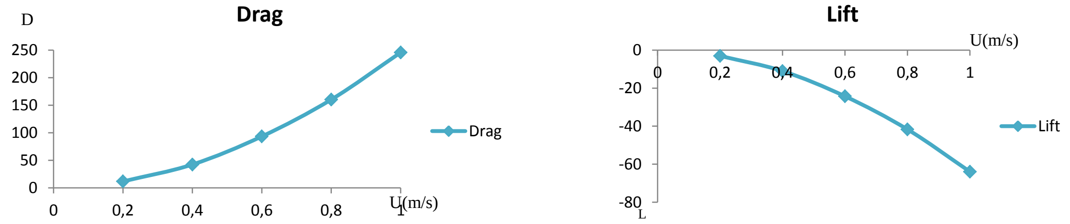
Contours of Static Pressure (pascal) (Time=2.4120e+01)

Dec 15, 2013
FLUENT 6.3 (3d, dp, pbns, ske, unsteady)

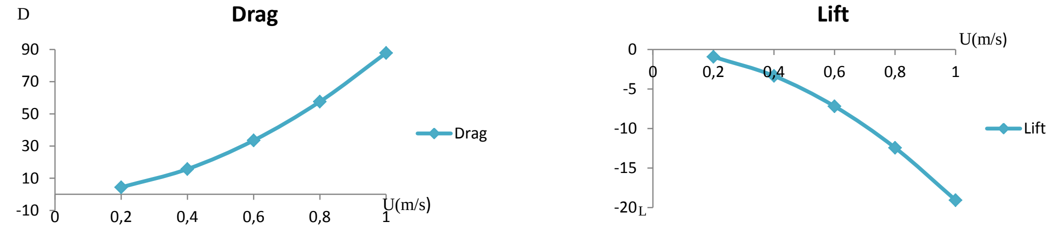
• Pathlines vorticity



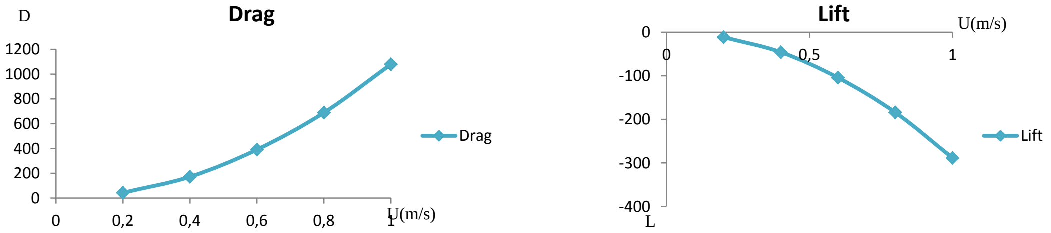
▪ Drag and lift force for three riser models



Cylindrical riser model

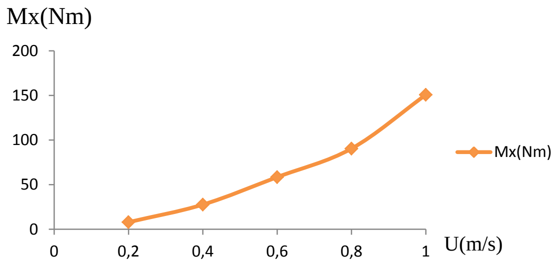


Streamlined fairing riser model

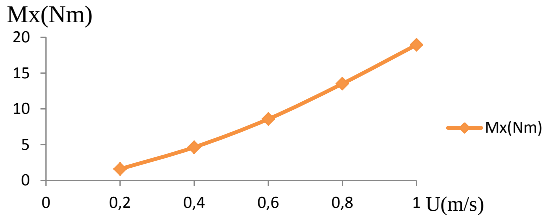


Straight cables riser model

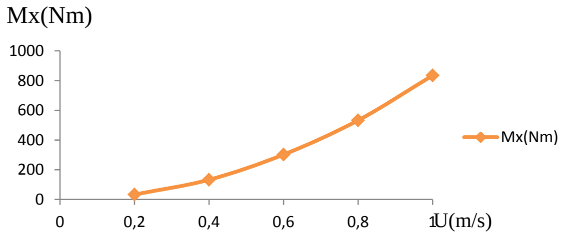
- **Torsional moments for three riser models**



Cylindrical riser model

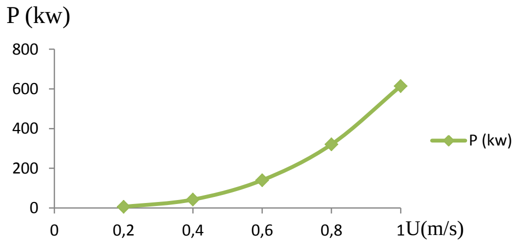


Streamlined fairing riser model

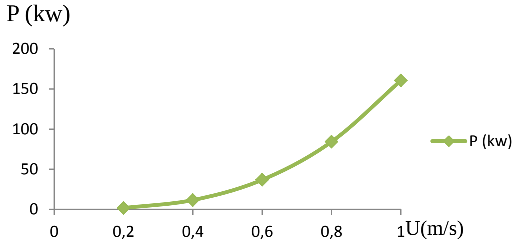


Straight cables riser model

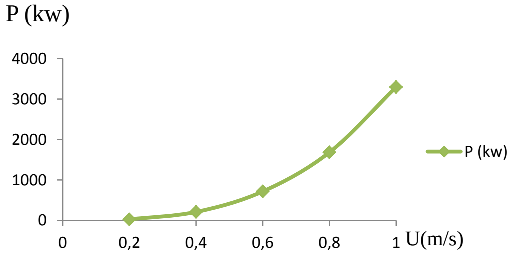
- **Power requirements for towing the risers from seafloor**



Cylindrical riser model

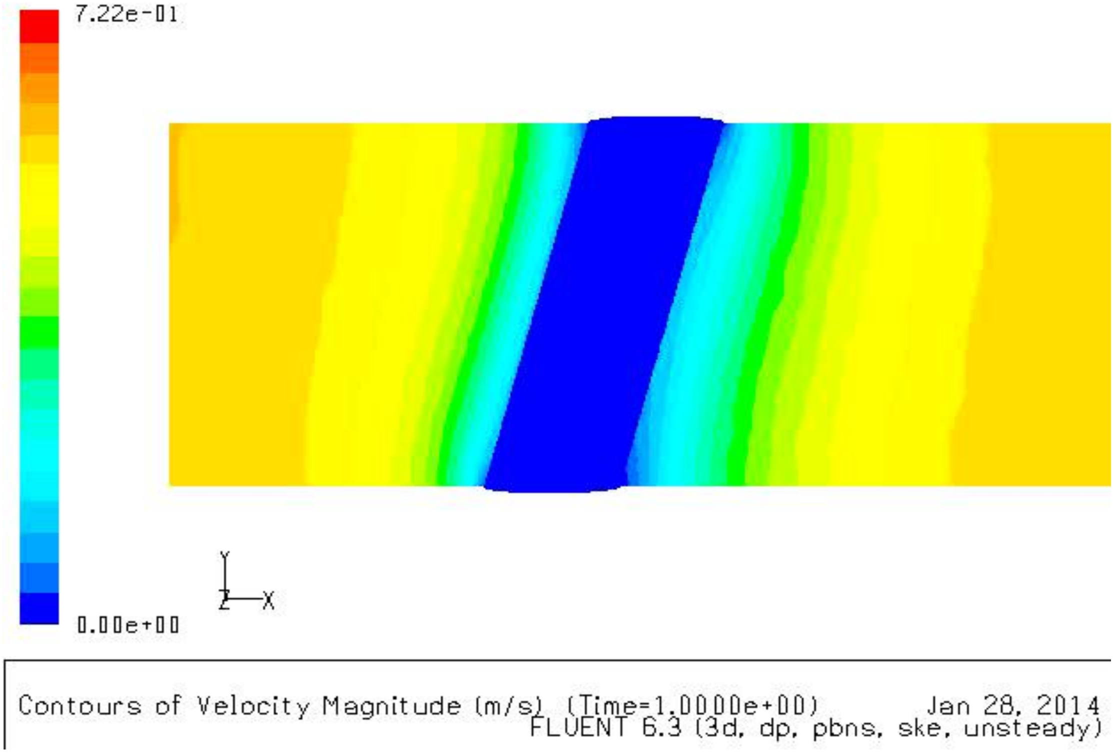


Streamlined fairing riser model

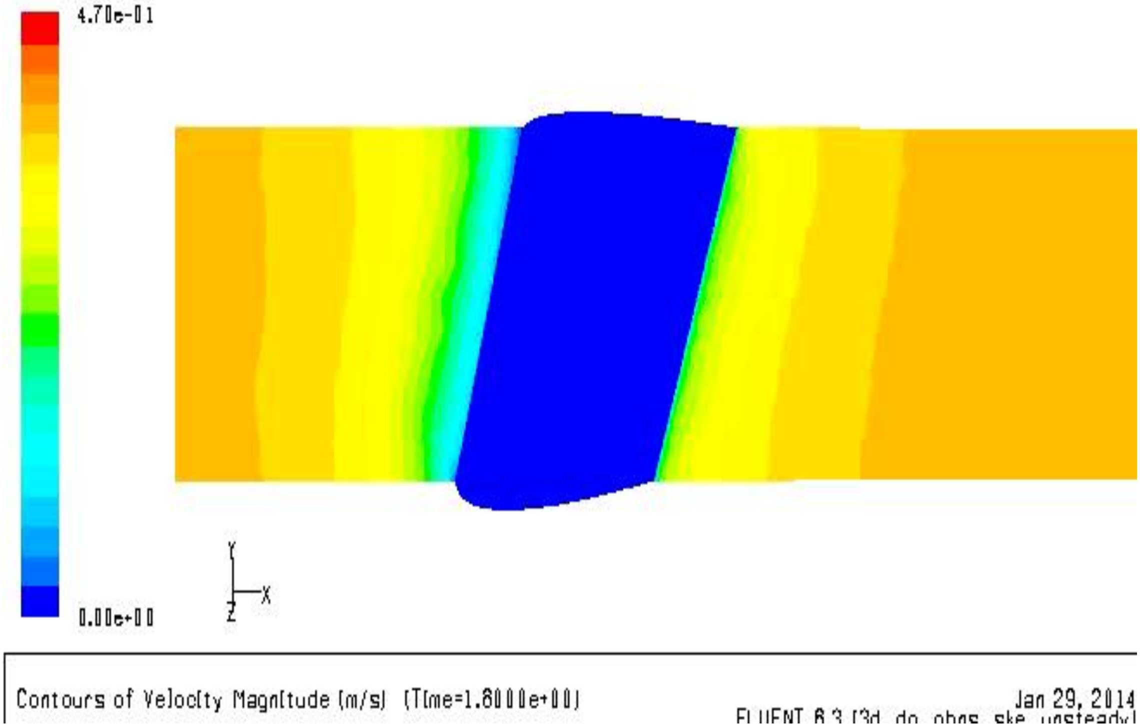


Straight cables riser model

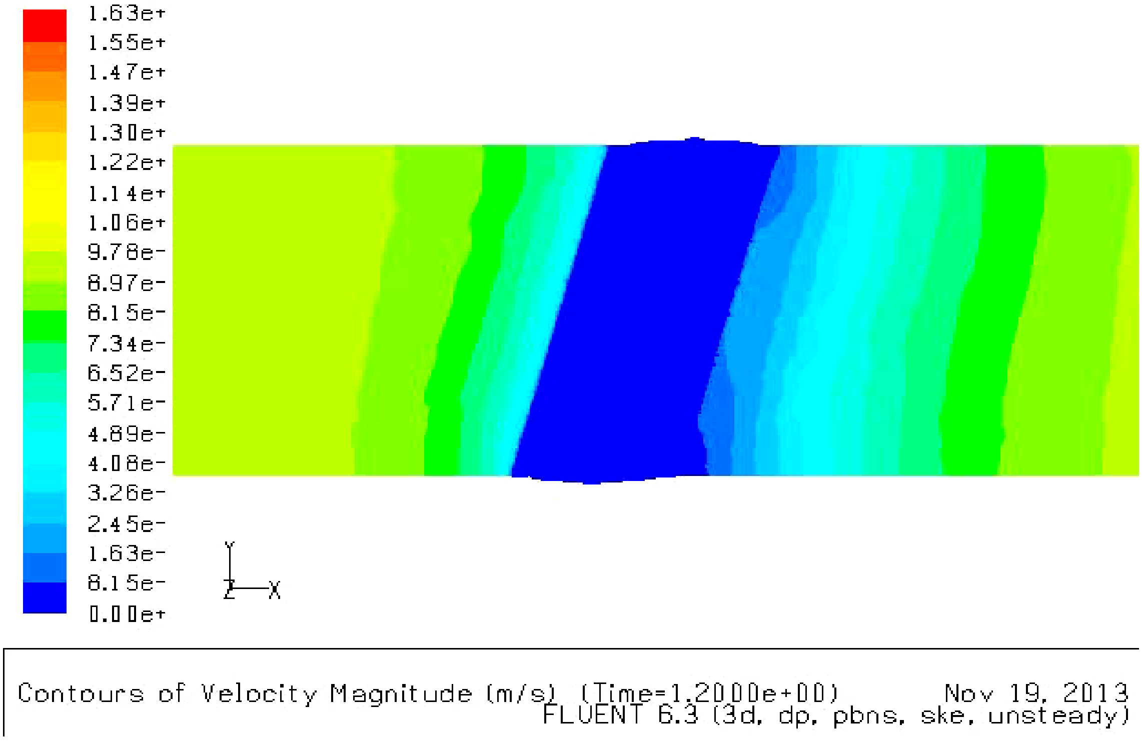
❖ Flow velocity animation over cylindrical riser model



❖ Flow velocity animation over streamlined fairing riser model



❖ Flow velocity animation over straight cables riser model



CONCLUSION

- The novel concept of self-unloading mining ship should be accomplished in mining applications on account of its important technical and economical benefits
- Ship structural design has very significant influence on the accident resistance and the collision energy absorption capability depending on the scantling
- The mining and unloading system strongly affect the adopted design solutions, to avoid the failure of the hull structure, the reinforcement should be maximum in those areas.
- The hull structure requires additional strength due to the nature of cargo and the planned location of ship operations, remote from ship repair services.
- Because of the suspected structural failure, the classification societies has to set new or revised requirements to give higher safety and survival margins.

- The streamlined fairing (NACA profile) could be an optimum riser model in alleviating the vortex shedding , but its complex geometry causes significant stresses and creates more problems in the use.
- The straight cables configuration can generate the least vortex-shedding intensity, minimum lift and minimum increase in drag, and little torsional moments and power requirements, if the geometry is arranged in helical form with a specific pitch angle.

- In order to hit the target of developing a commercial deep ocean mining technology and to improve new configurations for riser systems robust to loads imposed by the design extreme conditions, it is required to :
- Analyze the structural integrity of deep sea pipes following extreme events
- Perform a flow computation over diverse riser models to ensure the safety of the riser and the mining ship.

Thank you for your attention

Dziękuję bardzo za uwagę

شكرا لكم على انتباهكم