



SOFTWARE

Sesam user course

HydroD Hydrostatics & Stability

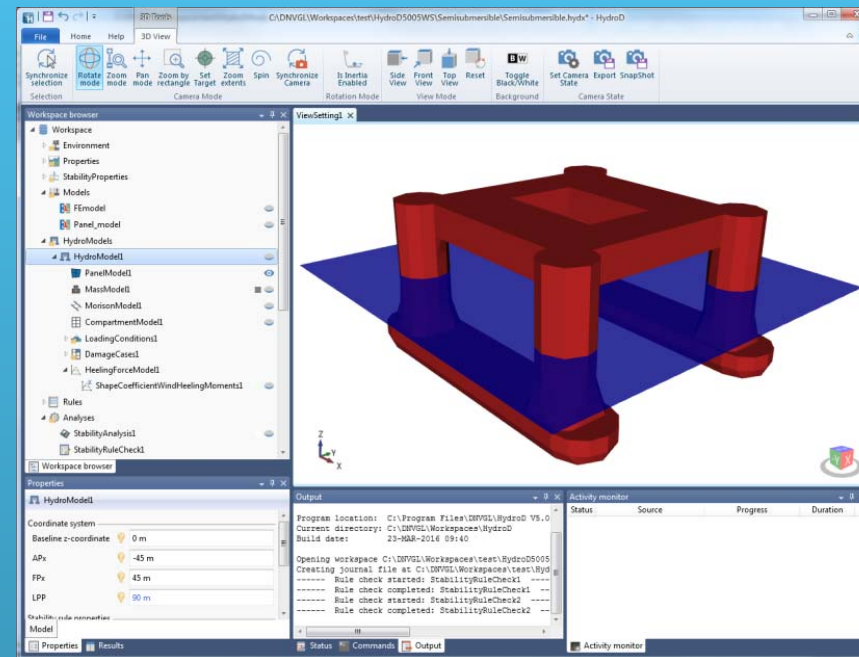
DNV GL
12 May 2016

Ungraded

Scope of presentation

Describe features & commands for performing a hydrostatic analysis, and their concepts

- Analysis setup
- Code-checking
- Reporting

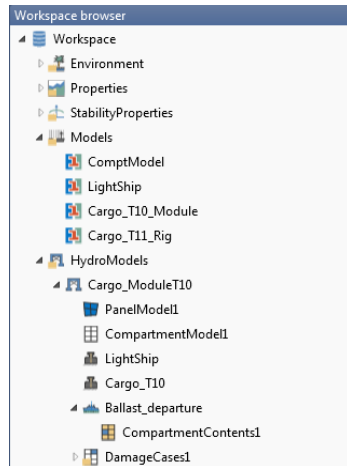


Ungraded

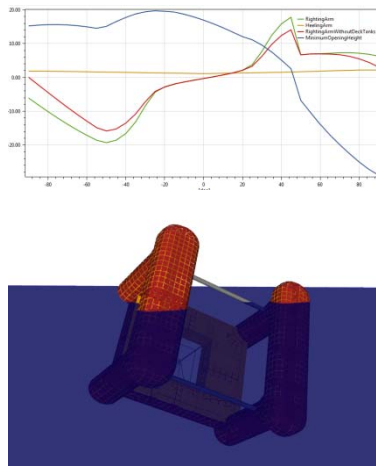
Why HydroD for Hydrostatics and Stability?

Function

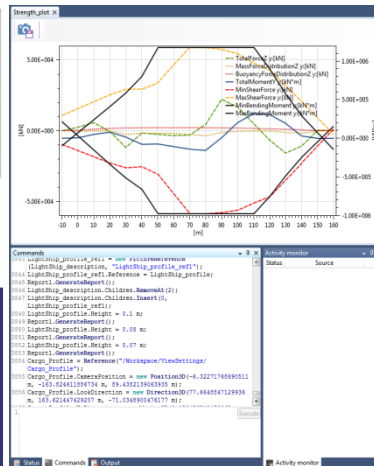
User friendly



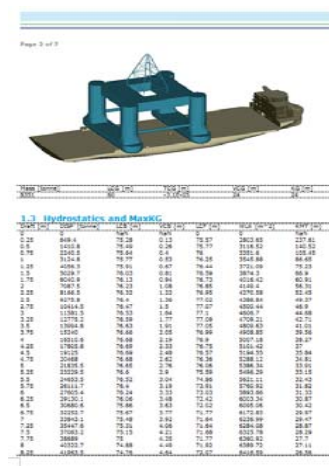
Robust



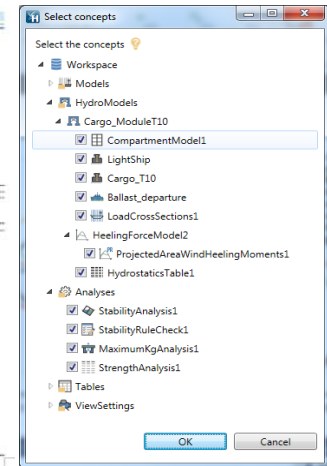
Flexible



Reportable

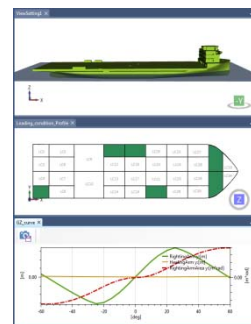


Reusable

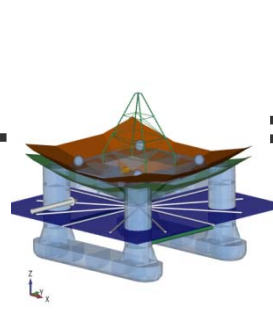


Application

Ship



Offshore

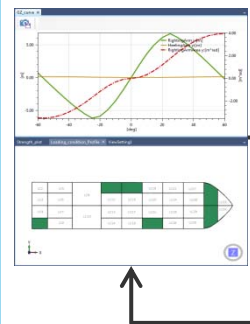


Temporary cond.

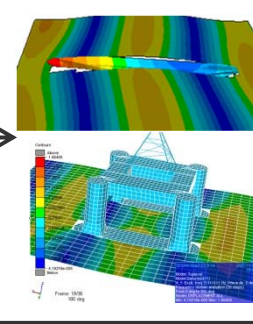


Integrated Engineering process

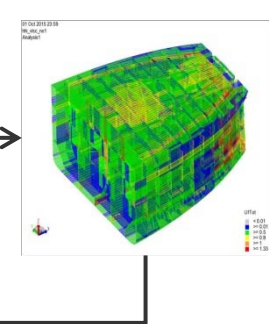
Stability



Motion&Acc.

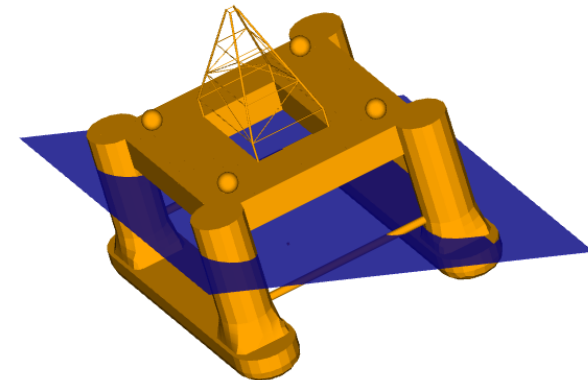
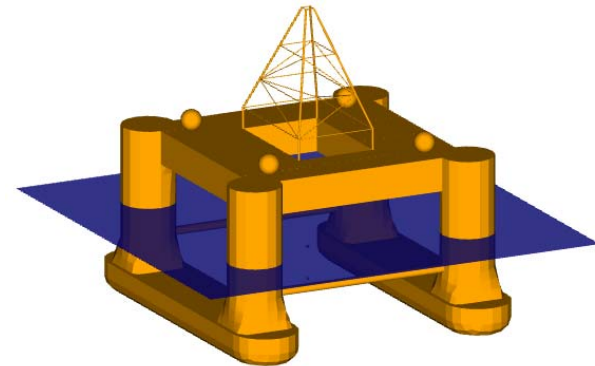


Structure



Some highlights

- Flexible and easy to do hydrostatic and stability computations in intact or damaged condition
- Variable filling or flooding of internal tanks (by specifying filling fraction)
- Automatic computation of trim, heel and draft to balance mass and buoyancy
 - No need for remodelling if non-zero trim and heel
- Automatic filling of tanks to balance mass and buoyancy in different loading conditions
 - No need to remodel with different fillings
- Stability codes for ships and mobile offshore structures



Ungraded

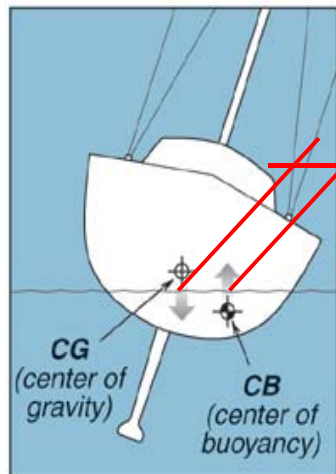
Main features

- Computation of draught, trim and heel
- Computation of GZ-curves and metacentric height
- Balancing vessel and maximizing GM by filling of n tanks
- Report, including tables and plots, of
 - buoyancy information (including block coefficient)
 - trim moment
 - flooding openings distance to waterline
 - righting and heeling moment curves, righting and heeling arm areas etc.
 - code check results
- Computation of calm sea sectional force and moment curves.
- Computation of wind heeling moment
- Max KG (AVCG) analysis
- Watertight/Weathertight integrity plan

Ungraded

Hydrostatic computations

- Accurate computations (no interpolations or approximations)
 - Exact level of free surface in internal tanks computed at every heel angle
 - Exact draught of model computed at every heel angle (ensuring constant displacement during the heel motion)
 - Option to iterate on trim balancing out trim moments
 - Elements cut in the waterline/free surface level to give exact volume and mass computations
 - Mass and centre of gravity of tank fluid computed by an analytically exact method

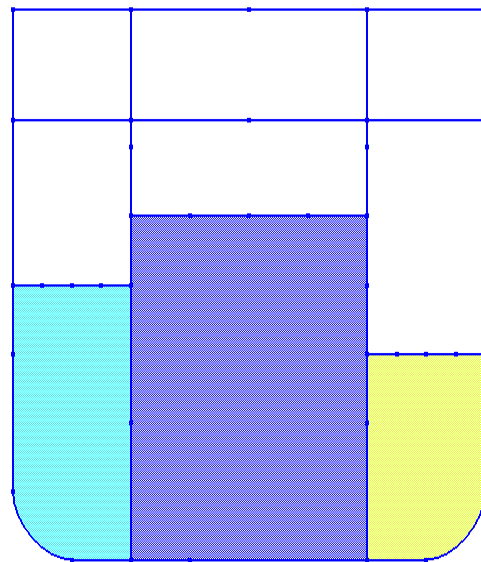


- **GZ** is the horizontal distance between CG and CB
- **GZ** provides an upward-acting torque called the righting moment (RM)
- **RM** is calculated by multiplying the GZ by the vessel's displacement

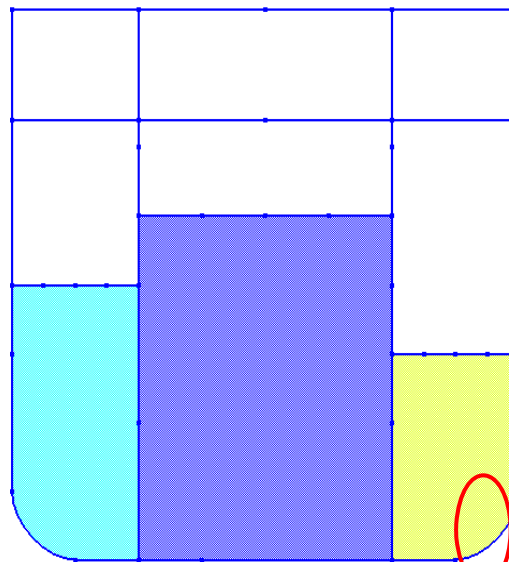
Ungraded

Flooded tanks

- HydroD will find new equilibrium position



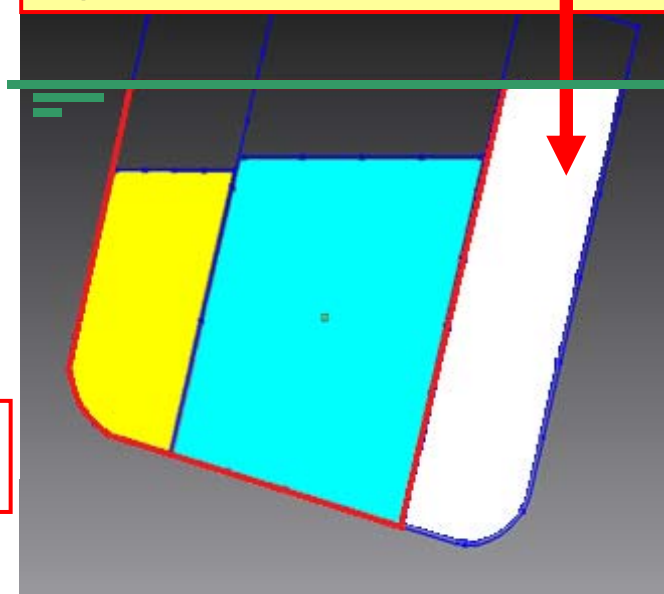
Equilibrium position
(draught, trim, heel)



A flooding occurs
in one of the tanks

Using lost buoyancy method

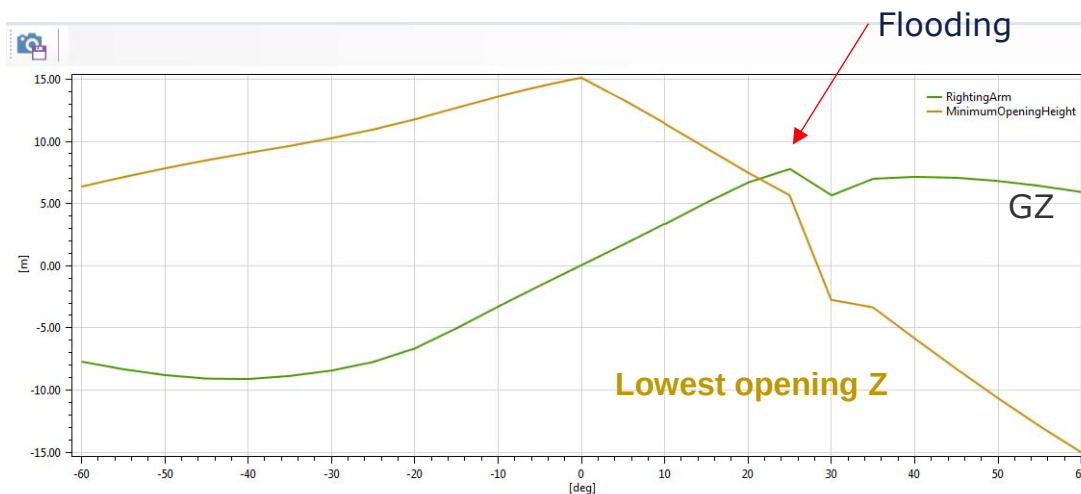
Flooded tank automatically
filled (or really emptied) until
equilibrium is reached



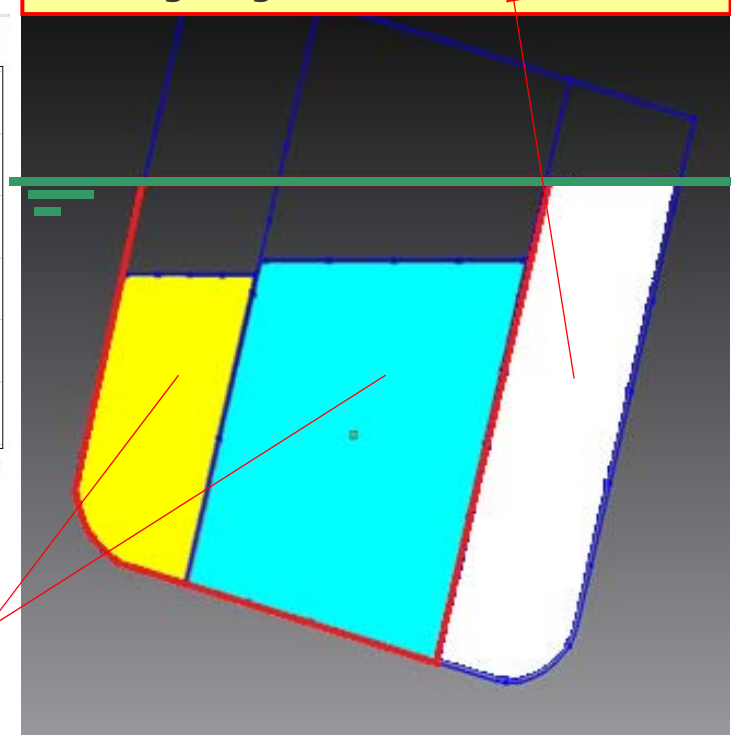
Closed tanks, same mass as
before, but different top surface

Results – Righting arm (GZ) curve – Flooded tanks

- Computing GZ-curve with flooded tanks
 - For each angle in computation (here -60 deg -> 60 deg) the free surface in all tanks are computed



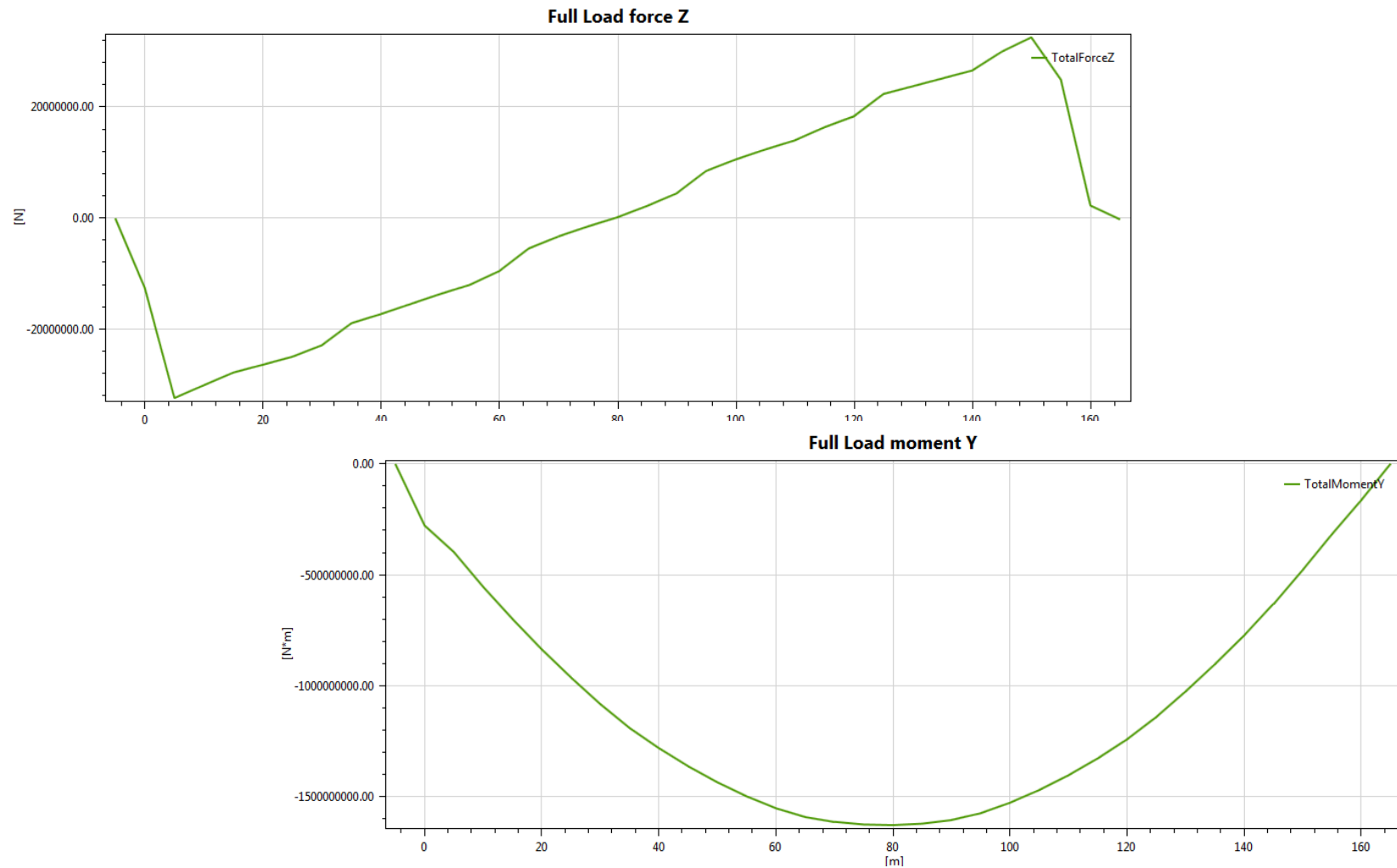
Flooded tank automatically changed by HydroD for each heeling angle



Closed tanks, different top surface for each heeling angle

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Results – Strength Analysis – Still water sectional loads



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Results

- A high number of results from the strength and stability analyses may be plotted and tabulated

Properties

Table1

General

Caption: Stability analysis

Show unit on header: ☐

Flip: ☐

Duplicate first column: ☐

Source

Concept: StabilityAnalysis2

Data set: Ballast / A0 deg results

Columns

	Field	Header	Format	Unit	Width
1	RotationAngle(H)	H		deg	
2	RightingArm(GZ)	GZ		m	
3	RightingMoment	RightingMoment		N*m	
4	RightingMomentArea	RightingMomentArea		N*m*rad	
5	HeelingArm	HeelingArm		m	
6	HeelingArmArea	HeelingArmArea		m*rad	
7	LateralTrim	LateralTrim		deg	
8	WaterlineZ	WaterlineZ		m	
9	RightingArmWithoutDeckTanks	RightingArmWithoutDeckTanks		m	
10	RightingArmFromDeckTanks	RightingArmFromDeckTanks		m	
11	RightingArmWithoutFreeSurfaceCorrection	RightingArmWithoutFreeSurfaceCorrection		m	
12	FreeSurfaceRightingArmCorrection	FreeSurfaceRightingArmCorrection		m	
13	MinimumOpening	MinimumOpening			
14	MinimumUnprotectedOpening	MinimumUnprotectedOpening			
15	MinimumOpeningHeight	MinimumOpeningHeight		m	
16	MinimumUnprotectedOpeningHeight	MinimumUnprotectedOpeningHeight		m	
17	MinimumWeathertightOpening	MinimumWeathertightOpening			
18	MinimumWeathertightOpeningHeight	MinimumWeathertightOpeningHeight		m	
19	DisplacementWeight(DISPM)	DISPM		N	
20	RightingArmArea	RightingArmArea		m*rad	
21	MetacentricHeight(GM)	GM		m	
22	HeelingMoment	HeelingMoment		N*m	

Table

Properties Results

Properties

Plot2

Data

Concept source: StabilityAnalysis2

Data source: Ballast / A0 deg

Sub Source: Ballast_A0 degResults

X

Data field: RotationAngle

Unit: deg

Y

Data fields: RightingArm, MinimumOpeningHeight

- ☐ RotationAngle
- ☒ RightingArm
- ☐ RightingMoment
- ☐ RightingMomentArea
- ☐ HeelingArm
- ☐ HeelingArmArea
- ☐ LateralTrim
- ☐ WaterlineZ
- ☐ RightingArmWithoutDeckTanks
- ☐ RightingArmFromDeckTanks
- ☐ RightingArmWithoutFreeSurfaceCorrection
- ☐ FreeSurfaceRightingArmCorrection
- ☒ MinimumOpeningHeight
- ☐ MinimumUnprotectedOpeningHeight
- ☐ MinimumWeathertightOpeningHeight
- ☐ DisplacementWeight
- ☐ RightingArmArea
- ☐ MetacentricHeight
- ☐ HeelingMoment
- ☐ HeelingMomentArea
- ☐ DeckHeight

Data Plot X-axis Y-axis

Properties Results

Units

Workspace browser

- Workspace
 - Environment
 - Location1
 - Properties
 - StabilityProperties
 - HeelAngles1
 - HeelAngles2
 - Models
 - Vessel
 - Hull
 - HydroModels
 - HydroModel1
 - PanelModel1
 - MassModel1
 - LoadCrossSections1
 - CompartmentModel1
 - LoadingConditions1
 - LoadingCondition1
 - CompartmentContents1
 - HydrostaticsTable1
 - DamageCases1
 - DamageCase1
 - Openings1
 - HeelingForceModel1

Properties

Workspace

Input units

Length: m

Mass: kg

Time: s

Basic units. A change here will change all units below.

Force: N

Angle: deg

Acceleration: m/s²

Density: kg/m³

Velocity: m/s

Area: m²

Volume: m³

KinematicViscosity: m²/s

Fraction: %

Moment: N*m

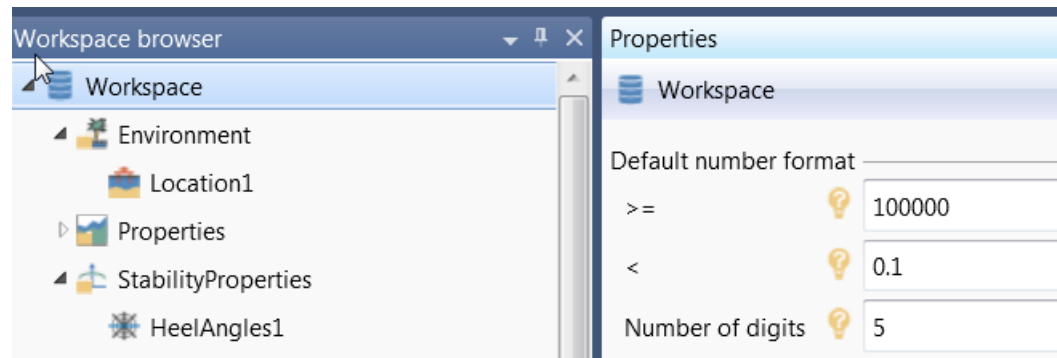
Length angle: m*rad

Moment angle: N*m*rad

Pressure: Pa

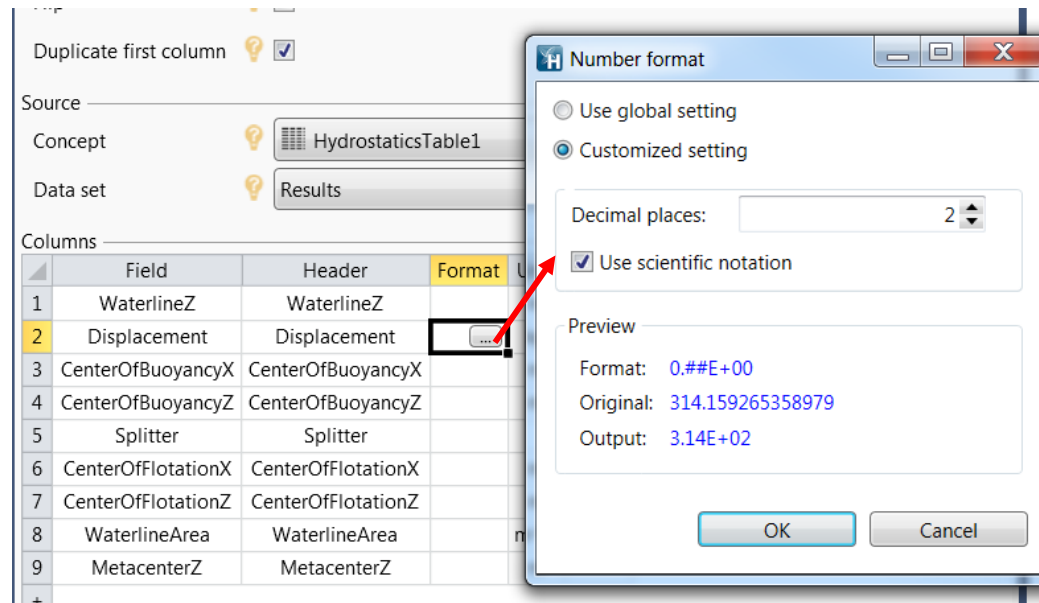
Ungraded

Number accuracy



Number setting in Workspace.

You can define your preferred default in File, Options.



Workspace setting may be modified for individual columns in a table

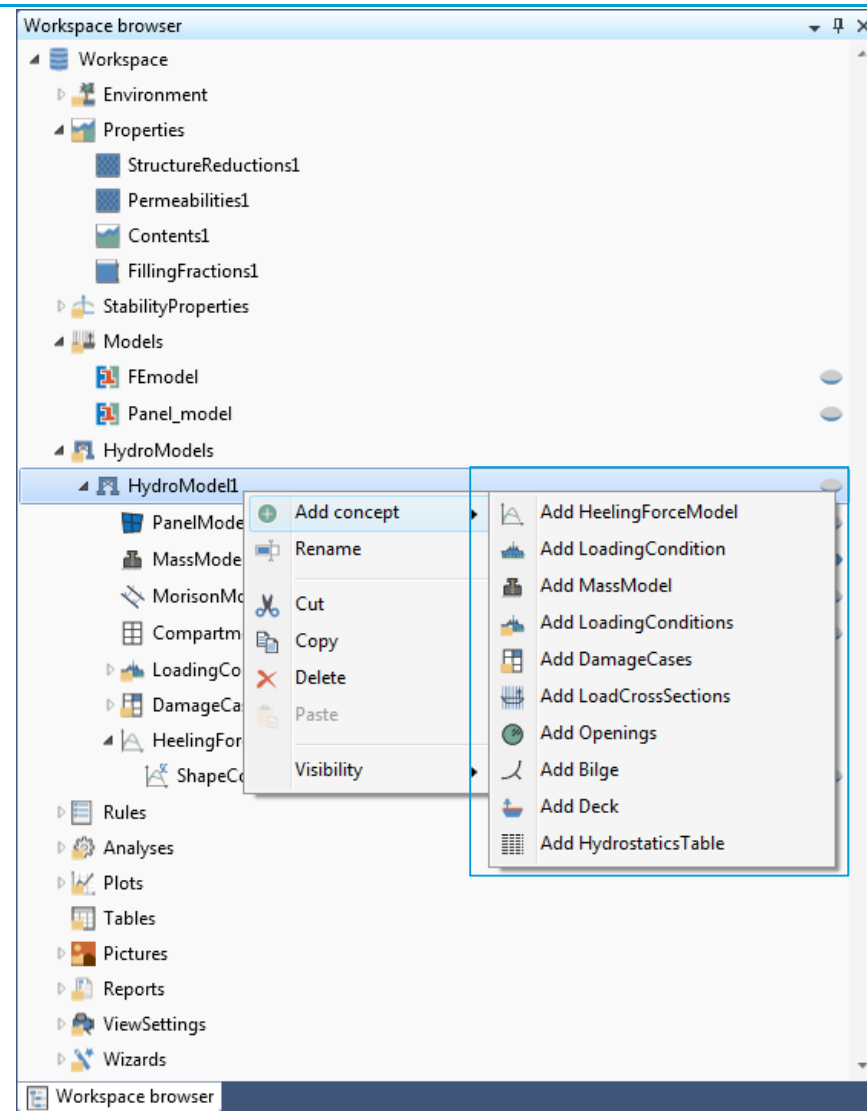
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Set-up of wanted features

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HydroModel Concepts

- A HydroModel will contain many concepts, depending on the wanted features and results for the analysis.
- Some concepts may be added directly from the Wizard
 - Wizard setup found at the bottom of the browser
- All concepts can be added from the browser, by RMB click



Ungraded

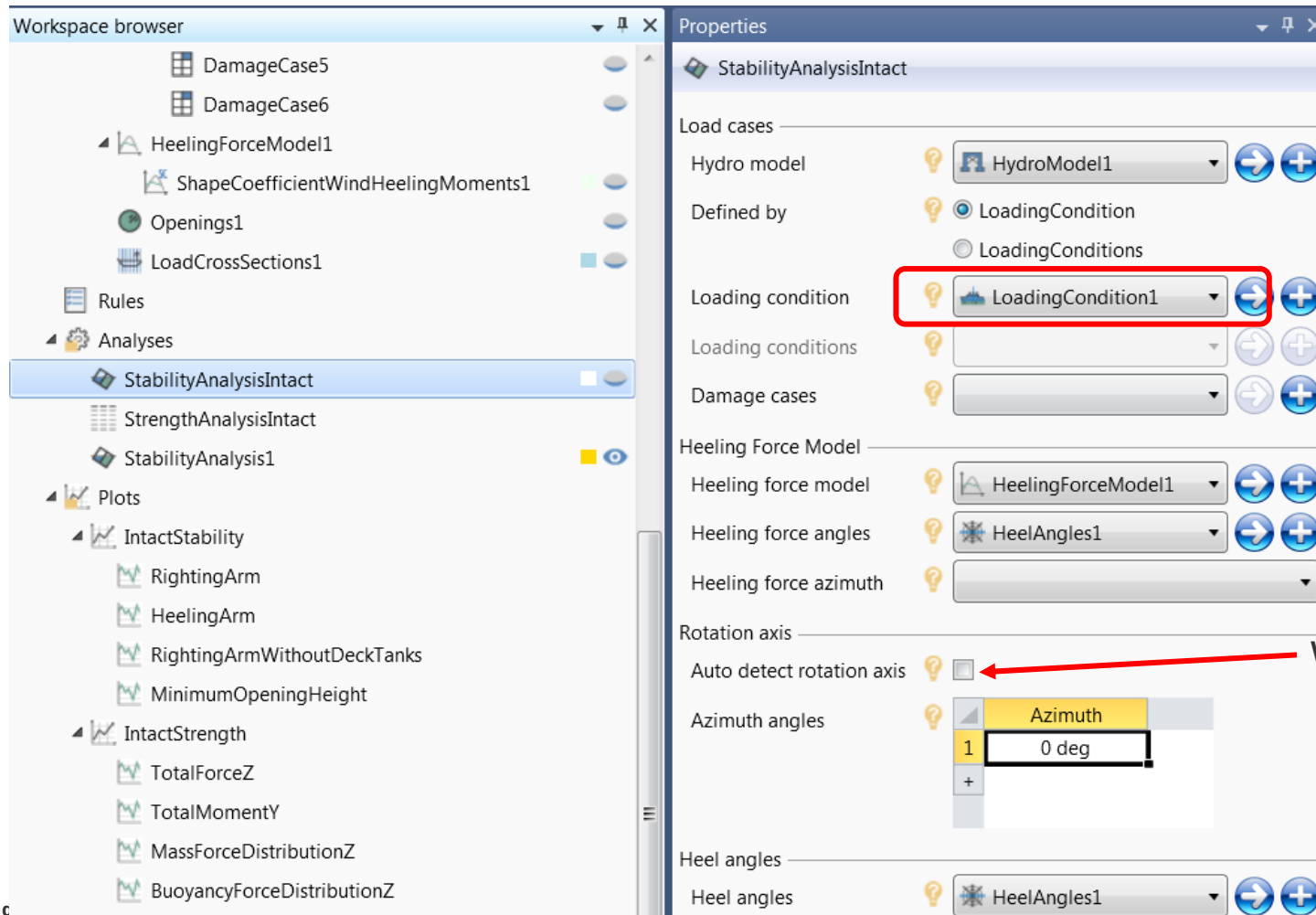
Efficient definitions of load cases

- Simplified user input for large damaged analyses – no need to generate 200 loading conditions and manually edit damages in each of those
- Define a set of intact loading conditions
- Define a set of damage cases
- HydroD will evaluate all combinations of intact conditions and damage cases
- This is implemented for stability analyses, rule checks and KG/AVCG



Stability of single loading condition

- The loading condition may contain damaged compartments



Weakest axis

Ungraded

Stability analysis of multiple loading conditions and damages

The screenshot displays the software interface for stability analysis configuration. The 'Workspace browser' on the left shows a hierarchical tree of models and analyses. The 'Properties' panel on the right shows the configuration for 'StabilityAnalysis1'.

Workspace browser:

- DamageCase5
- DamageCase6
- HeelingForceModel1
- ShapeCoefficientWindHeelingMoments1
- Openings1
- LoadCrossSections1
- Rules
- Analyses
 - StabilityAnalysisIntact
 - StrengthAnalysisIntact
 - StabilityAnalysis1**
- Plots
 - IntactStability
 - RightingArm
 - HeelingArm
 - RightingArmWithoutDeckTanks
 - MinimumOpeningHeight
 - IntactStrength
 - TotalForceZ
 - TotalMomentY
 - MassForceDistributionZ
 - BuoyancyForceDistributionZ
- Tables

Properties panel (StabilityAnalysis1):

- Load cases:**
 - Hydro model: HydroModel1
 - Defined by: LoadingCondition (selected), LoadingConditions
 - Loading condition: LoadingCondition1
 - Loading conditions: LoadingConditions1** (highlighted with a red box)
 - Damage cases: DamageCases1** (highlighted with a red box)
- Heeling Force Model:**
 - Heeling force model: HeelingForceModel1
 - Heeling force angles: (empty)
 - Heeling force azimuth: (empty)
- Rotation axis:**
 - Auto detect rotation axis: (unchecked)
 - Azimuth angles: Azimuth
 - 1: 0 deg
- Heel angles:**
 - Heel angles: HeelAngles1

Ungraded

Or combine a single loading condition with a set of damages

The screenshot displays the software interface for configuring a stability analysis. The **Workspace browser** on the left shows a tree structure of objects, with **StabilityAnalysis1** selected under the **Analyses** folder. The **Properties** panel on the right shows the configuration for **StabilityAnalysis1**.

Load cases

- Hydro model: HydroModel1
- Defined by: LoadingCondition

Loading condition

- Loading condition: LoadingCondition1 (highlighted with a red box)
- Loading conditions: (empty)

Damage cases

- Damage cases: DamageCases1 (highlighted with a red box)

Heeling Force Model

- Heeling force model: HeelingForceModel1
- Heeling force angles: (empty)
- Heeling force azimuth: (empty)

Rotation axis

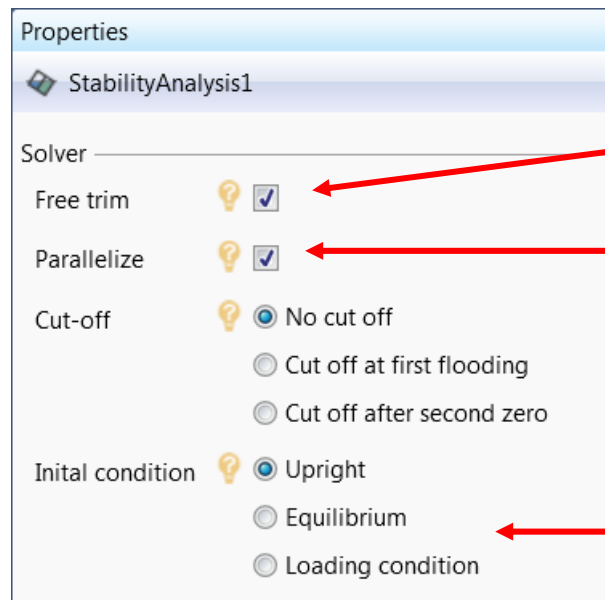
- Auto detect rotation axis: ☐
- Azimuth angles:

	Azimuth
1	0 deg
+	

Heel angles

- Heel angles: HeelAngles1

Stability properties – Options tab

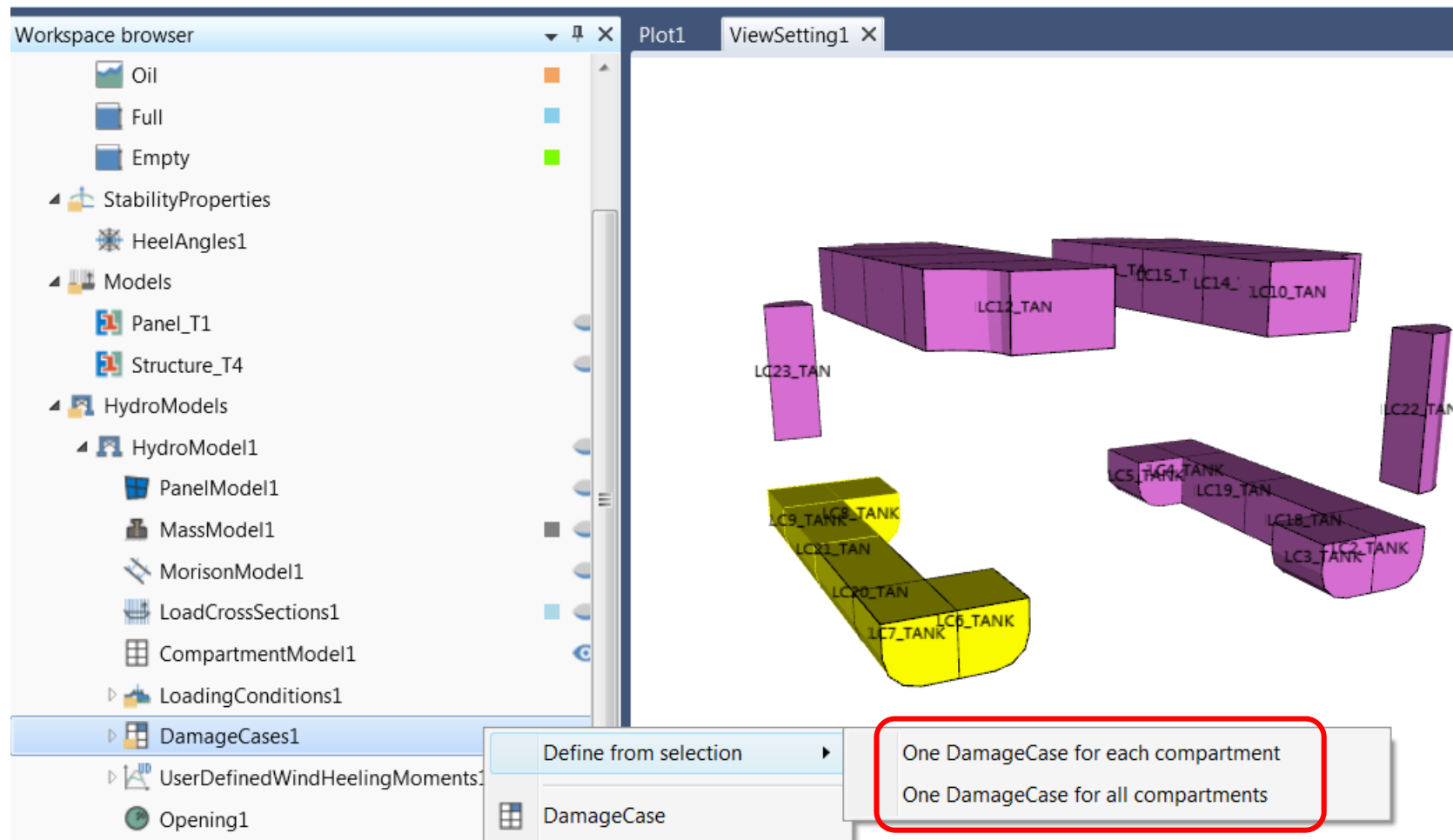


Expensive computation

Run several loading conditions in parallel
(max no given in File, Options)

The condition corresponding to zero
rotation angle

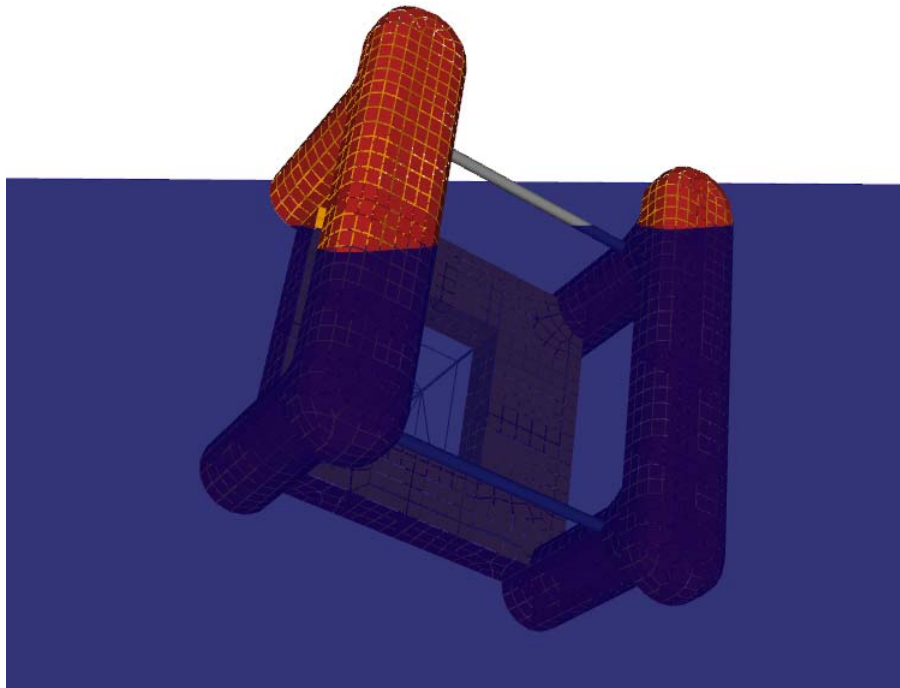
Quick and easy definition of damages



Ungraded

Robust hydrostatic equilibrium calculation

- Any orientation and damage condition will find equilibrium

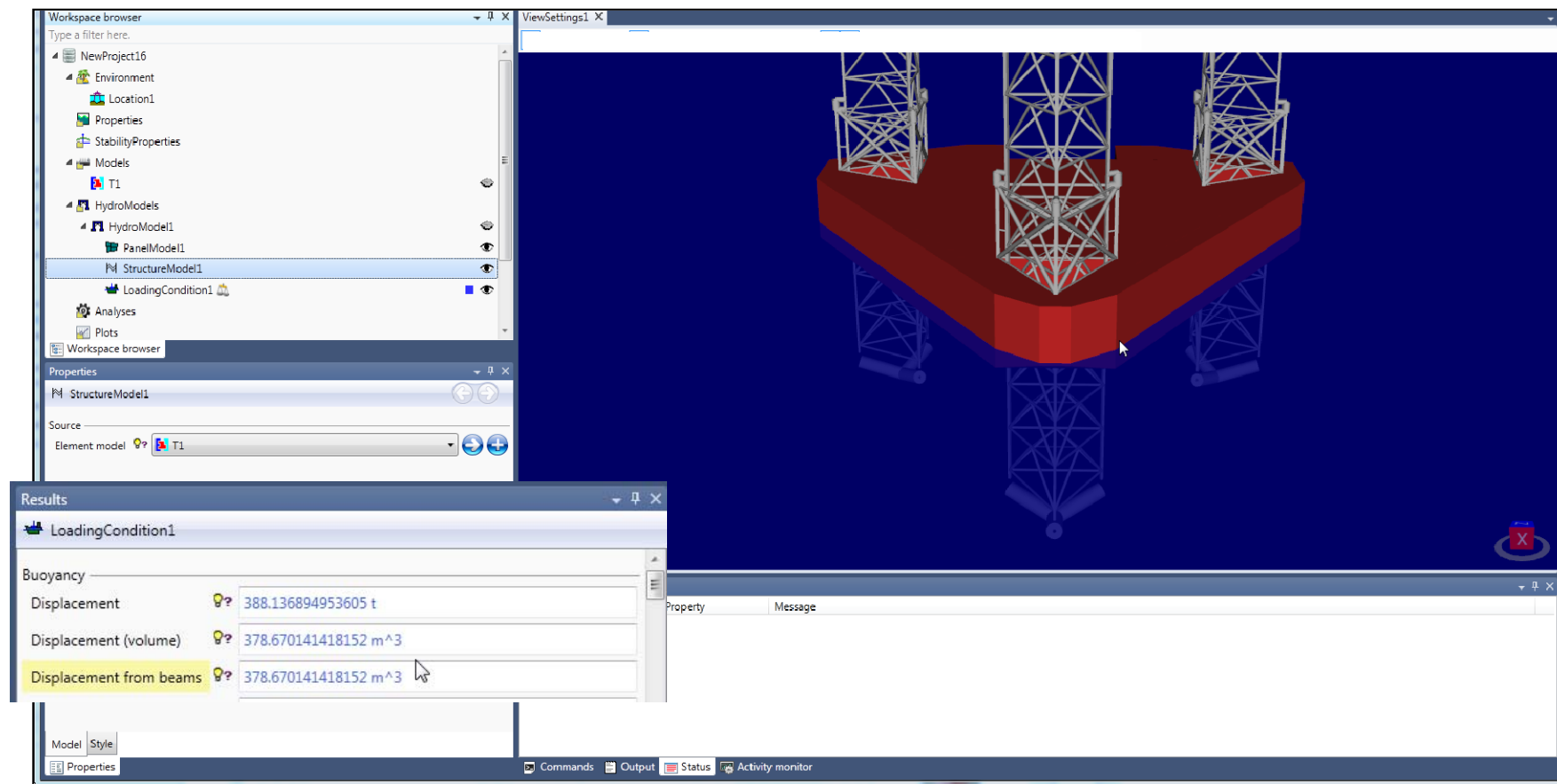


Mass	
Total mass	2.592E+07 kg
Centre of gravity X	1.281E-06 m
Centre of gravity Y	-1.1033E-08 m
Centre of gravity Z	7.6782 m
Dry mass	2.1259E+07 kg
Compartment contents	4.6615E+06 kg
LCG	1.281E-06 m
TCG	-1.1033E-08 m
VCG	7.6782 m
KG	7.6782 m
Balance	
The loading condition is in hydrostatic equilibrium.	
Mass error	1.8626E-08 kg
Relative mass error	7.186E-14 %
X alignment error	-1.281E-06 m
Relative X alignment error	9.8859E-07 %
Y alignment error	1.1033E-08 m
Relative Y alignment error	8.5149E-09 %

Ungraded

Beams contribute to buoyancy

- In hydro statics and stability analysis – the beams contribute to buoyancy



Ungraded

Wind heeling moment calculations

Method	Example	HydroD 4	HydroD 5
User defined	Results from wind tunnel tests	For single wind azimuth angle	For multiple wind azimuth angles and drafts
Projected area	Ship stability rules	N/A as curve	HydroD calculates projected area and heeling moment curve
Shape coefficients	Offshore stability rules	N/A*	Shape coefficients are specified by the user, HydroD calculates heeling moment curve

* HydroD 4 implements a method based on a blocked empiric grid and drag/block coefficients

User defined wind heeling moments

- The user will be able to input multiple wind directions for AVCG analyses (or KG)
- 3-dimensional input table (Waterline, azimuth, heel angle)
 - Select which parameter to keep fixed
 - Give table for each specified value of the “fixed” parameter
 - Example shows table for azimuth/heel for a given waterline
- Specify the heeling moments
- HydroD will interpolate (linear interpolation) needed
- Copy from Excel is supported

UserDefinedWindHeelingMoments1

Type

Type ☐ Azimuth ☒ Waterline Z ☐ Heel angle

Properties

UserDefinedWindHeelingMomentTable1

Rotation axis

Azimuth angle

Waterline

Waterline Z

Heel angle

Heel angle

Properties

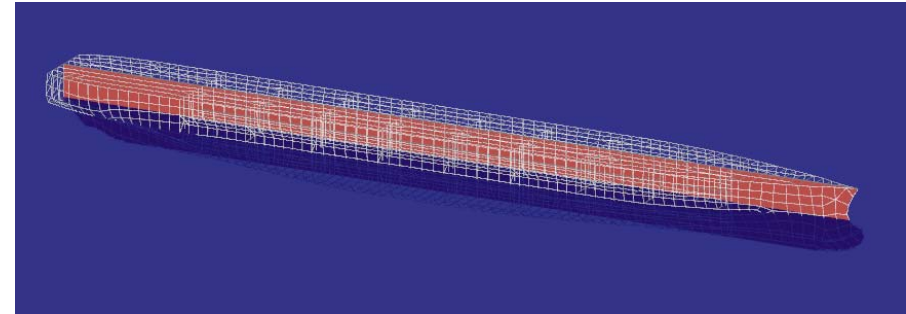
UserDefinedWindHeelingMomentTable1

	H0 deg	H10 deg	H20 deg	H30 deg
A0 deg	0 N*m	0 N*m	0 N*m	0 N*m
A45 deg	0 N*m	0 N*m	0 N*m	0 N*m
A90 deg	0 N*m	0 N*m	0 N*m	0 N*m

Ungraded

Wind heeling moments by projected area

- Used by stability rules for ships
- The user must specify grid resolution for projected area calculation
- Wind heeling lever



Containership - projected area (red)

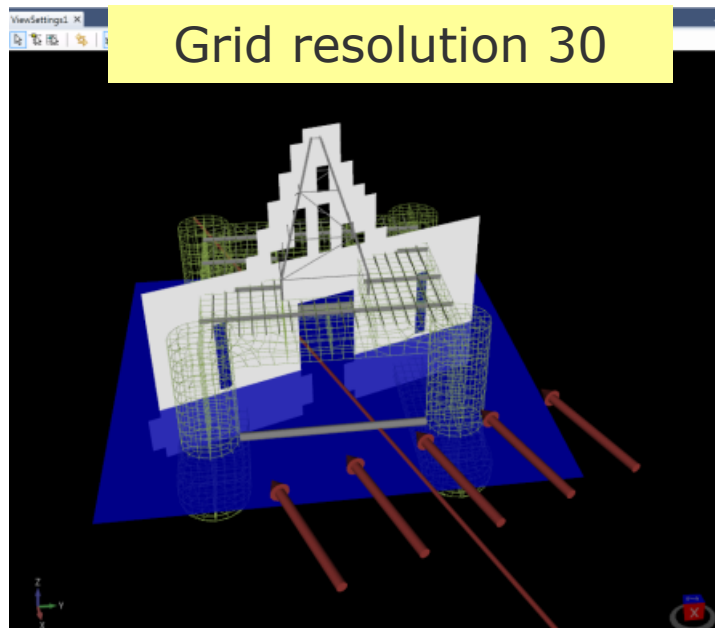
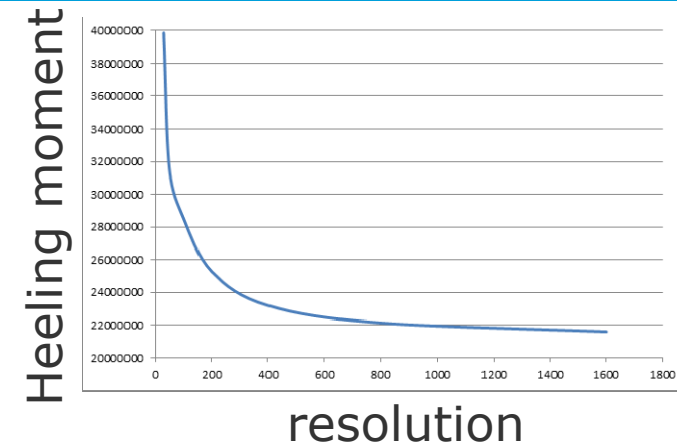
$$l_{w_1} = \frac{PAZ}{1000g\Delta}$$

P	Wind pressure	Defined by the rules
A	Projected area	Calculated by HydroD
Z	Vertical distance*	Calculated by HydroD
g	Gravity	Defined by the rules
Δ	Displacement	Calculated by HydroD

Ung

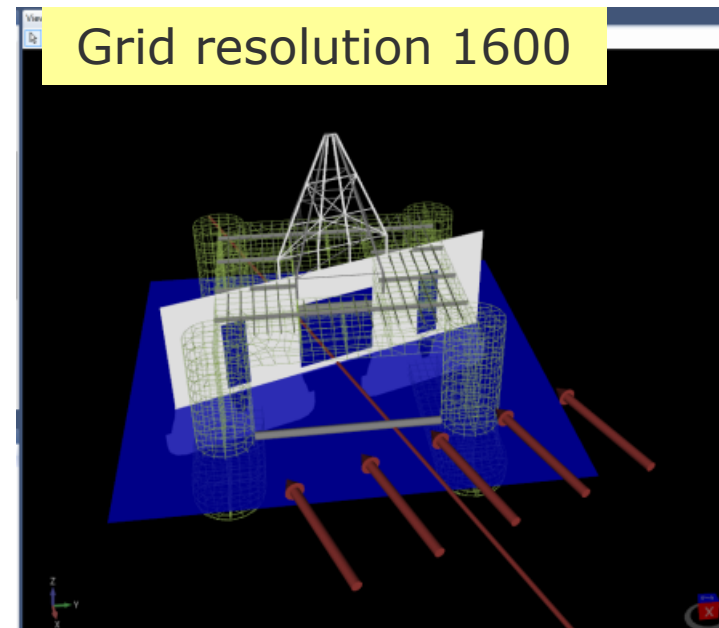
Projected area grid resolution

- Low grid resolution gives conservative heeling moment, but it is quick to run higher resolutions
 - Resolution 30: 10 sec
 - Resolution 400: 16 sec
 - Resolution 1600: 68 sec



Grid resolution 30

Ungraded



Grid resolution 1600

Wind heeling moments by shape coefficients

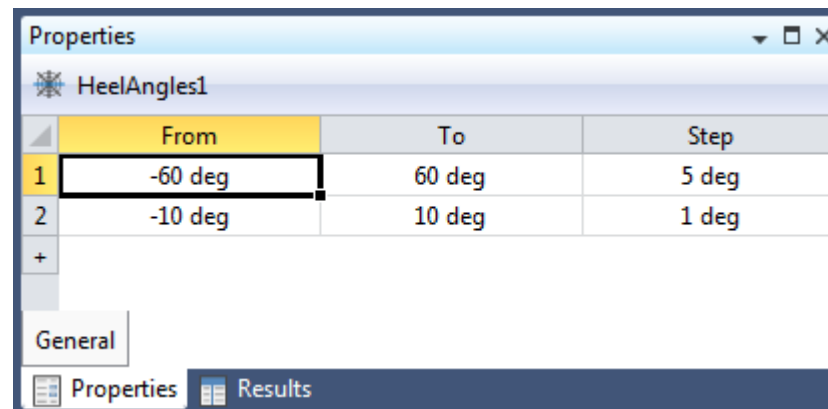
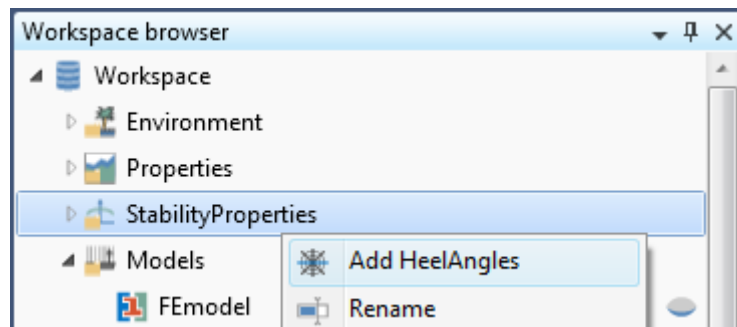
- Used by offshore stability rules
- Wind force (IMO MODU 3.2.3 / DNV OS C301 B101)

$$F = 0.5 C_s \cdot C_h \cdot P \cdot V^2 \cdot A$$

C_s	Shape coefficient	Defined by the user
C _h	Height coefficient	Defined by the rules
P	Air mass density	Defined by the rules
V	Wind velocity	Defined by the rules
A	Projected area	Calculated by HydroD

Heel angle input

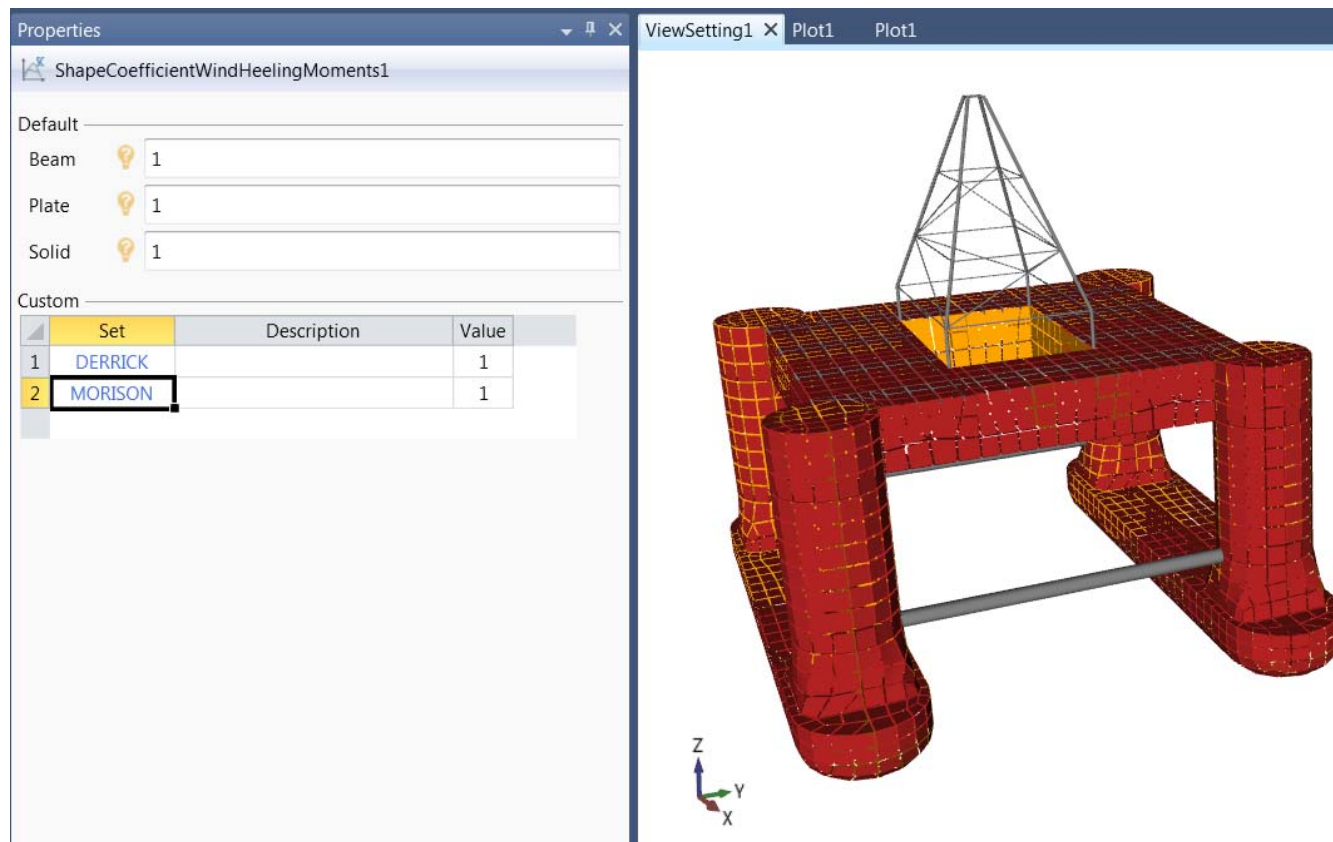
- Defined as a stability property
- Used in the stability analysis



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Shape coefficient input

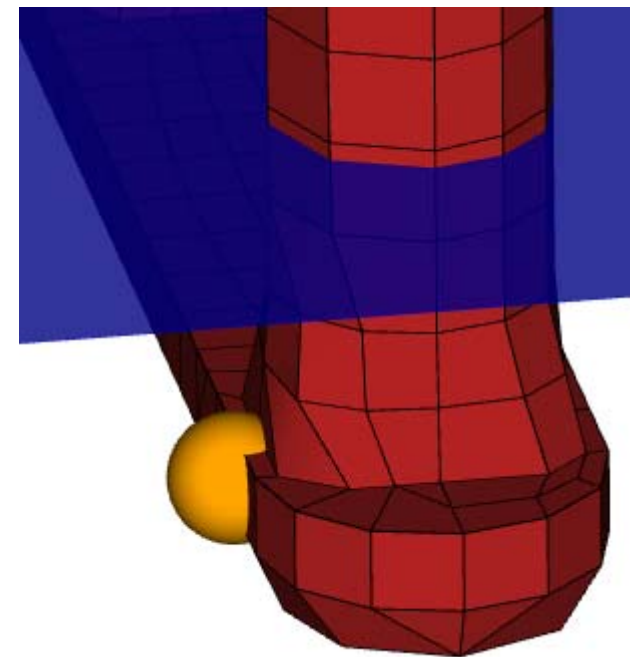
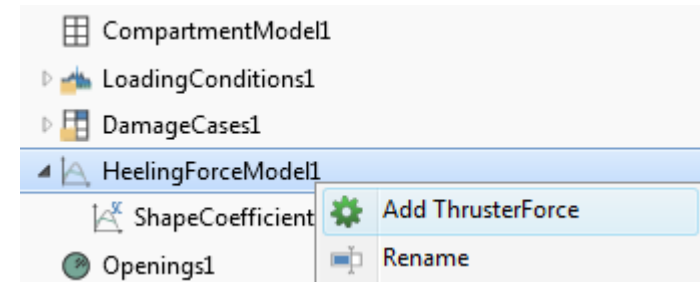
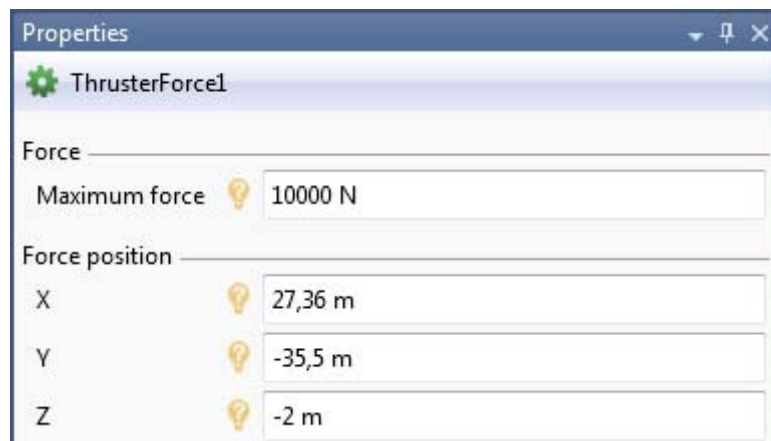
- Assign to set (as predefined in GeniE)
- Assign default to element type



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Thrusters

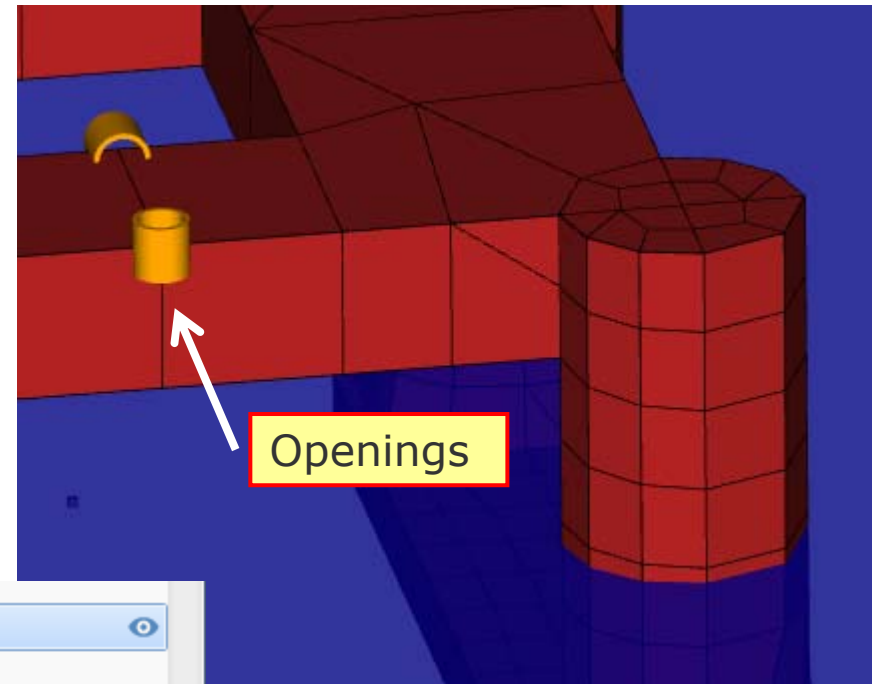
- Define thruster
 - Part of a Heeling force model
 - One resulting thruster in one model
 - Maximum force given
 - Give position



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Opening Concept

- One or more flooding openings may be defined.
- The distance between the waterline and the opening will be computed and displayed for different heel angles.
- An opening may be connected to a tank. The tank will be flooded when the opening is submerged



Openings1

Rules

Analyses

Workspace browser

Properties

Openings1

	Name	Type	Position X	Position Y	Position Z	Connected	Visible	Direction
1	SingleOpening1	Unprotected	14,36 m	0 m	33,5 m	LC10_TAN	☒	1;0;0
2	SingleOpening2	Unprotected	27,36 m	0 m	33,5 m	LC12_TAN	☒	0;0;1

Ungraded

MaximumKG analysis (AVCG analysis in HydroD4)

Workspace browser

- LoadingConditions1
- DamageCases1
- UserDefinedWindHeelingMoments1
- Opening1
- ShapeCoefficientWindHeelingMoments1
- Analyses
 - StabilityAnalysis1
 - StabilityRuleCheck1
 - LoadAnalysis1
 - MaximumKgAnalysis1**
 - StabilityAnalysis2
- Plots
 - Plot1
 - Total
 - Gravity
 - Bouyancy
 - GravityDistribution
 - BouyancyDistribution
- Tables
- Reports
 - Report1
 - Section1
 - Picture1
 - Text1
 - Plot1
 - Plot2
 - Section2
 - Plot1
 - ViewSettings
 - ViewSetting1**
 - Wizards

Properties

MaximumKgAnalysis1

Model

Location

Location1

Hydro model

HydroModel1

Orientation

Heel

0 deg

Trim

0 deg

Waterlines

	Waterline Z
1	10 m
2	11 m
3	12 m
4	13 m
5	14 m
6	15 m
7	16 m
8	17 m
*	

Stability analysis settings

Azimuth angles

	Azimuth
1	0 deg
2	10 deg
*	

Heel angles

HeelAngles1

Heeling moments

Wind heeling moments

UserDefinedWindHee

Heel angles

HeelAngles1

Intact stability

Rule

NMA intact stability criteria

Model Options

Intact stability

Rule

NMA intact stability criteria

Reference

ABS MODU intact stability criteria

DNV intact stability criteria

IMO general stability criteria

IMO MODU intact stability criteria

MARPOL intact stability criteria

NMA intact stability criteria

Damage stability

Include damage cases
☒

Damage

DamageCases1

Rule

NMA damaged stability criteria

Reference

ABS MODU damaged stability criteria

DNV damaged stability requirements

IBC damaged stability criteria

IGC damaged stability criteria

IMO MODU damaged stability criteria

MARPOL damaged stability criteria

NMA damaged stability criteria

Model Options

Rule checks

Ungraded

Intact stability curves

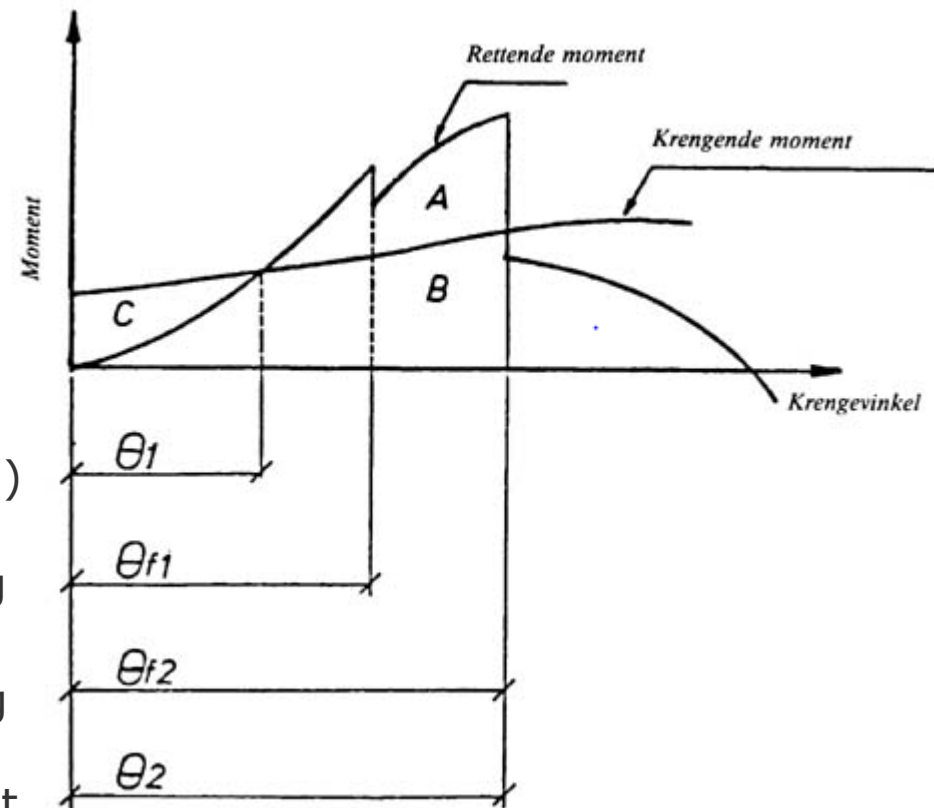
- Criteria are typically related to:
 - Value of the angles
 - Area under righting moment curve vs. area under heeling moment curve
 - Distance from openings to free surface

First intercept (equilibrium with wind)

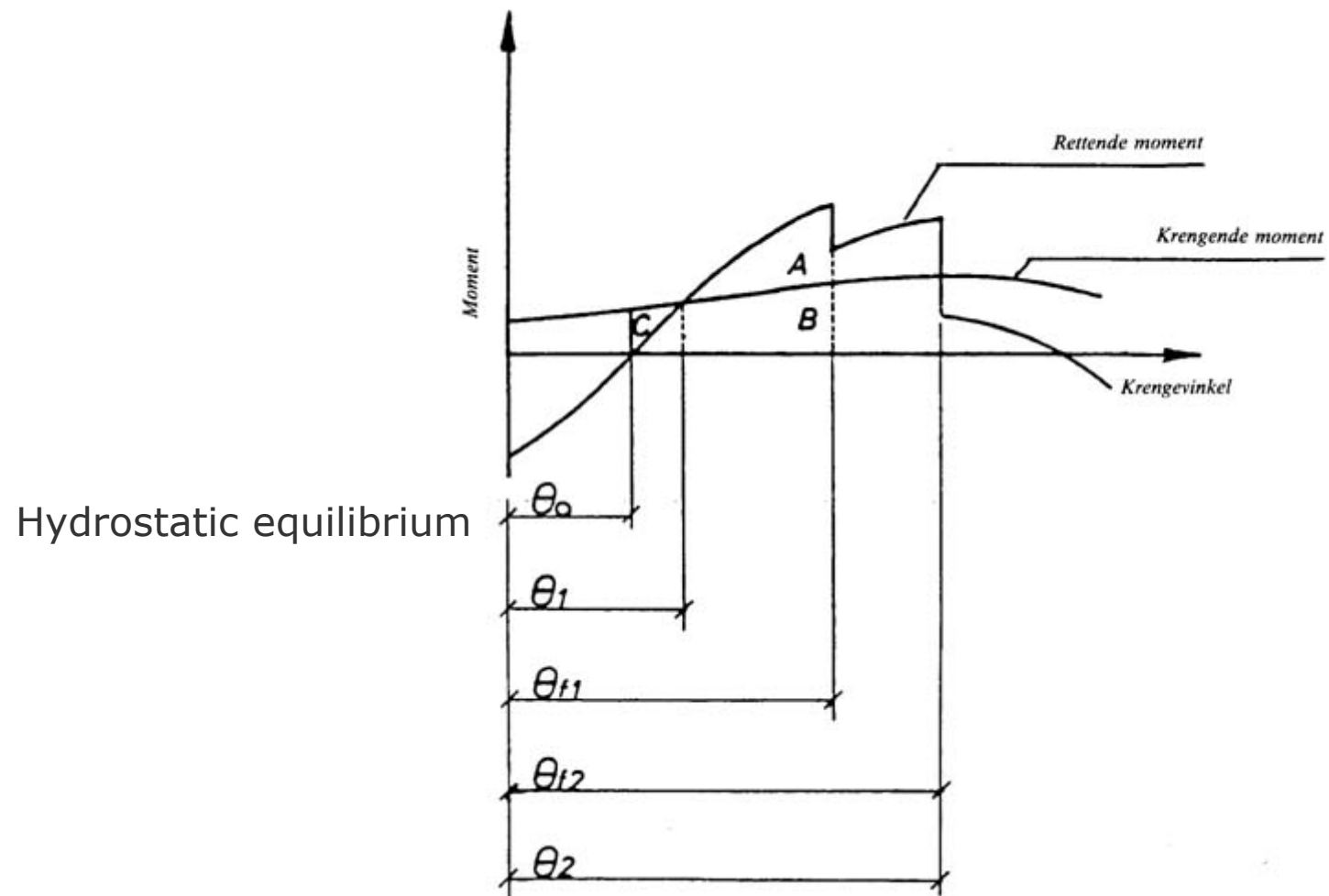
First flooding

Second flooding

Second intercept



Damaged stability diagram



Ungraded

Typical criteria in the rules

- Maximum or minimum value of angles
- Relation between righting and heeling arm/moment
 - Values
 - Area under curve (=work)
- Example (NMA rules):

The static angle of heel due to wind shall not exceed 17 degrees in any condition.

The area under the righting moment curve to the second intercept, or any lesser angle, is not to be less than 30 % in excess of the area under the wind heeling moment curve to the same limiting angle.

All main rule sets supported

Properties

StabilityRule1

Stability Rule

Stability rule category ☒ Intact rule
☐ Damaged rule

Criteria source ☒ Predefined criteria list
☐ Custom criteria list

Stability criteria

Reference

IMO MODU intact stability criteria
ABS MODU intact stability criteria
DNVGL intact stability criteria
NMA intact stability criteria for Mobile Offshore Units
MARPOL intact stability criteria
IMO general stability criteria

IMO MODU damaged stability criteria
ABS MODU damaged stability criteria
DNVGL damaged stability requirements
NMA damaged stability criteria for Mobile Offshore Units
MARPOL damaged stability criteria
IGC damaged stability criteria
IBC damaged stability criteria

Ungraded

Watertight and weathertight integrity surfaces

Properties

LimitSurface1

Input

Stability analyses  StabilityAnalysis1

Surface constraints

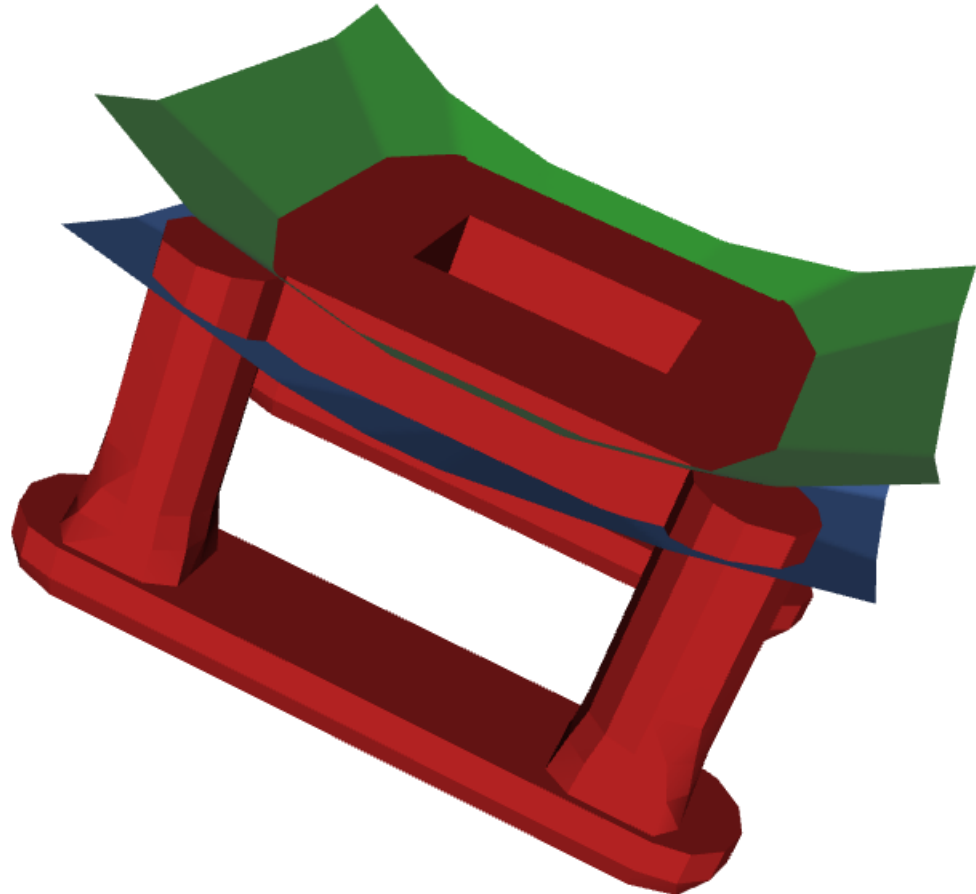
	Applies To	Name
1	WatertightIntegrity	NMA watertight integrity constraint (§22.2.A) e
+		

Parameters

	Name	Value	Default Value	Unit
1	MinGZBeforeFlooding	2.5	2.5	m
2	MinDeckTankMargin	1	1	m

Option

Parallelize  



Ungraded

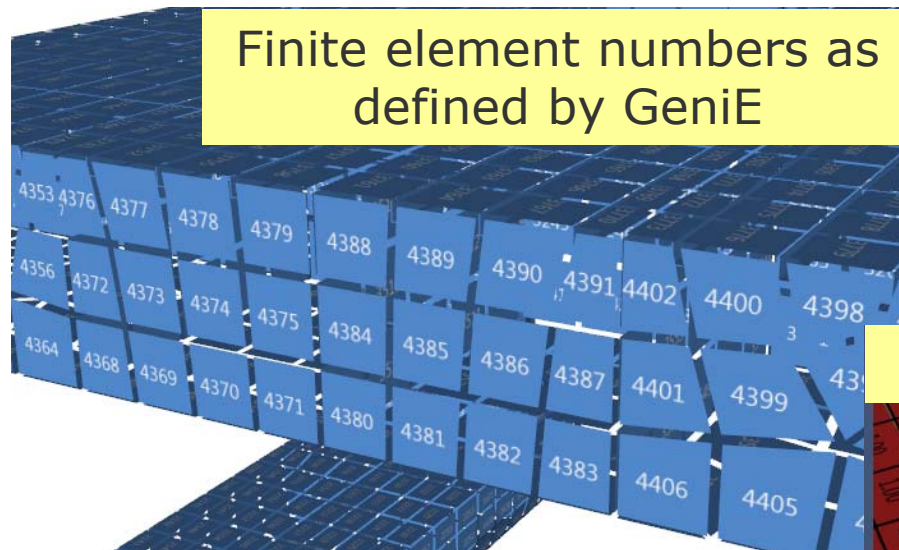
Verification and reporting

- Verify models and input
- Create reports including pictures, plots and tables
 - Automatically updated after reanalysis

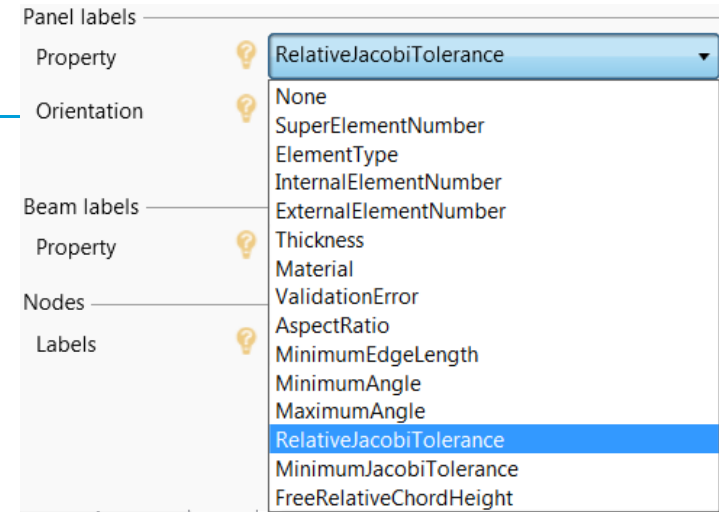
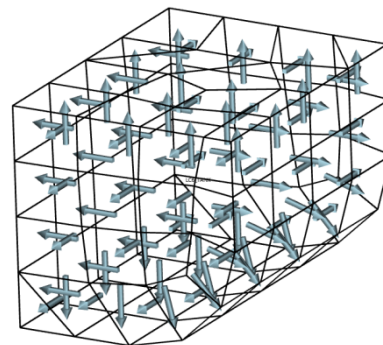
Ungraded

Easier to verify the model inside HydroD

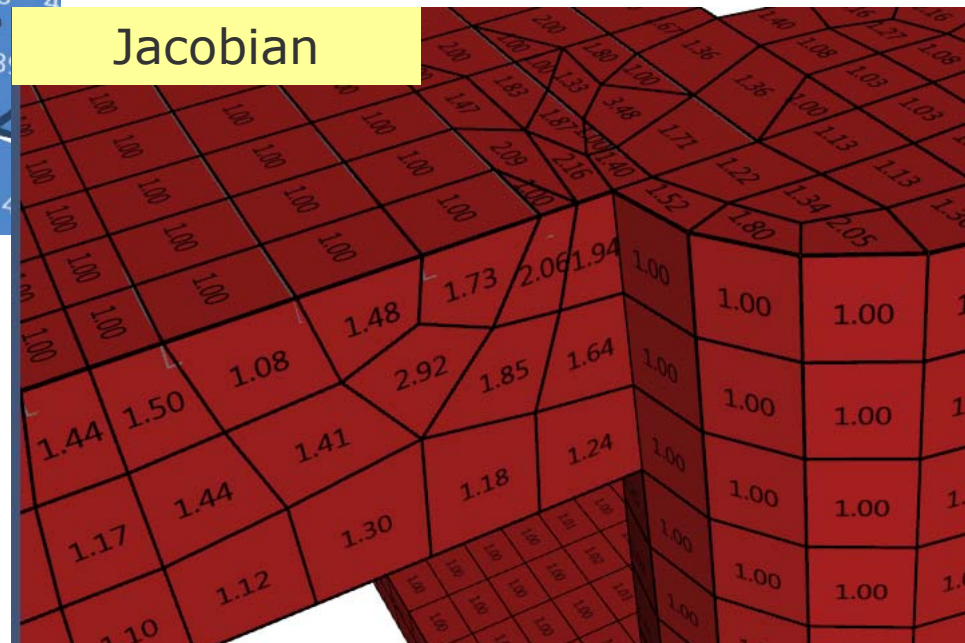
- No need for other tools to view details



Verify compartments



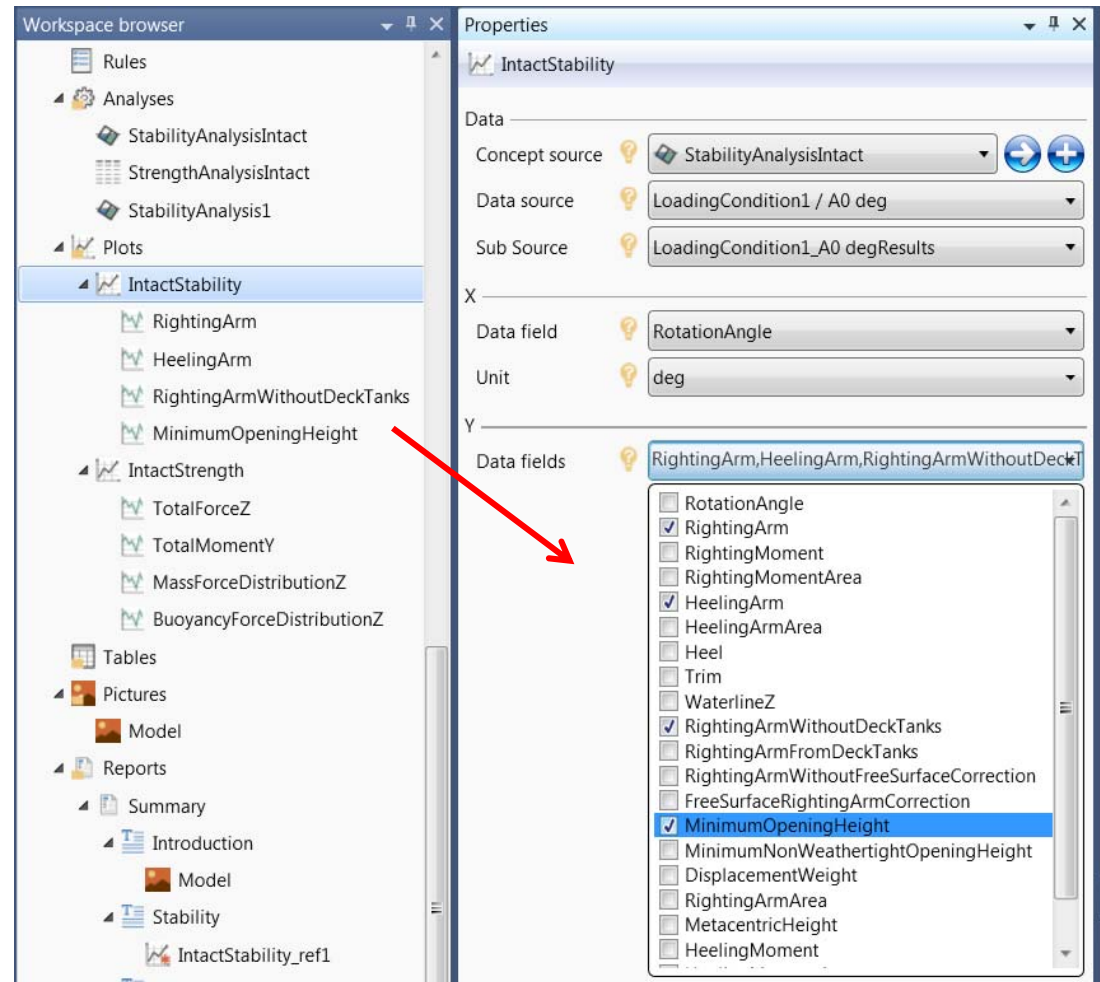
Jacobian



Ungraded

Reporting engine

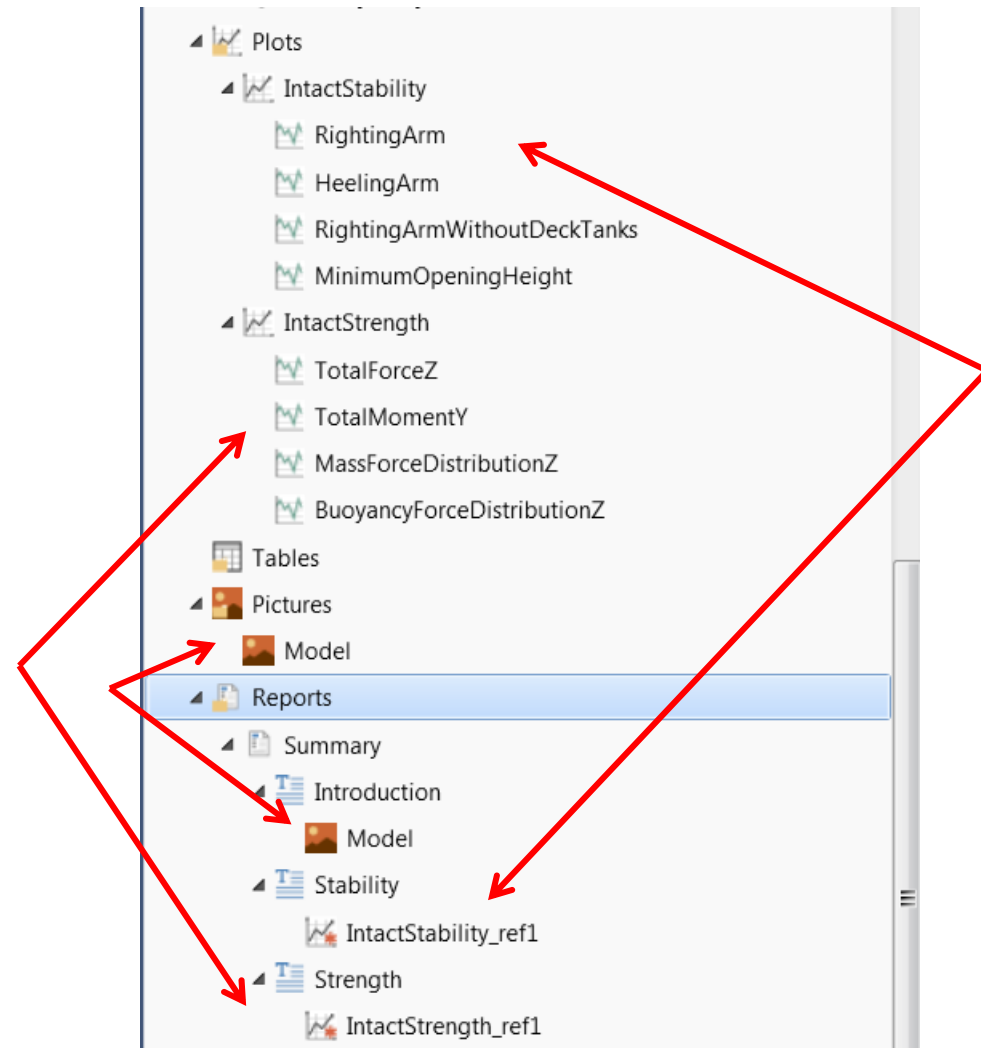
- Define templates for
 - Table
 - Plot
 - Report
- Report style
 - Created in Word format
 - Word templates can be used
- Customize report contents
- Copy/paste report structure
- Regenerate reports at any time
- Reports are part of the scriptable model
- Tables and plots are bound to analysis output



Ungraded

Automatic updating of reports

- Store plots, tables or pictures in separate folders
 - Reuse in many reports (by reference)
- Or store directly in the report
- Tables and plots are automatically updated when the analysis is run again
- Pictures may be static (a fixed picture) or dynamic (based on what is currently displayed in a defined ViewSetting)

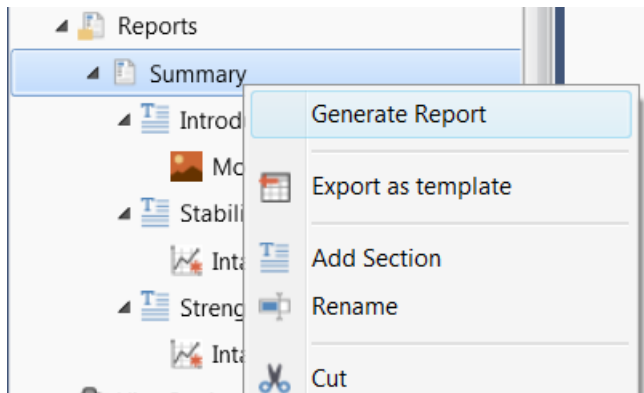
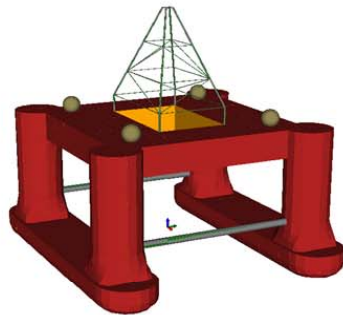


Ungraded

Create reports in Word format using company / project template

1 THE MODEL TO BE ANALYZED

The example semisubmersible

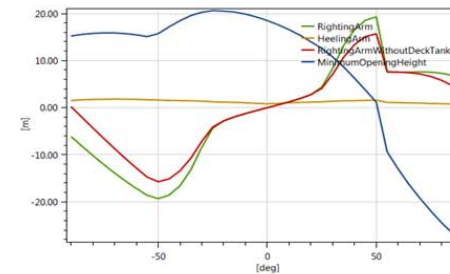


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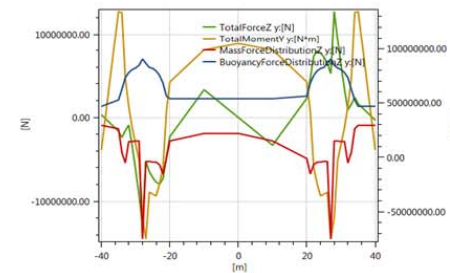
Page 2

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2 RESULTS FROM STABILITY ANALYSIS



3 RESULTS FROM STRENGTH ANALYSIS



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SAFER, SMARTER, GREENER

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