

Safran

ANSA and Meta Post contribution to the study of Safran Open 60' race yacht crashworthiness

4th ANSA & μ ETA International Conference

THESSALONIKI, June 1st-3rd, 2011

Philippe BIAGI



Study of Safran Open 60' race yacht crashworthiness

Safran Engineering Services

SAFRAN GROUP

54,900 employees in over 30 countries

Aerospace

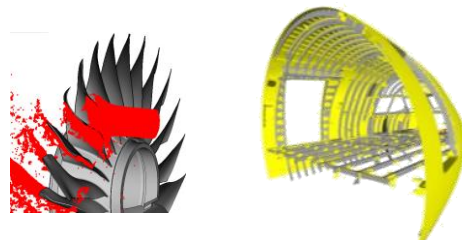
Defence

Security

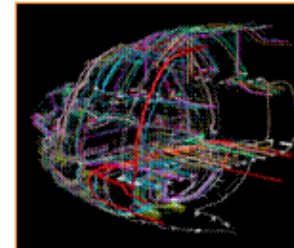
- A Labinal (SAFRAN Group) subsidiary dedicated to engineering services
- A global footprint with 3200 engineers and technicians



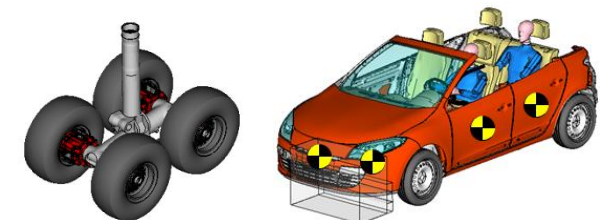
Avionics &
Embedded Systems



Aerostructures



Electrical Systems



Propulsion &
Mechanical Systems

This document and the information contained are Safran Engineering Services property and shall not be copied or disclosed to any third party without Safran Engineering Services prior written authorization.

Study of Safran Open 60' race yacht crashworthiness

Safran 60'

- Imoca Open 60 class monohull racing yacht 60 feet long, 18 feet wide
- Skipper: Marc Guillemot

- Jacques Vabre 2009 winner
- Vendee Globe 2009 3rd
- SNSM Record 2009 winner
- Round Spain 2010 winner
- Route du Rhum 2010 3rd



- Manufacturer: Larros shipyard (Thierry Eluère)
- Naval architects : Cabinet Van Peteghem-Lauriot Prévost and Guillaume Verdier
- Extensive involvement of the Safran Group's engineers, giving the boat the benefits of technologies transferred from cutting-edge aerospace applications.

This document and the information contained are Safran Engineering Services property and shall not be copied or disclosed to any third party without Safran Engineering Services prior written authorization.

- Vendee Globe 2009: hit by an U.F.O. (probably a whale), Safran'60 lost its keel eight weeks after impact but without damage hull integrity.
- Vendee Globe 2009: the Bell sister ship dismasted in severe slamming conditions.
- Barcelona World Race 2010: Foncia dismasted under 30 knots South-West wind.
- Barcelona World Race 2010: Président dismasted as it slammed into a wave sailing under gennaker at 18 knots.
- Jules Verne 2010: Banque Populaire V hit an U.F.O. at 37 knots and damaged the daggerboard.



Keel remaining parts after failure
(titanium belt)

- Objectives:**
- Predict the yacht behaviour in case of dynamic impacts
 - Validate yacht integrity in case of severe impacts
 - Estimate possible weight gain/performance

This document and the information contained are Safran Engineering Services property and shall not be copied or disclosed to any third party without Safran Engineering Services prior written authorization.

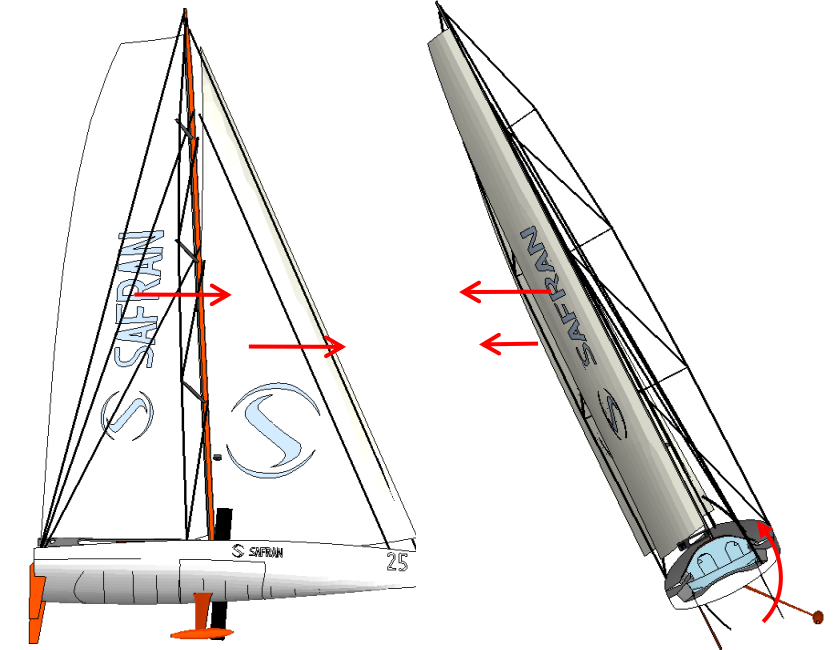
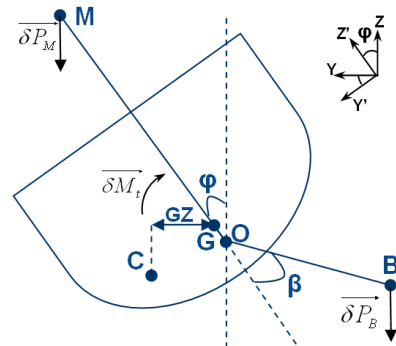
Study of Safran Open 60' race yacht crashworthiness

Ship's configuration

Sailing configuration

Sailing characteristics

Ship configuration and sailing forces

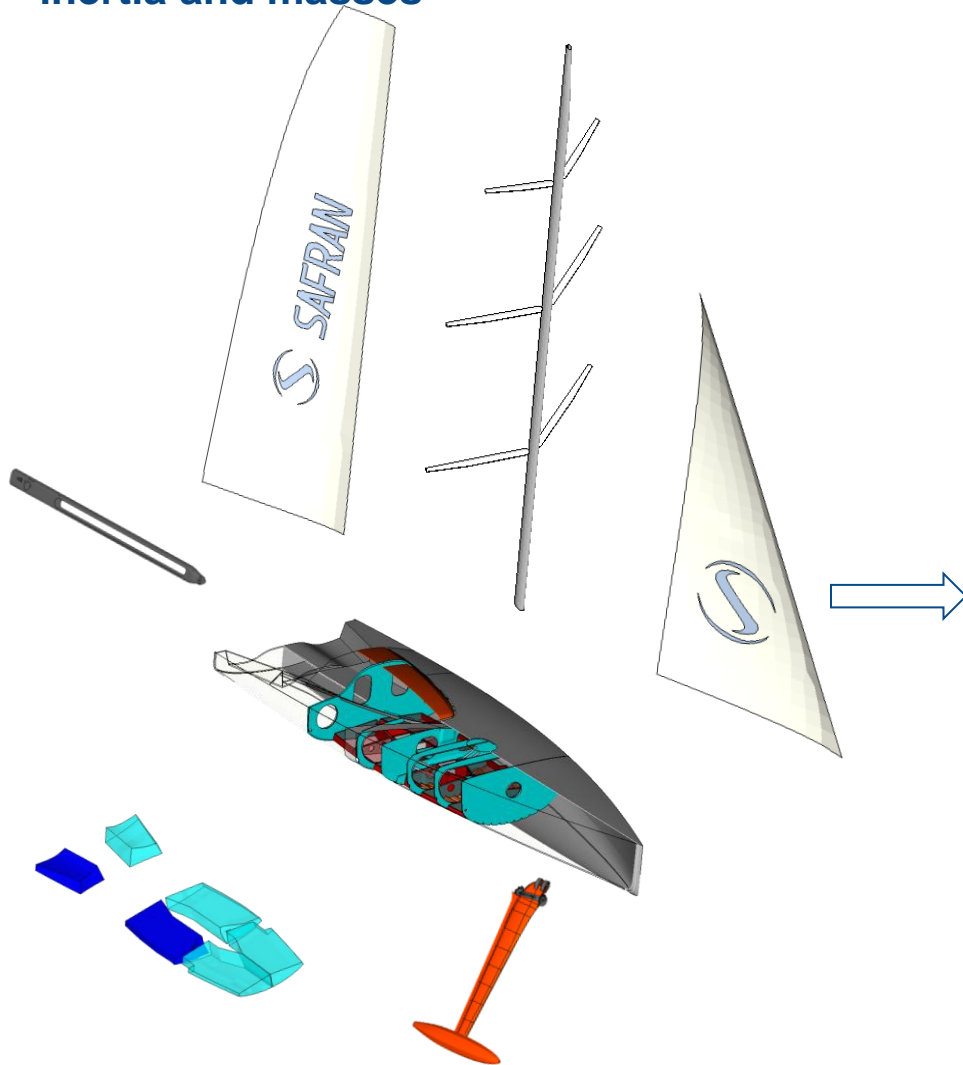


This document and the information contained are Safran Engineering Services property and shall not be copied or disclosed to any third party without Safran Engineering Services prior written authorization.

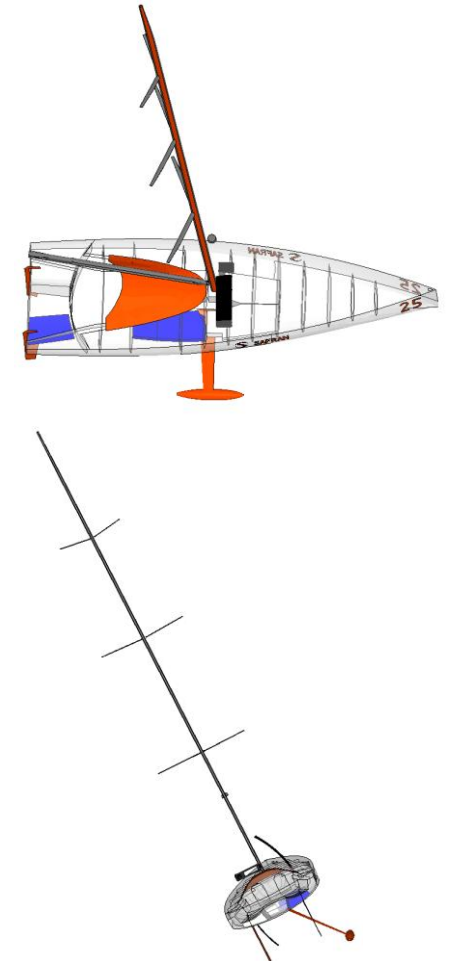
Study of Safran Open 60' race yacht crashworthiness

Ship configuration

Include model to obtain ship configuration, inertia and masses



Transformation cards to obtain ship configuration

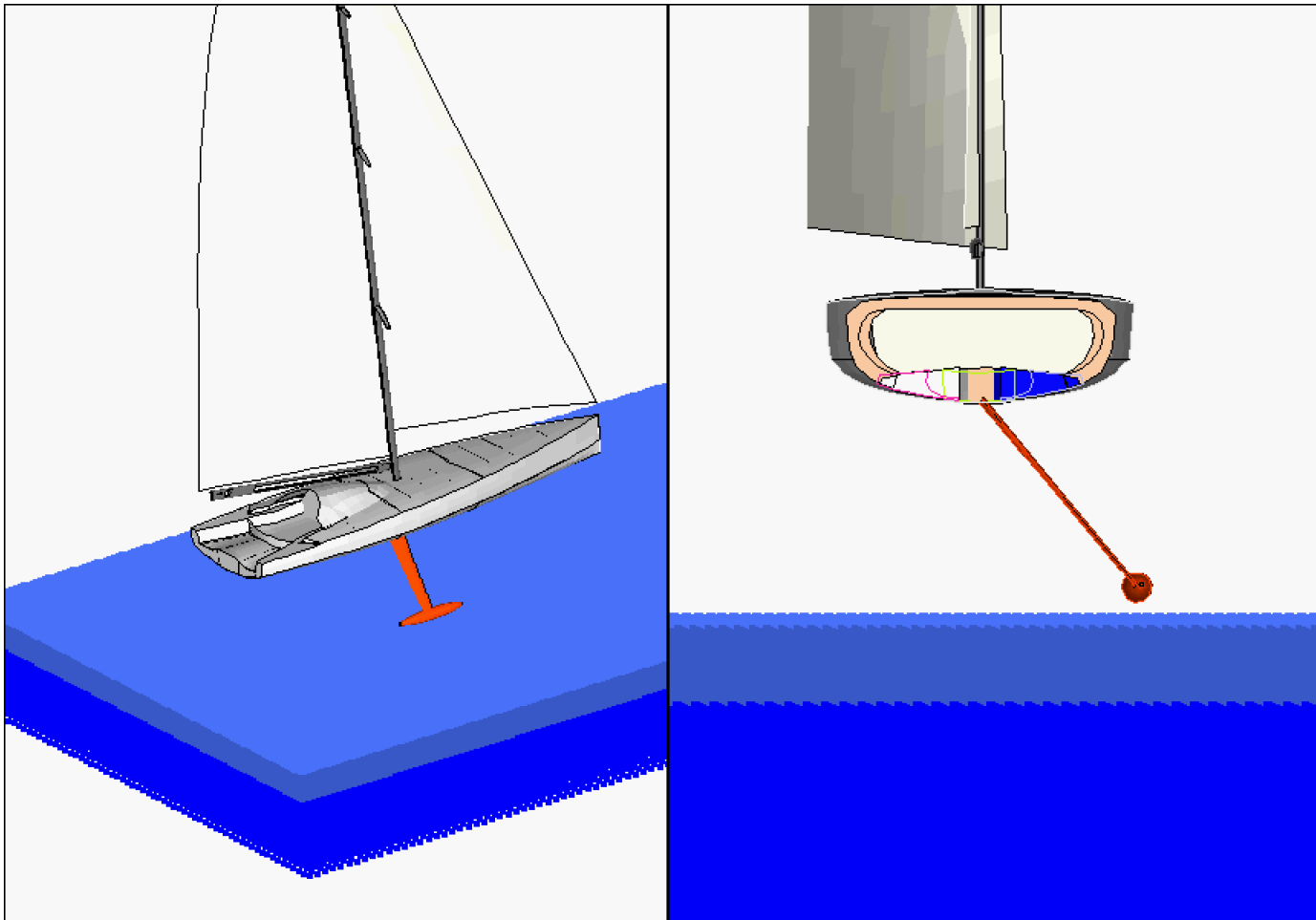


This document and the information contained are Safran Engineering Services property and shall not be copied or disclosed to any third party without Safran Engineering Services prior written authorization.

Study of Safran Open 60' race yacht crashworthiness

Sea modelling

Simulation of the ship dropped in the sea

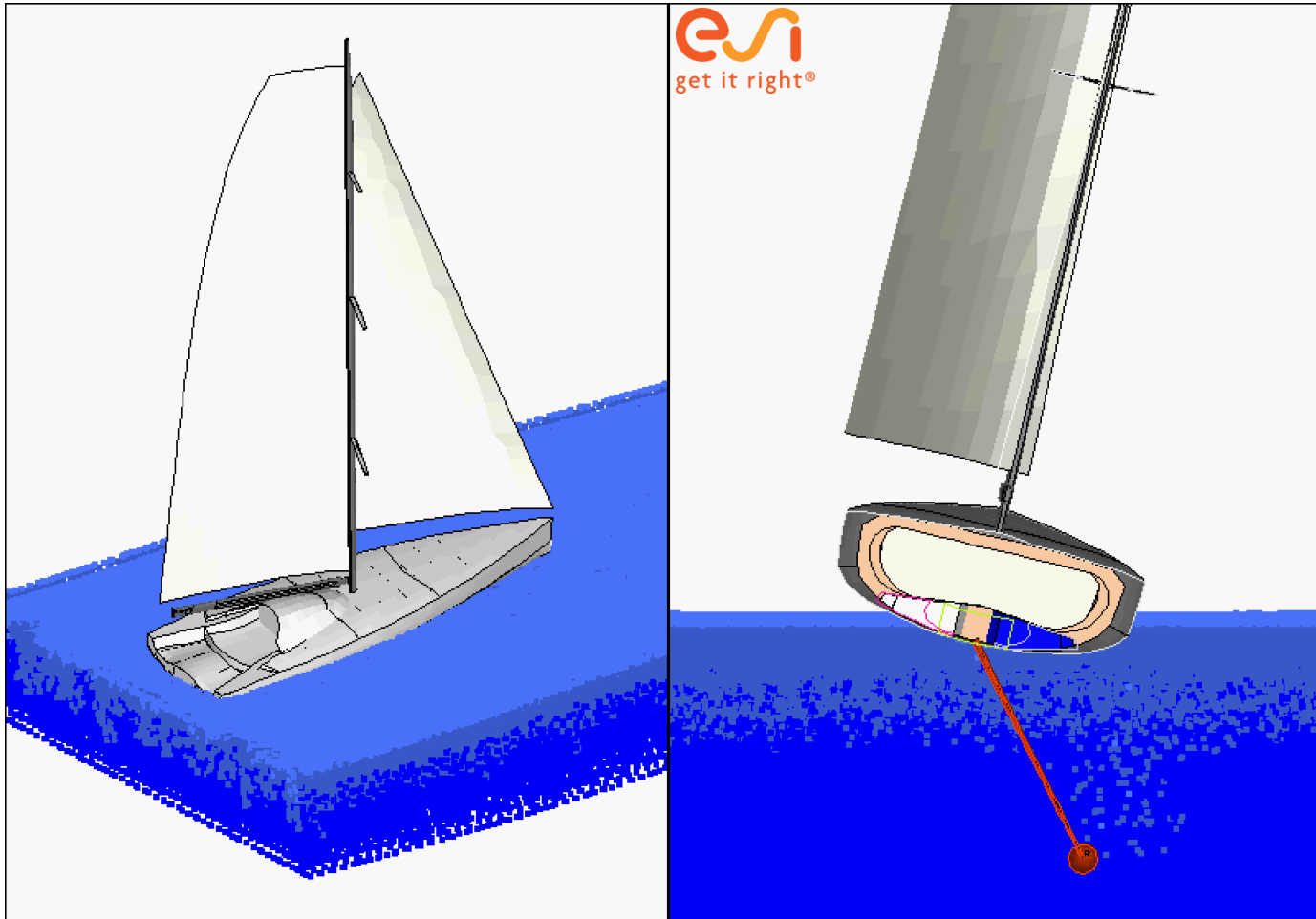


This document and the information contained are Safran Engineering Services property and shall not be copied or disclosed to any third party without Safran Engineering Services prior written authorization.

Study of Safran Open 60' race yacht crashworthiness

Sea modelling

Wind forces simulation



This document and the information contained are Safran Engineering Services property and shall not be copied or disclosed to any third party without Safran Engineering Services prior written authorization.

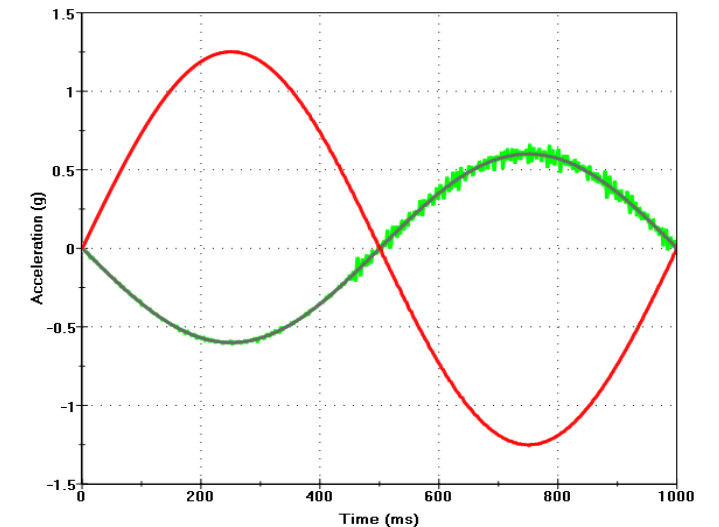
Study of Safran Open 60' race yacht crashworthiness

Hull modelling

Rigid ship slamming simulation



Hull center of gravity acceleration

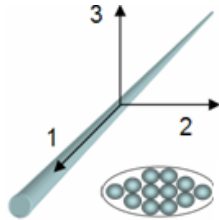


This document and the information contained are Safran Engineering Services property and shall not be copied or disclosed to any third party without Safran Engineering Services prior written authorization.

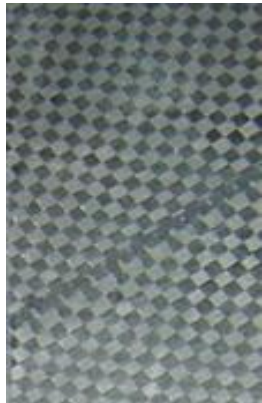
Study of Safran Open 60' race yacht crashworthiness

Composites modelling

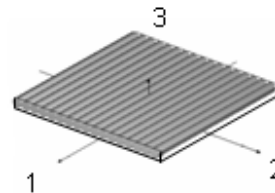
1-Constituent (Matrix/Yarn/honeycomb)



| Mechanical Properties | | |
|-------------------------|------|---------|
| Young's Modulus[11] | E11 | 276000 |
| Young's Modulus[22=33] | E22 | 18000 |
| Shear Modulus | G12 | 6000 |
| Shear Modulus | G23 | 3000 |
| Poisson's Ratio [12=13] | NU12 | 0.3 |
| Poisson's Ratio [23] | NU23 | 0.3 |
| Density | RO | 1.78e-3 |



2-Reinforcement (Unidirectional, Weave..)



| Import Yarn Charact... | UD_YARN | FIB_CARB_HR... |
|-----------------------------|---------|----------------|
| Areal Density | RHO | 300e-6 |
| Density | RO | 1.78e-3 |
| Fiber Direction | | |
| Young's Modulus [11] | E11 | 276000 |
| Transverse Direction | | |
| Young's Modulus [22] | E22 | 18000 |
| Shear Coupling | | |
| Shear Modulus [12=13] | G12 | 6000 |
| Shear Modulus [23] | G23 | 3000 |
| Poisson's Ratio [12] | NU12 | 0.3 |

Material 131
(Multi-layered shell) with ply

3-Ply definition

| | | |
|--------------------|---|--------|
| C. HR-240 300 g/m2 | 1 | 90 deg |
| C. HR-240 300 g/m2 | 1 | 90 deg |
| C. HR-240 150 g/m2 | 1 | 90 deg |
| C. HM-400 400 g/m2 | 1 | ±45° |
| C. HM-460 300 g/m2 | 1 | 0° |

| Reinforcement Sele... | | | |
|------------------------------|---------------|-----------------|-------------------------|
| Reinforcement Type | REIN_TYPE | UD | |
| Reinforcement Name | REINFORCEMENT | UDC_HR_300 | Select Reinforcement... |
| Matrix Selection | | | |
| Matrix Name | MATRIX | PR520 | Select matrix... |
| Micro Mechanical A... | | | |
| Select Option | MICRO_ANL | Micromechani... | |
| Fibre Volume Fraction | FVF | 0.6 | |
| Select Law | MICRO_LAW | Hashin relation | |
| Compute Properties with... | | | Compute |

4-Laminate definition

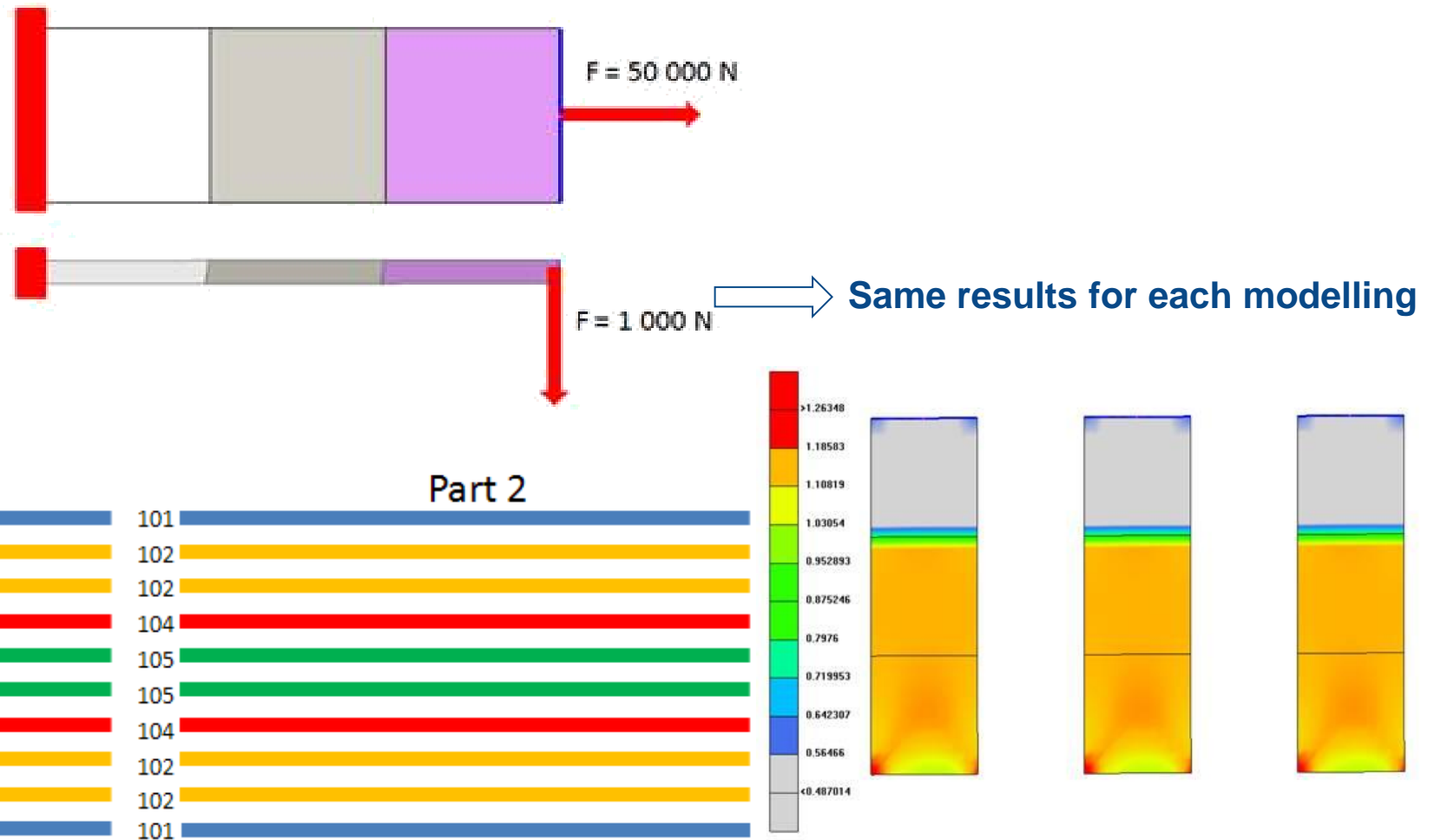
| | | | | |
|----------|----------|----------|---|----------|
| PLY_U... | UD (Ply) | PLY_1... | 0 | 0.277778 |
| PLY_U... | UD (Ply) | PLY_2... | 0 | 0.277778 |
| PLY_U... | UD (Ply) | PLY_3... | 0 | 0.277778 |

This document and the information contained are Safran Engineering Services property and shall not be copied or disclosed to any third party without Safran Engineering Services prior written authorization.

Study of Safran Open 60' race yacht crashworthiness

Composites modelling

Modelling validation



This document and the information contained are Safran Engineering Services property and shall not be copied or disclosed to any third party without Safran Engineering Services prior written authorization.

Study of Safran Open 60' race yacht crashworthiness

Composites modelling

Ply database

```

PLY /      1      1
NAME PLY_1_COMP_a
 85000.    6000.
 65000.    3500.    2200.
   0.      0.      0.
   0.      0.      0.
    
```



100 g/m²



200 g/m²



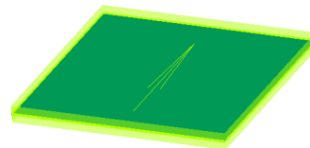
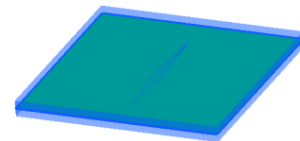
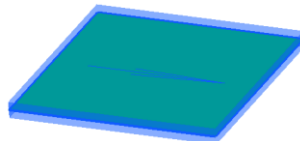
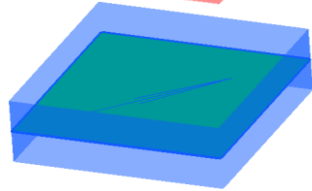
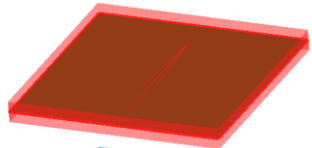
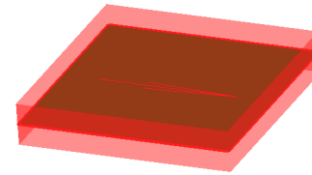
300 g/m²



Layer database

```

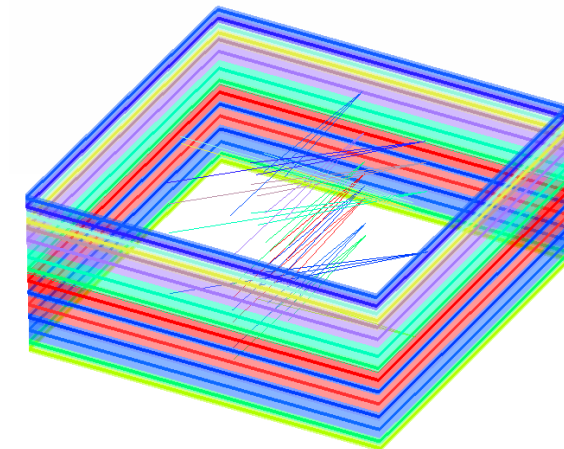
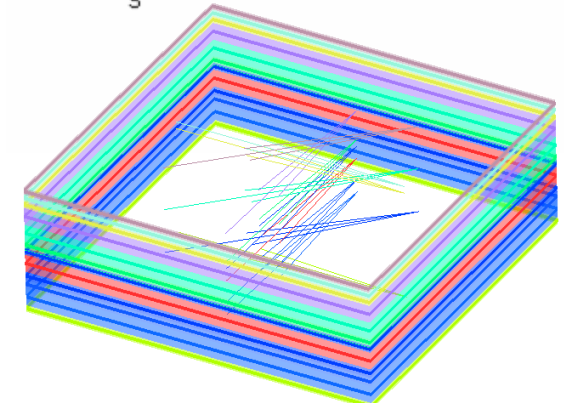
LAYER /      36
NAME Layer_1_a
   1      0.15      45.
    
```



Material database

```

MATER /      32001      131      0      0      1.
NAME COMPOSITE_BF_1
 0.1      0.      18      1
 1
 2
 3
 4
 5
    
```



This document and the information contained are Safran Engineering Services property and shall not be copied or disclosed to any third party without Safran Engineering Services prior written authorization.

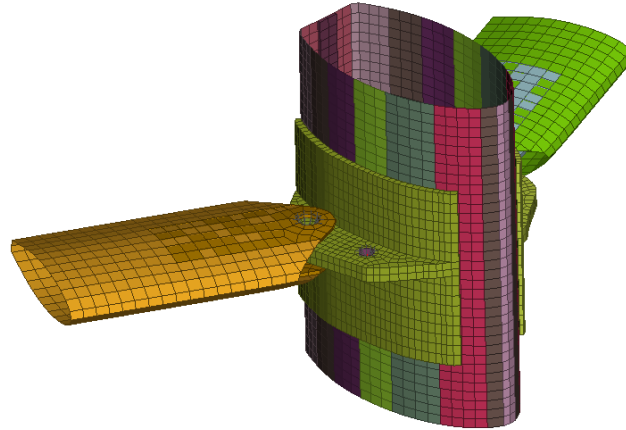
Study of Safran Open 60' race yacht crashworthiness

Mast modelling

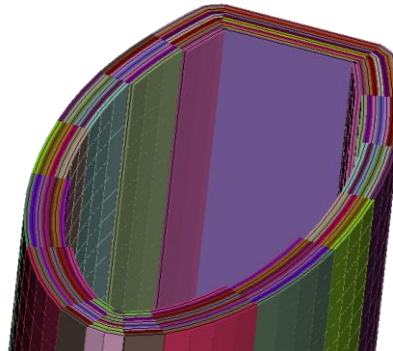
Mast modelling



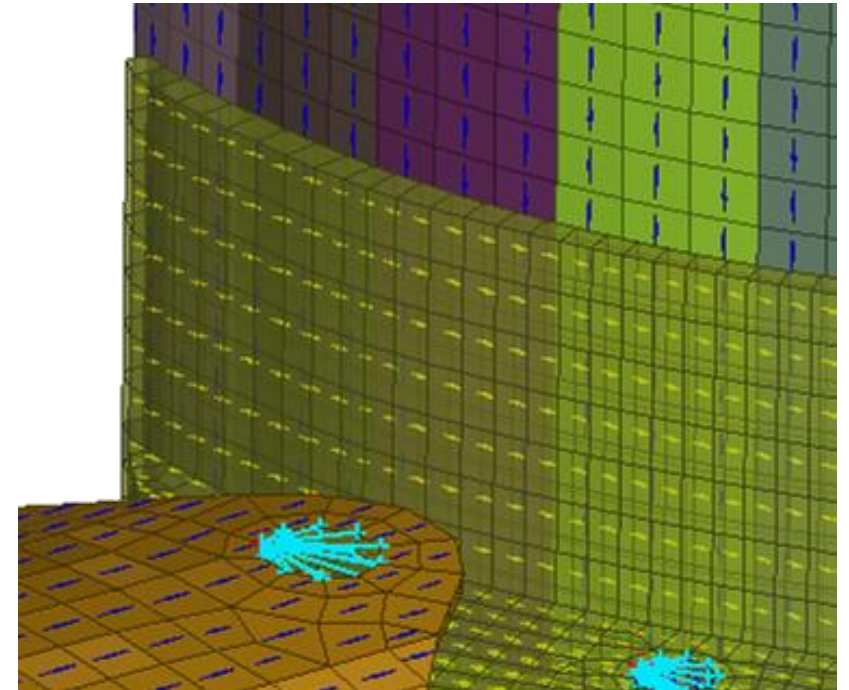
Meshing



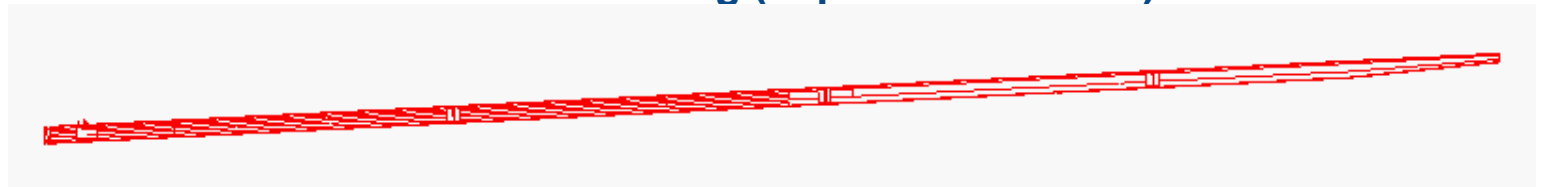
Composite materials



elements orientation (ori file)



Mast validation with static loading (implicit simulation)

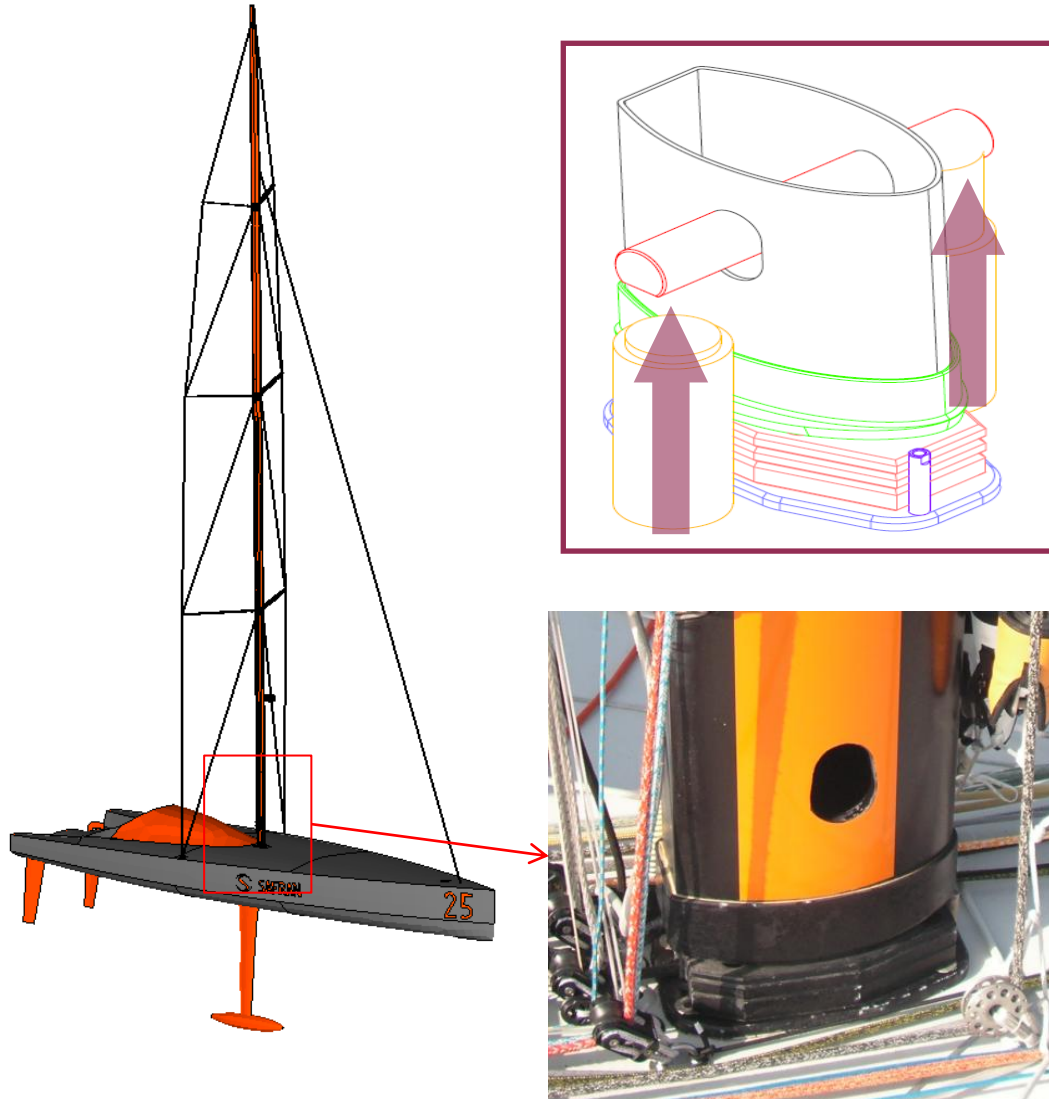


This document and the information contained are Safran Engineering Services property and shall not be copied or disclosed to any third party without Safran Engineering Services prior written authorization.

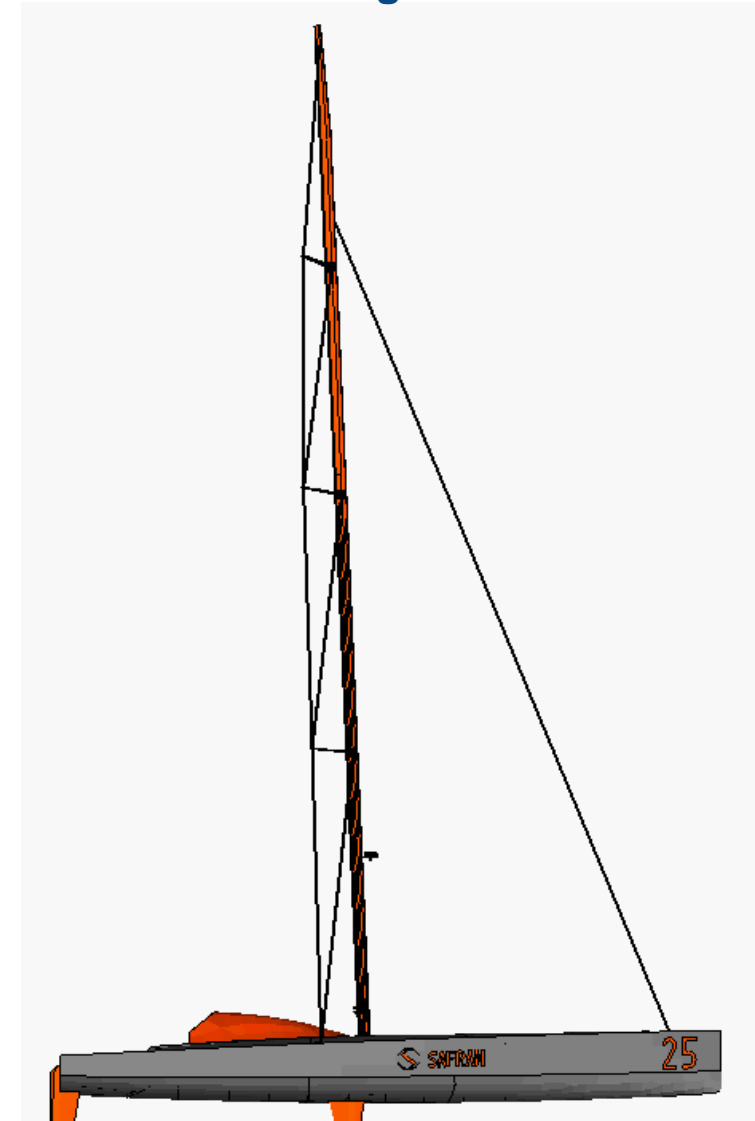
Study of Safran Open 60' race yacht crashworthiness

Mast constraining

Mast constraining principle



Mast constraining simulation



This document and the information contained are Safran Engineering Services property and shall not be copied or disclosed to any third party without Safran Engineering Services prior written authorization.

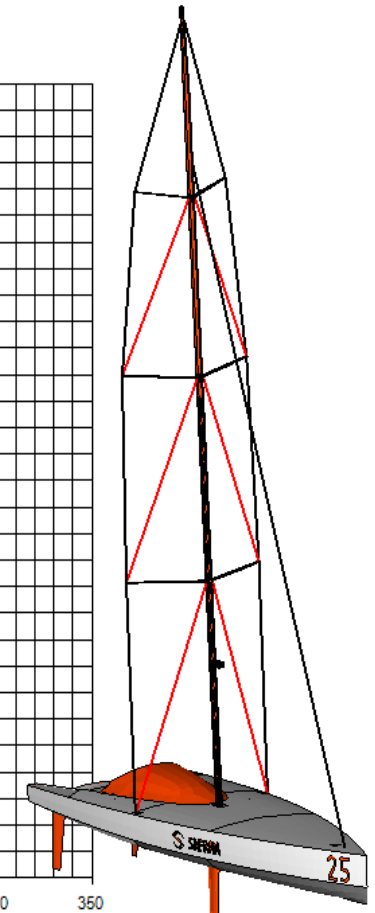
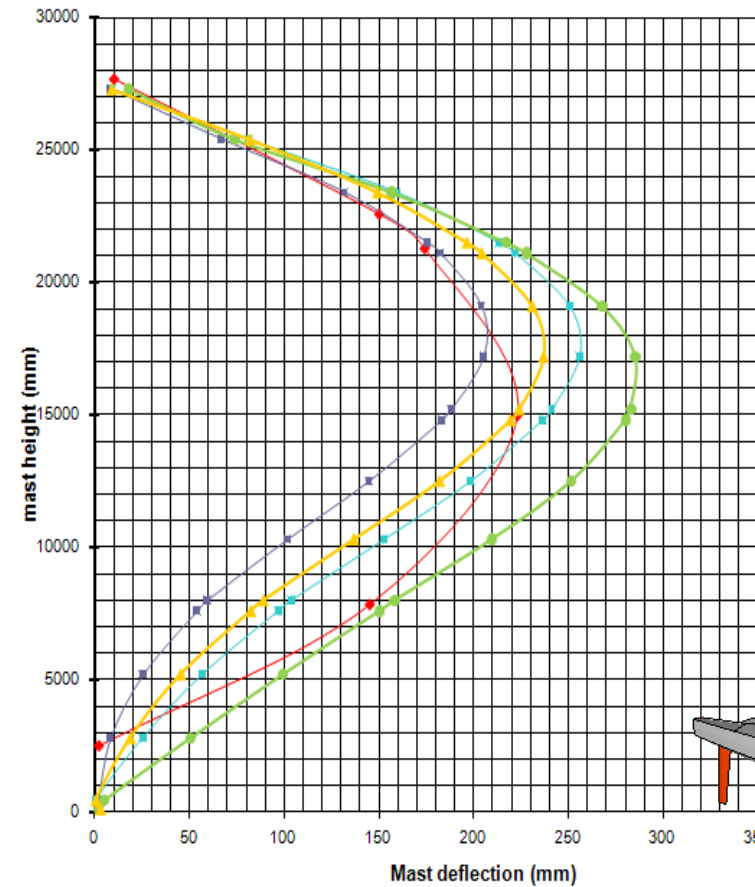
Study of Safran Open 60' race yacht crashworthiness

Mast constraining

Cables slack



Mast deflection

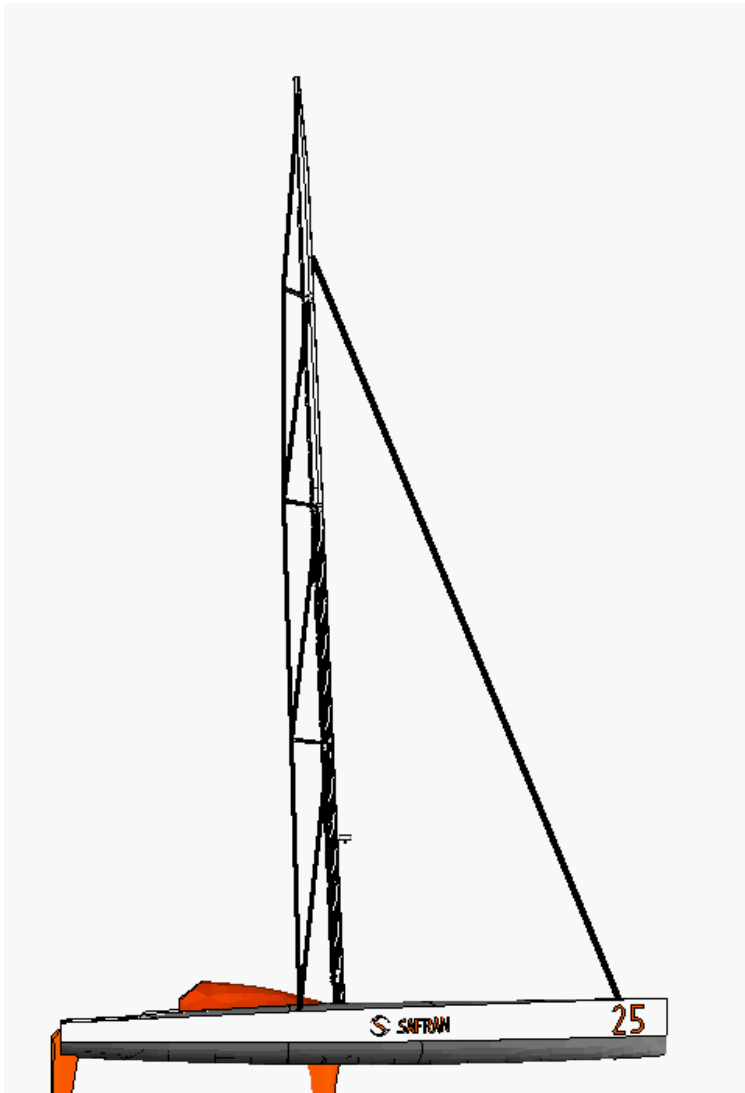


This document and the information contained are Safran Engineering Services property and shall not be copied or disclosed to any third party without Safran Engineering Services prior written authorization.

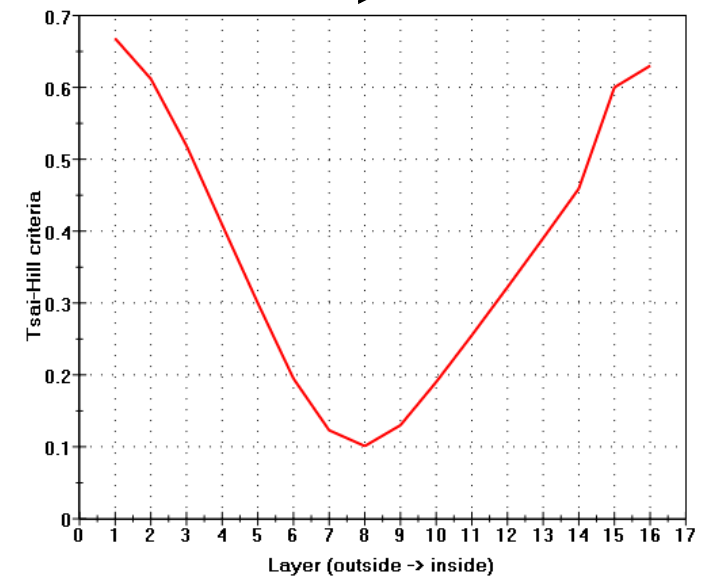
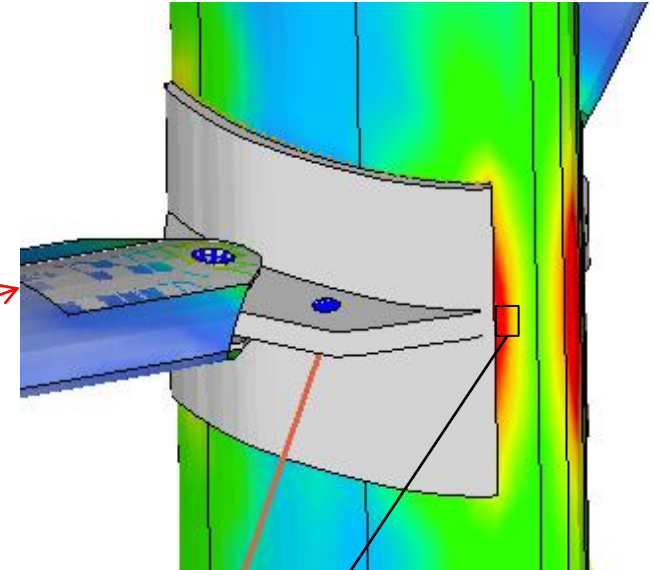
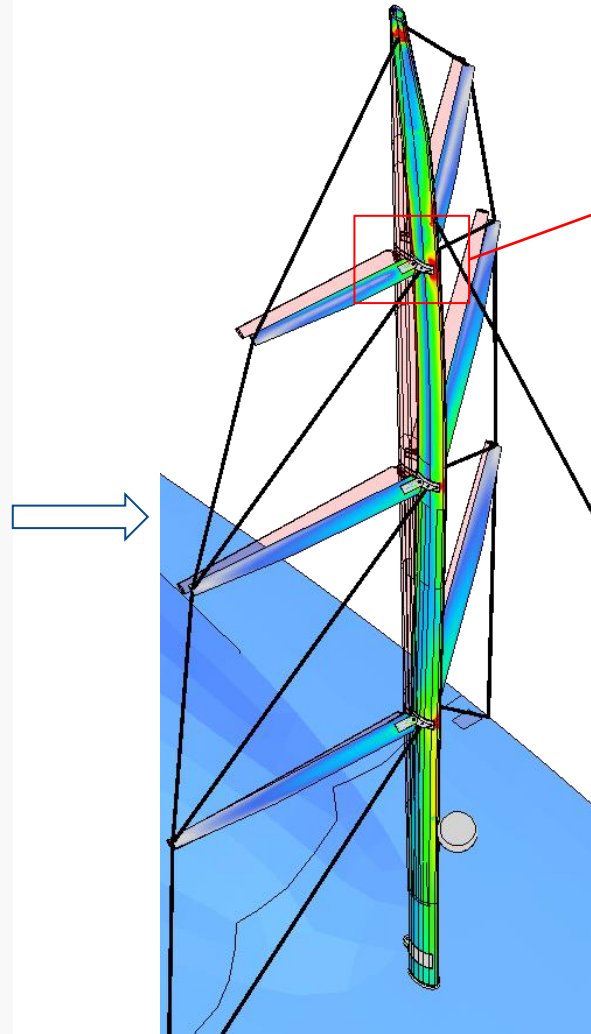
Study of Safran Open 60' race yacht crashworthiness

pretension

Mast constraining



Tsai-Hill criteria

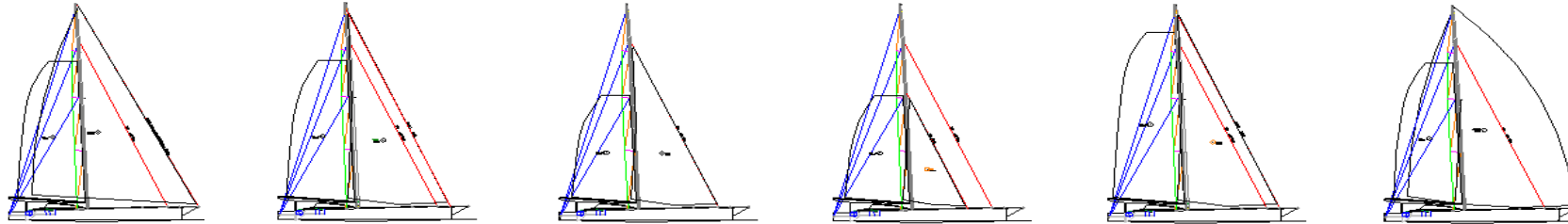


This document and the information contained are Safran Engineering Services property and shall not be copied or disclosed to any third party without Safran Engineering Services prior written authorization.

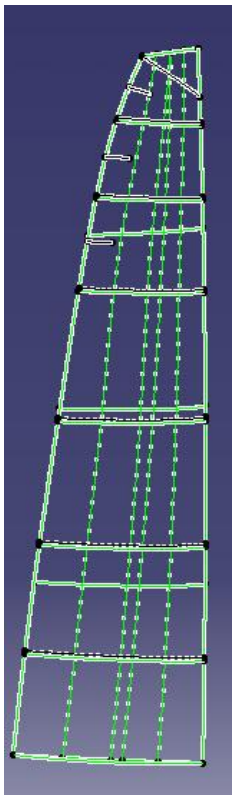
Study of Safran Open 60' race yacht crashworthiness

Sails modelling

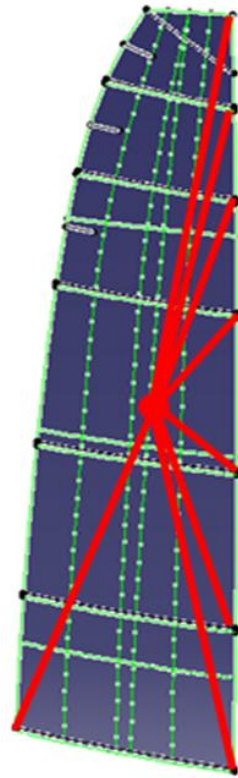
Sails configuration



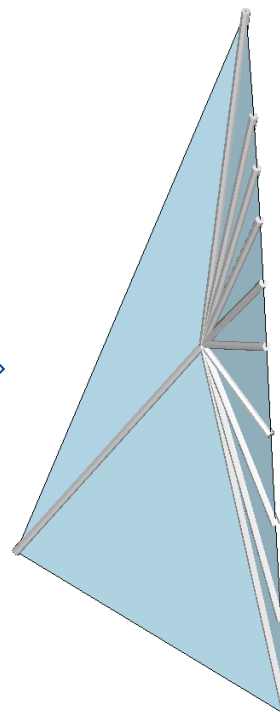
Sails CAD



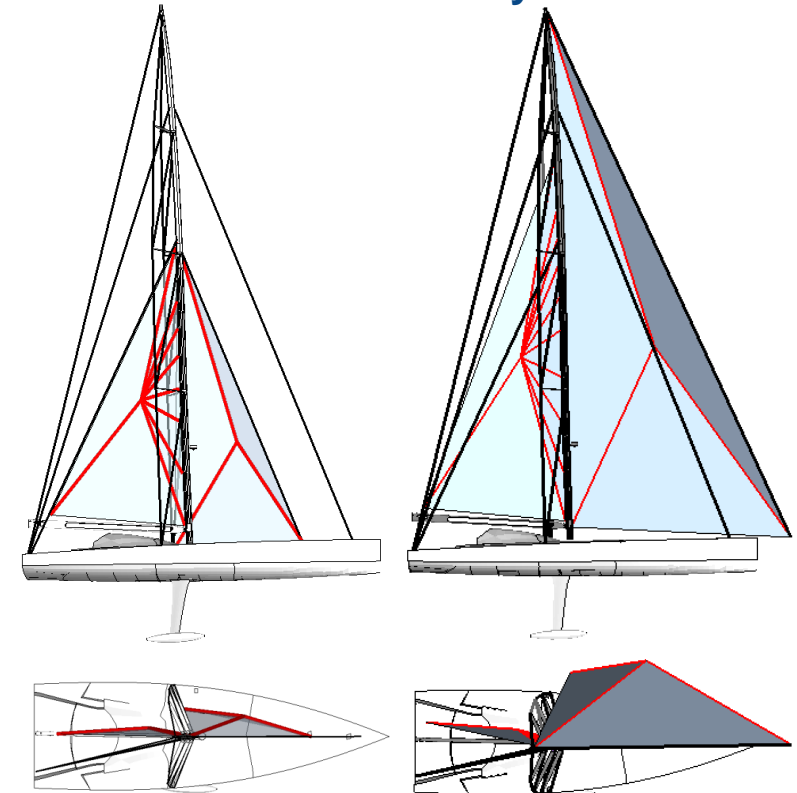
Spring connections



Spring model



Model Assembly



This document and the information contained are Safran Engineering Services property and shall not be copied or disclosed to any third party without Safran Engineering Services prior written authorization.

Study of Safran Open 60' race yacht crashworthiness

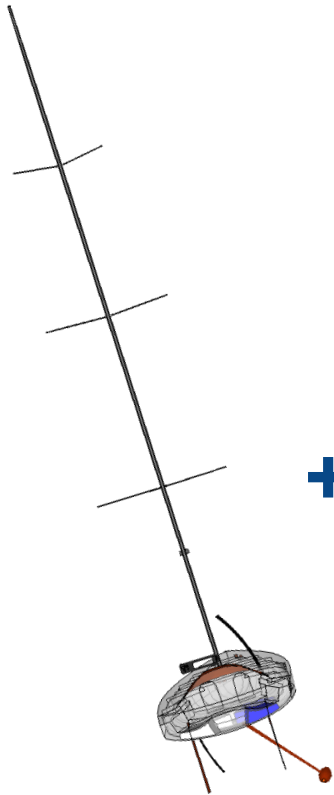
Shipping conditions

Ship configuration

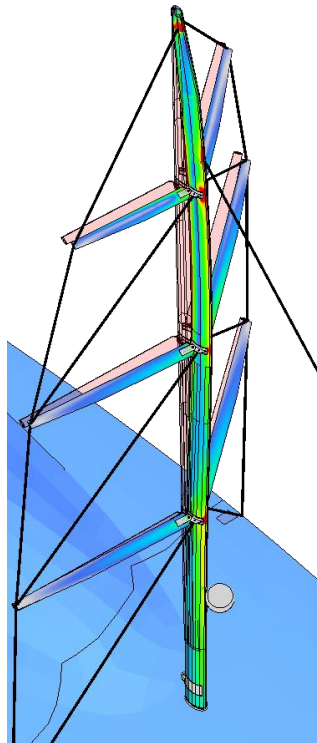
Mast constraining
(PICKING)

Sails &
Wind forces

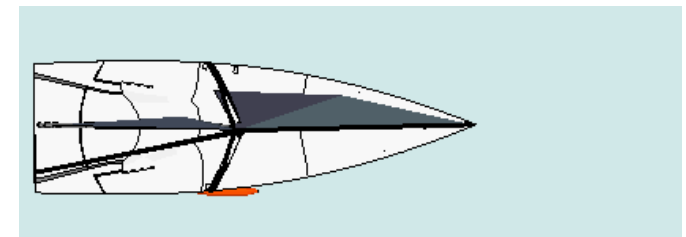
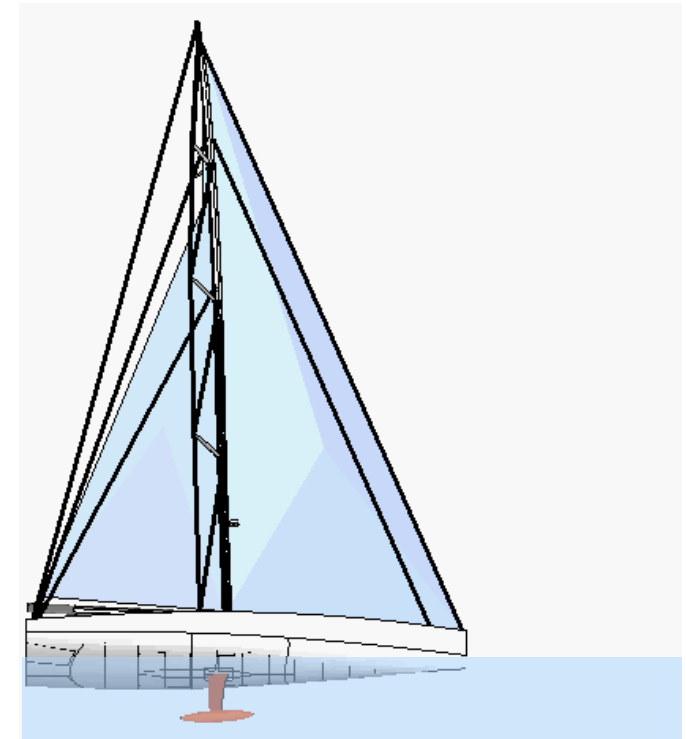
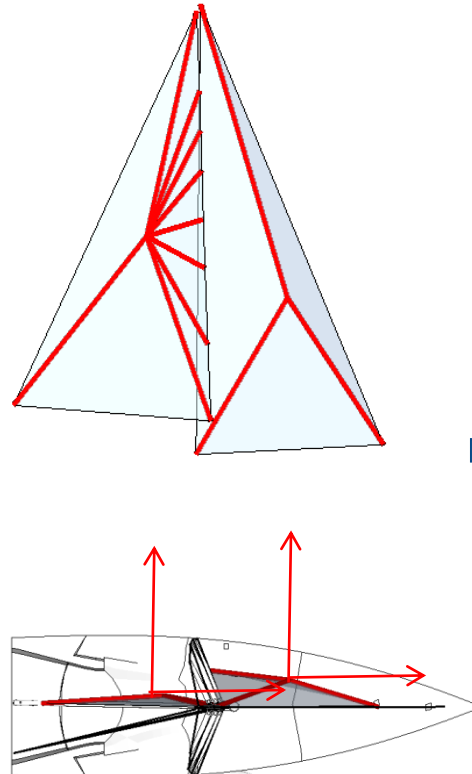
Shipping conditions simulation



+



+

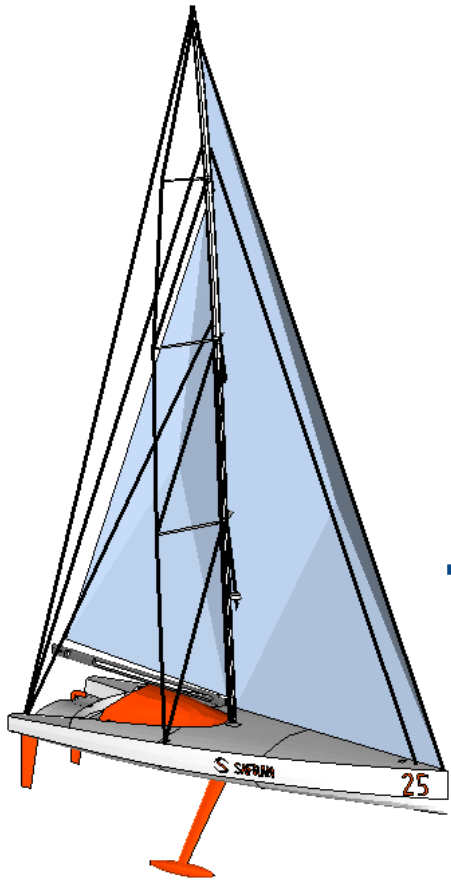


This document and the information contained are Safran Engineering Services property and shall not be copied or disclosed to any third party without Safran Engineering Services prior written authorization.

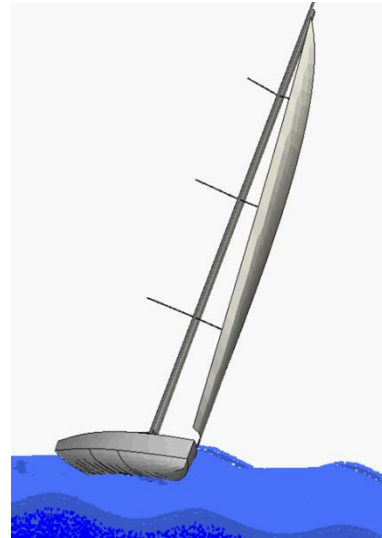
Study of Safran Open 60' race yacht crashworthiness

Slamming

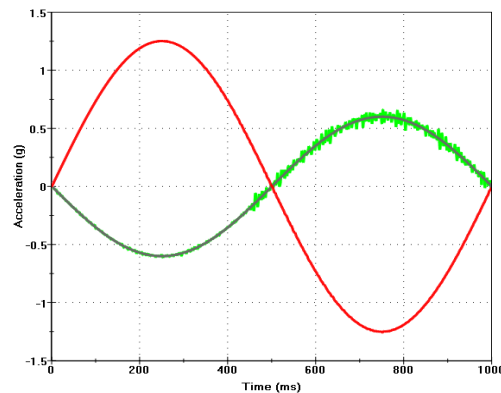
Shipping conditions simulation



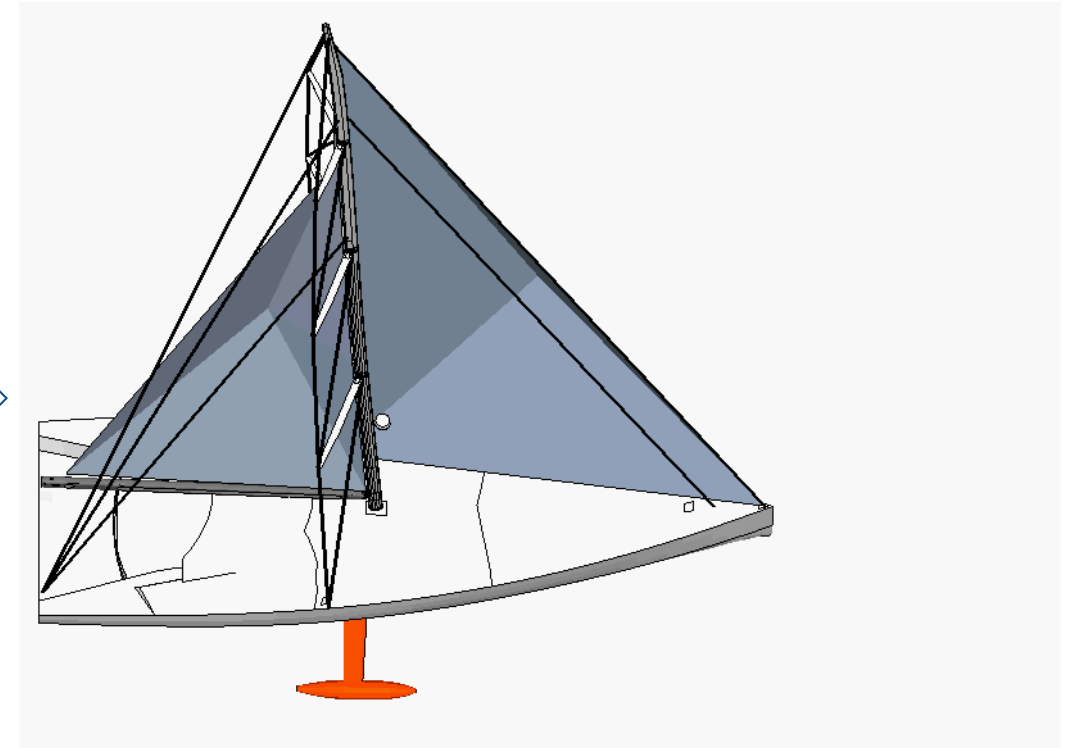
+



Hull center of gravity
acceleration &
rotations from rigid
model slamming
simulation

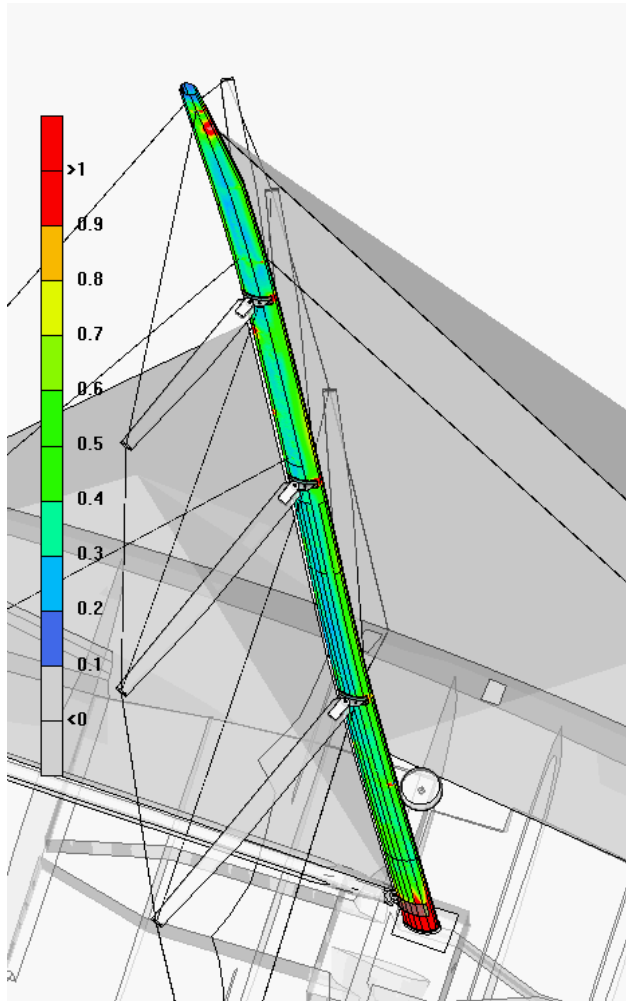


Slamming simulation with composite
modelling

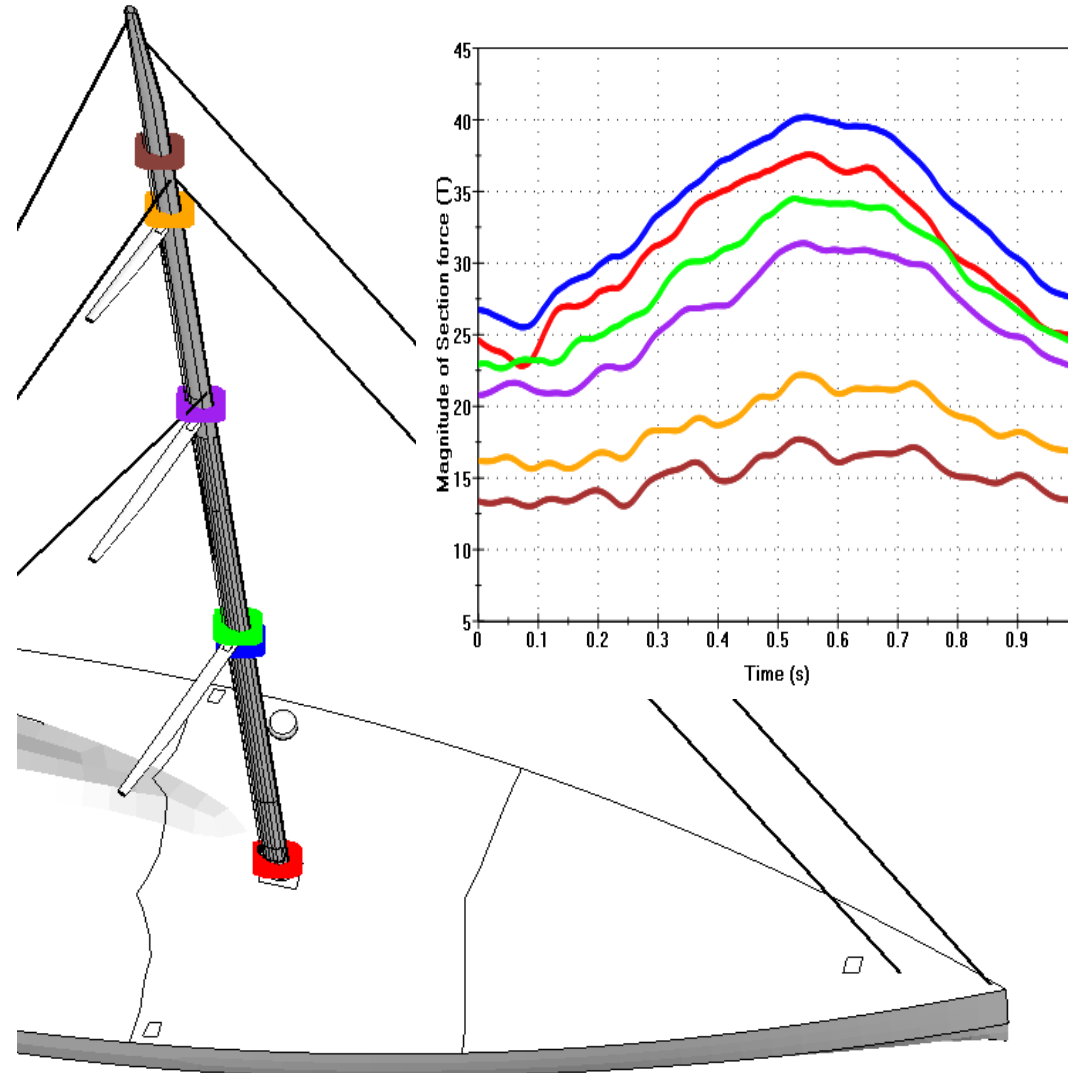


This document and the information contained are Safran Engineering Services property and shall not be copied or disclosed to any third party without Safran Engineering Services prior written authorization.

Tsai-Hill criteria



Forces in mast cross-sections

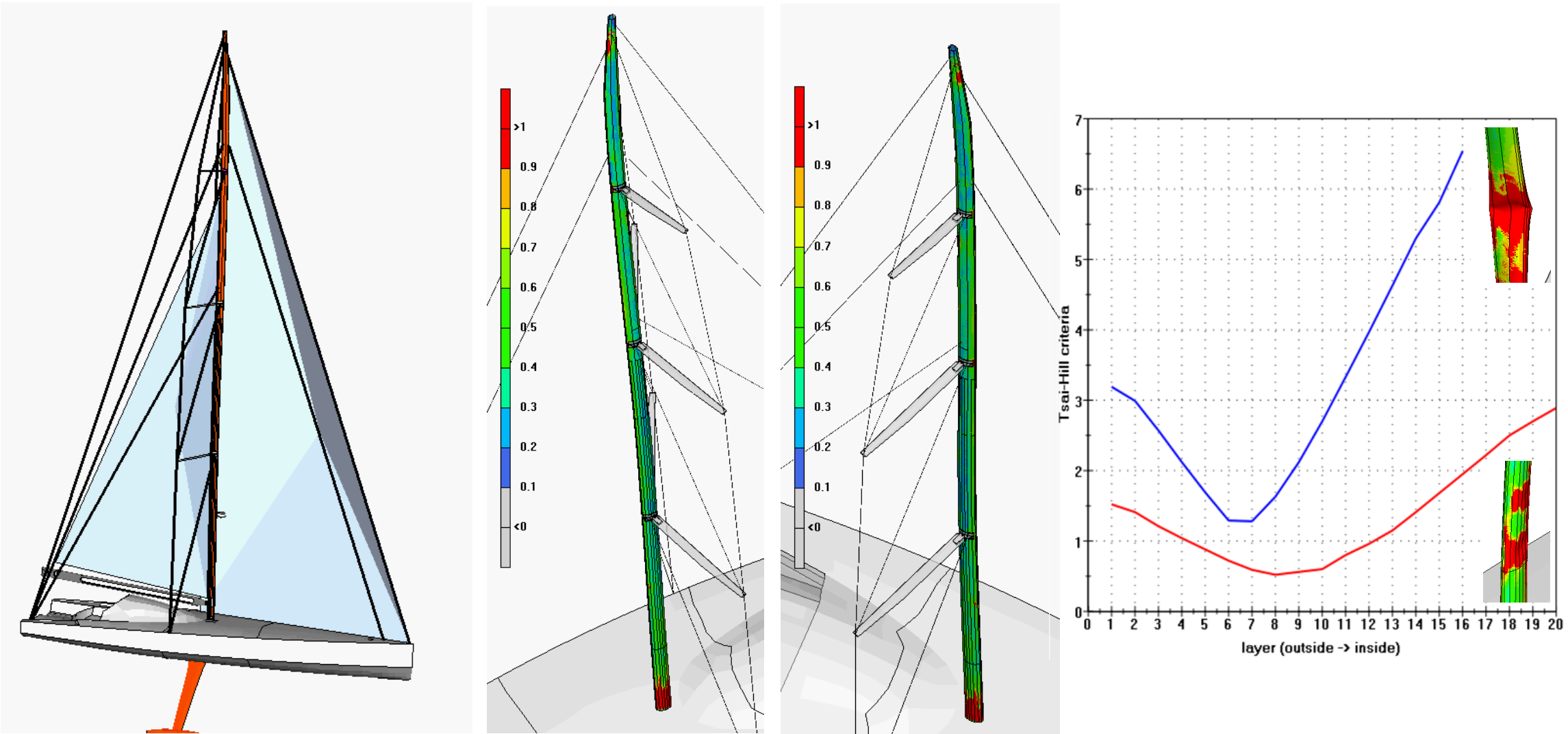


This document and the information contained are Safran Engineering Services property and shall not be copied or disclosed to any third party without Safran Engineering Services prior written authorization.

Study of Safran Open 60' race yacht crashworthiness

Slamming

Slamming impact for a different ship configuration and sea condition

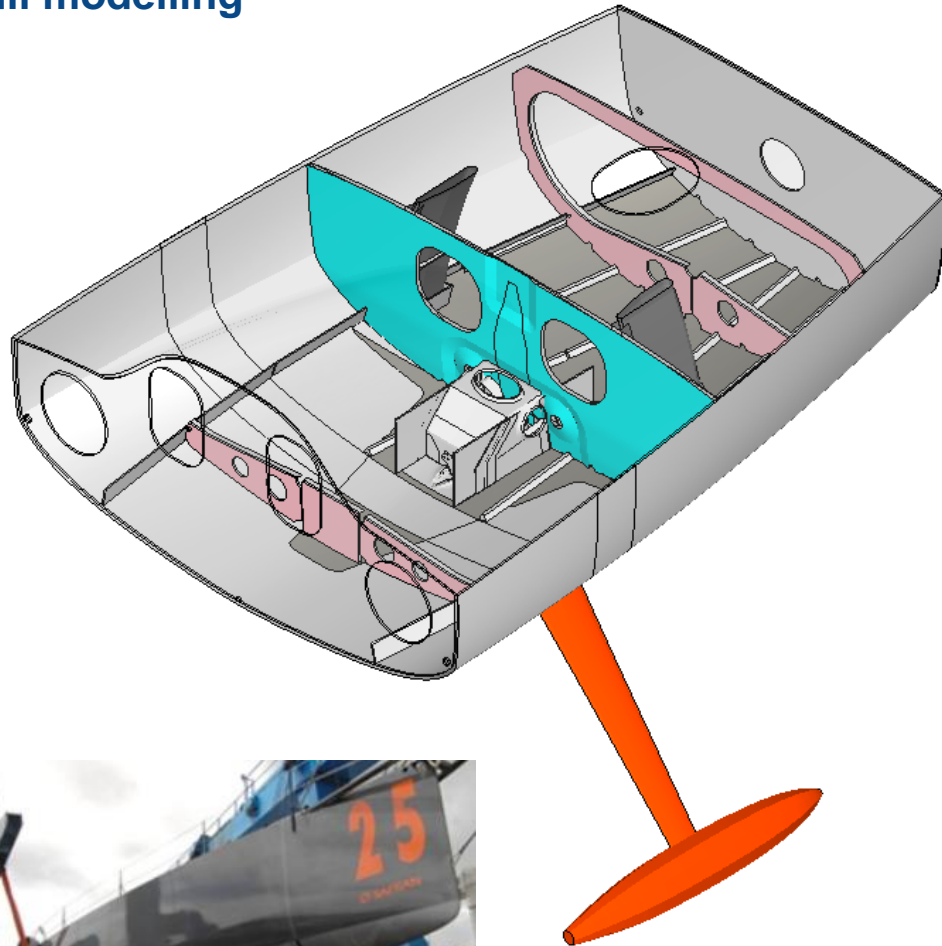


This document and the information contained are Safran Engineering Services property and shall not be copied or disclosed to any third party without Safran Engineering Services prior written authorization.

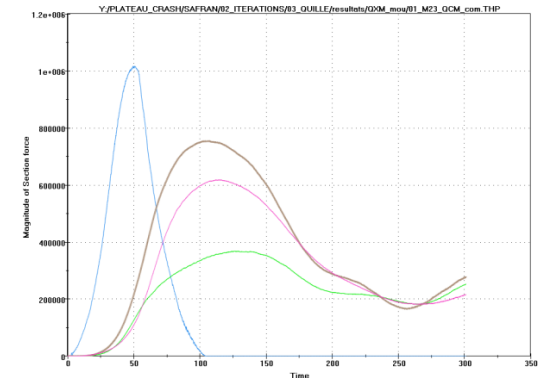
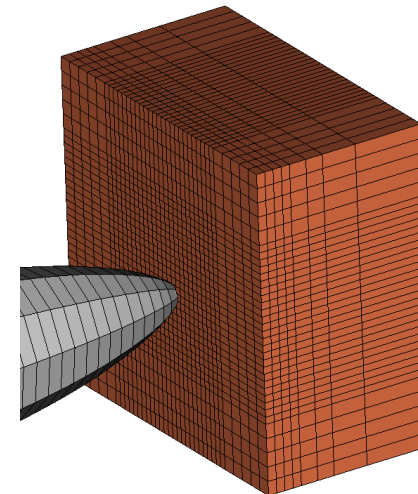
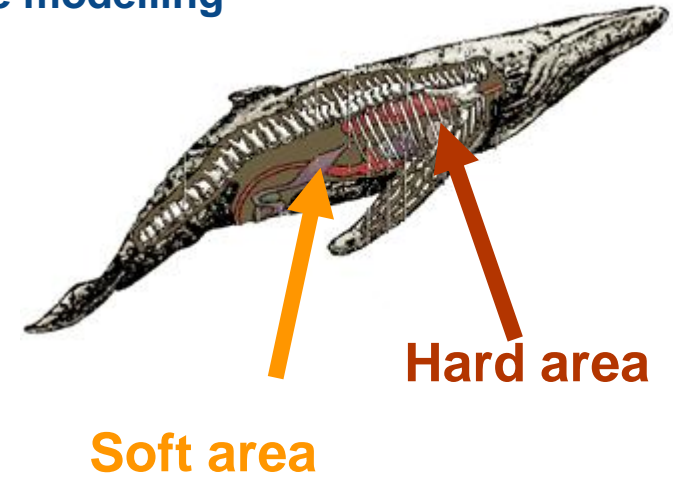
Study of Safran Open 60' race yacht crashworthiness

Keel Impact Simulation

Hull modelling



Whale modelling

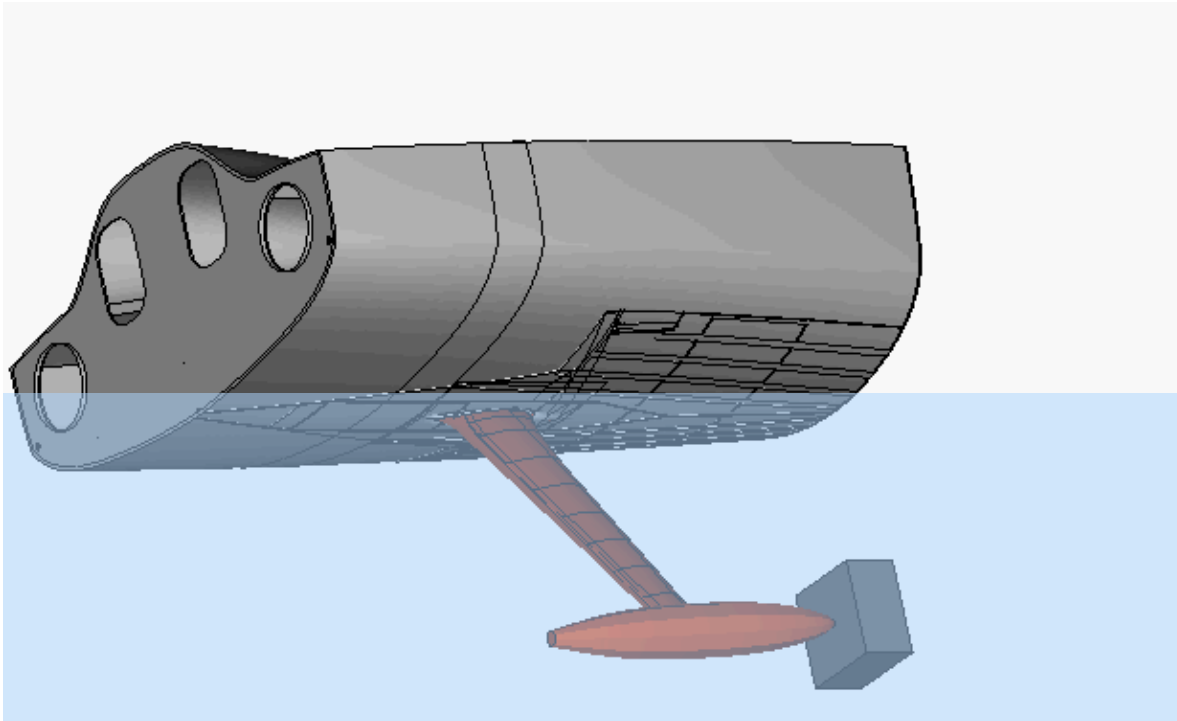


This document and the information contained are Safran Engineering Services property and shall not be copied or disclosed to any third party without Safran Engineering Services prior written authorization.

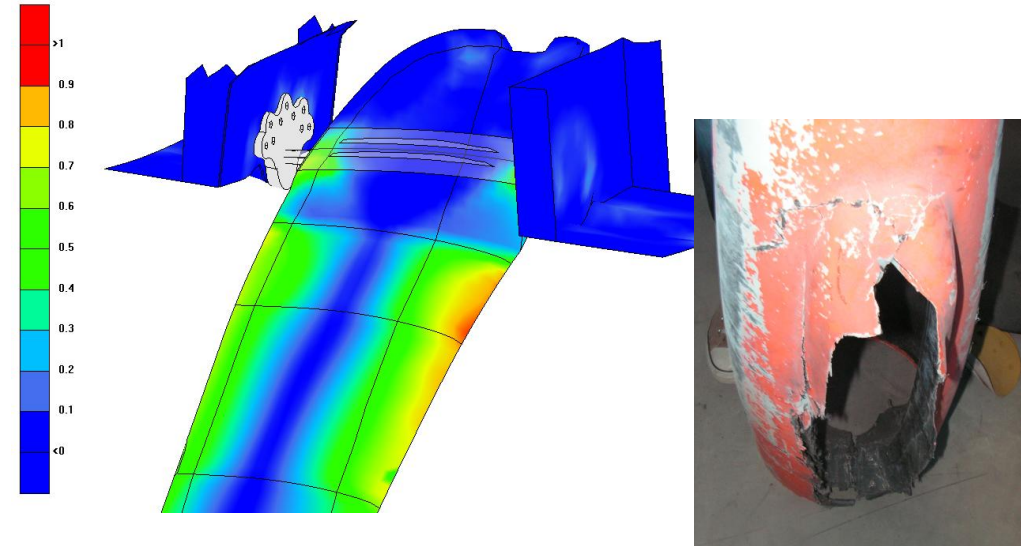
Study of Safran Open 60' race yacht crashworthiness

Keel Impact Simulation

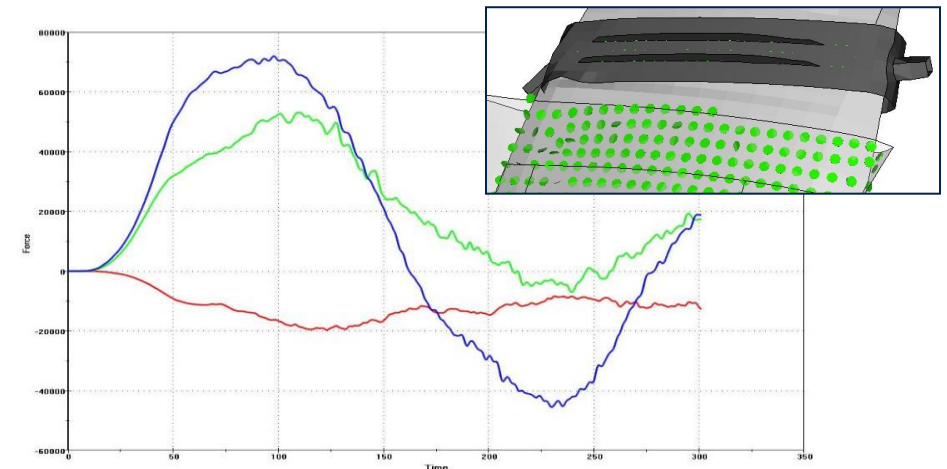
Impact simulation



Tsai-Hill criteria



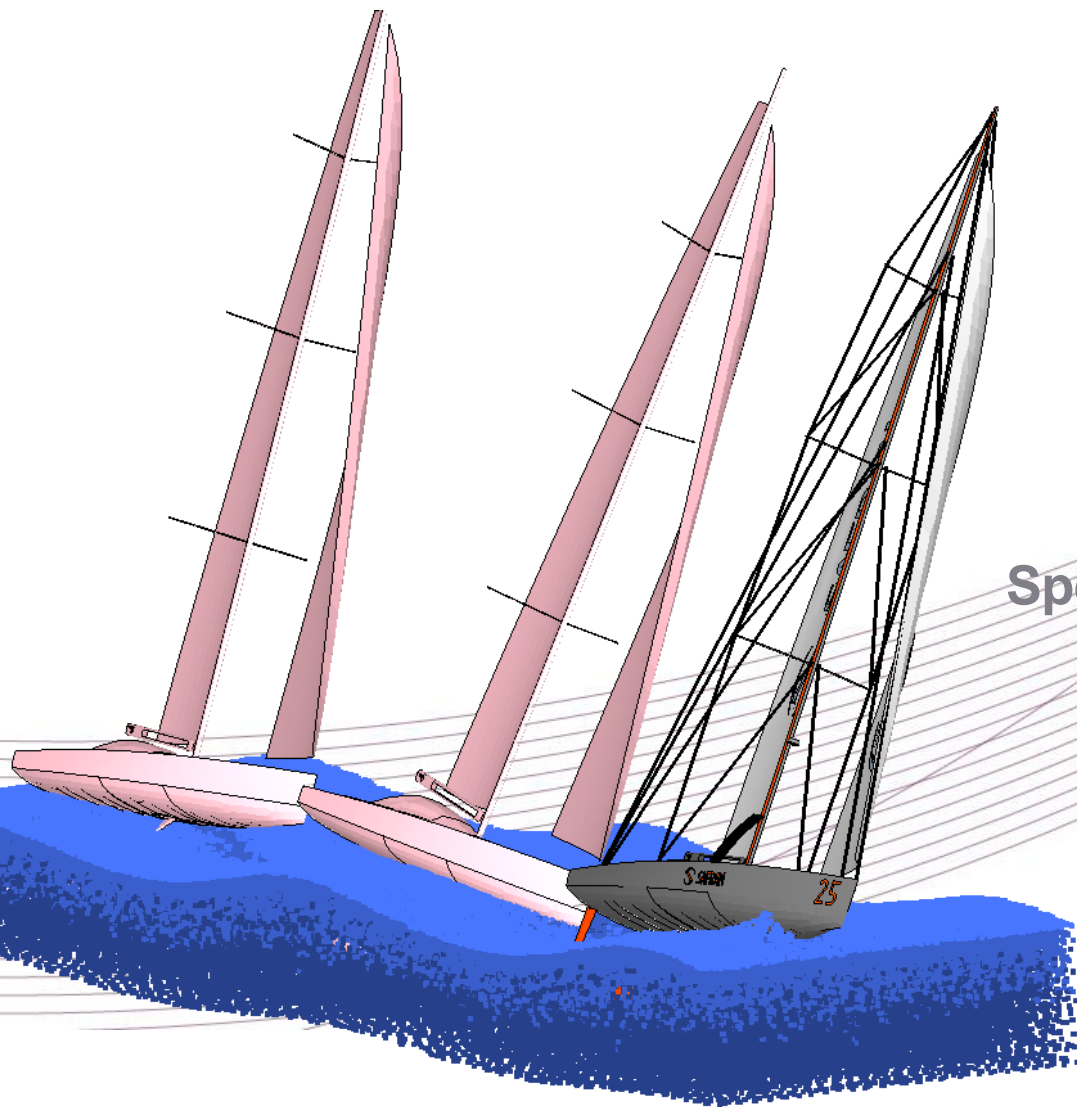
Forces in glue between keel core and keel cover



This document and the information contained are Safran Engineering Services property and shall not be copied or disclosed to any third party without Safran Engineering Services prior written authorization.

Safran

Thank you for your attention



Special thanks to Safran Engineering Services
co-workers (Abel Arbor, Celine Ruffin, Loic
Faure, Rémi Rebours), Guillaume Verdier.