This project has recived funding from European Union's Horizon 2020 research and innovation programme under grant agreement N° 723360

Computational Analysis Tools

Julio García-Espinosa, Compass IS
E: julio@compassis.com
W: www.compassis.com

1st FIBRESHIP Workshop / 14th June 2018, London

Computational Analysis Tools

- FRP-structures of large-length ships need to be able to withstand extreme loads and environmental conditions with minimum maintenance. Furthermore, large vessels are classified according to their expected life, and therefore it is essential to have advanced simulation tools that are able to assess and optimize the life-time performance of FRP-based ship structures.
- FIBRESHIP will overcome this challenge by delivering a rational, robust and validated set of computational analysis solutions for assessing the structural integrity of large-length FRP ships during their life time.
- Another challenge in the design of large-length FRP is to demonstrate 'steel equivalence' to fulfil the fire-safety requirements. For this purpose fire risk analyses, based on advanced simulation tools, are required.
- FIBRESHIP will develop an innovative coupled analysis solution for fire/smoke dynamics/propagation and collapse assessment of FRP composite structures.

- **New computational analysis needs have been identified for the structural and collapse assessment and fire collapse of the future large-length FRP vessels.**
- **Those analysis solutions have application on design, building, operation and maintenance.**
- **The new solutions will be based on existing technology (from previous R&D projects), with special attention paid to practicality and usability.**

Constitutive model for FRP materials

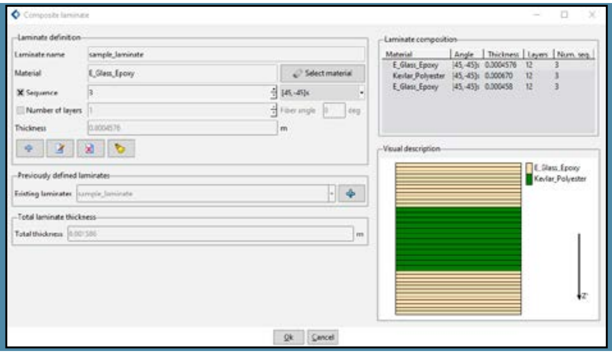
Solution: Constitutive model for FRP materials (basic component)

Objectives: Integrate (within a FEM GUI) an advanced constitutive model for FRP materials based on the Serial/Parallel mixing theory (SP-RoM) + explicit Kachanov-type damage (including model implementation and validation).

Components: GiD, Tdyn-Ramseries, SP-RoM thermomechanical model (new).

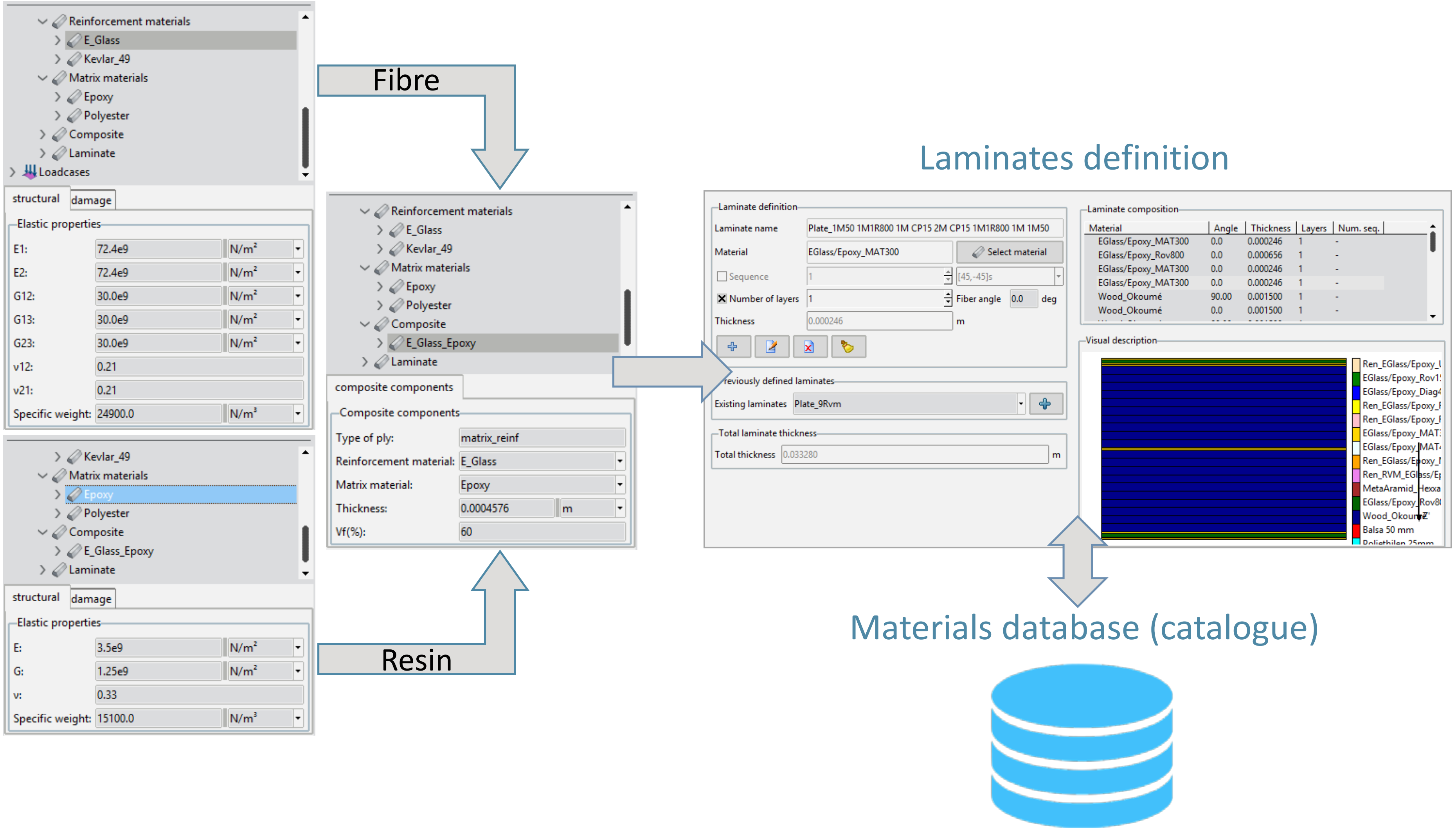
Other characteristics: Usability (easy definition, local axes, ...).

Constitutive model for FRP materials



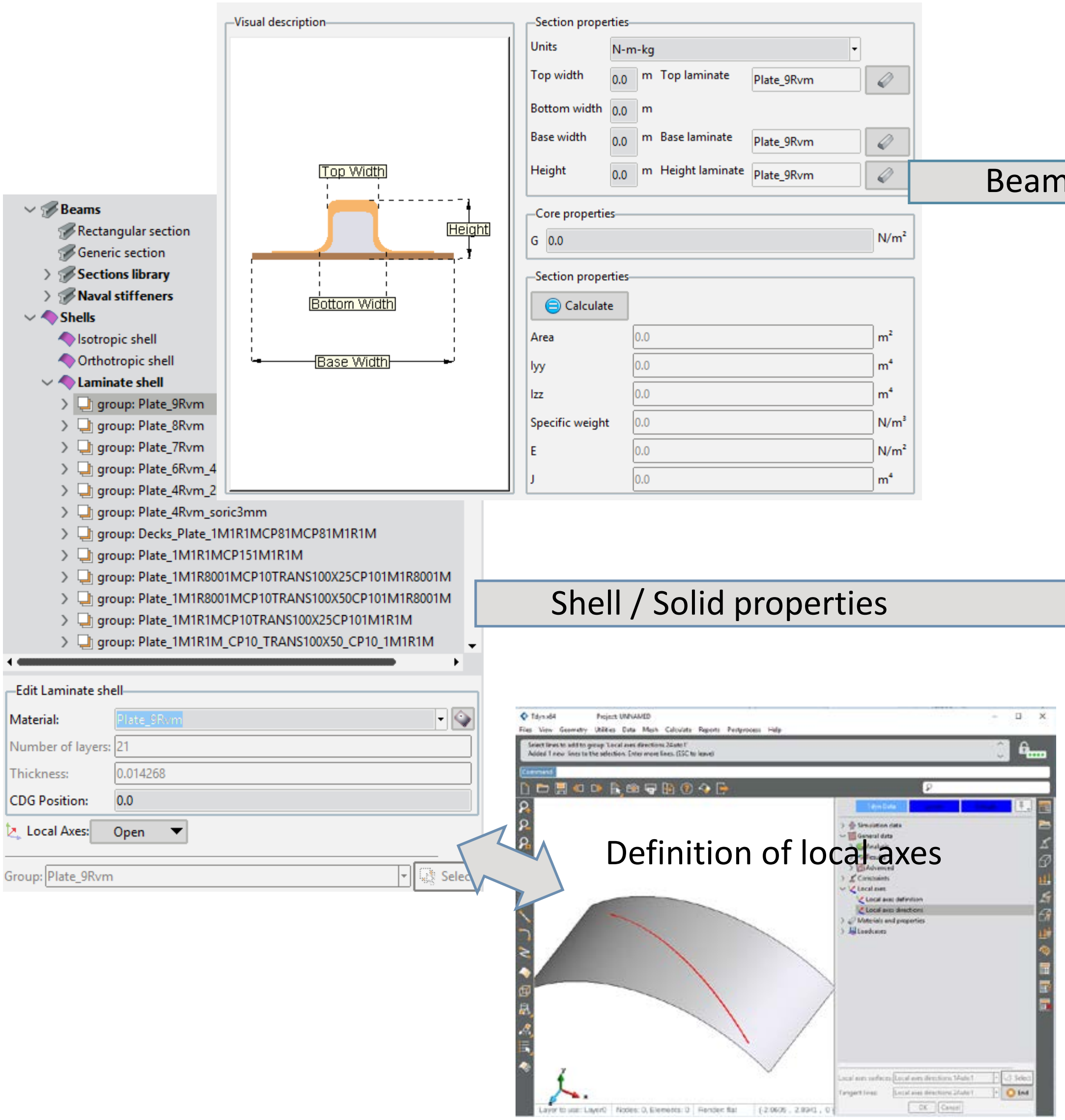
Constitutive model for FRP materials

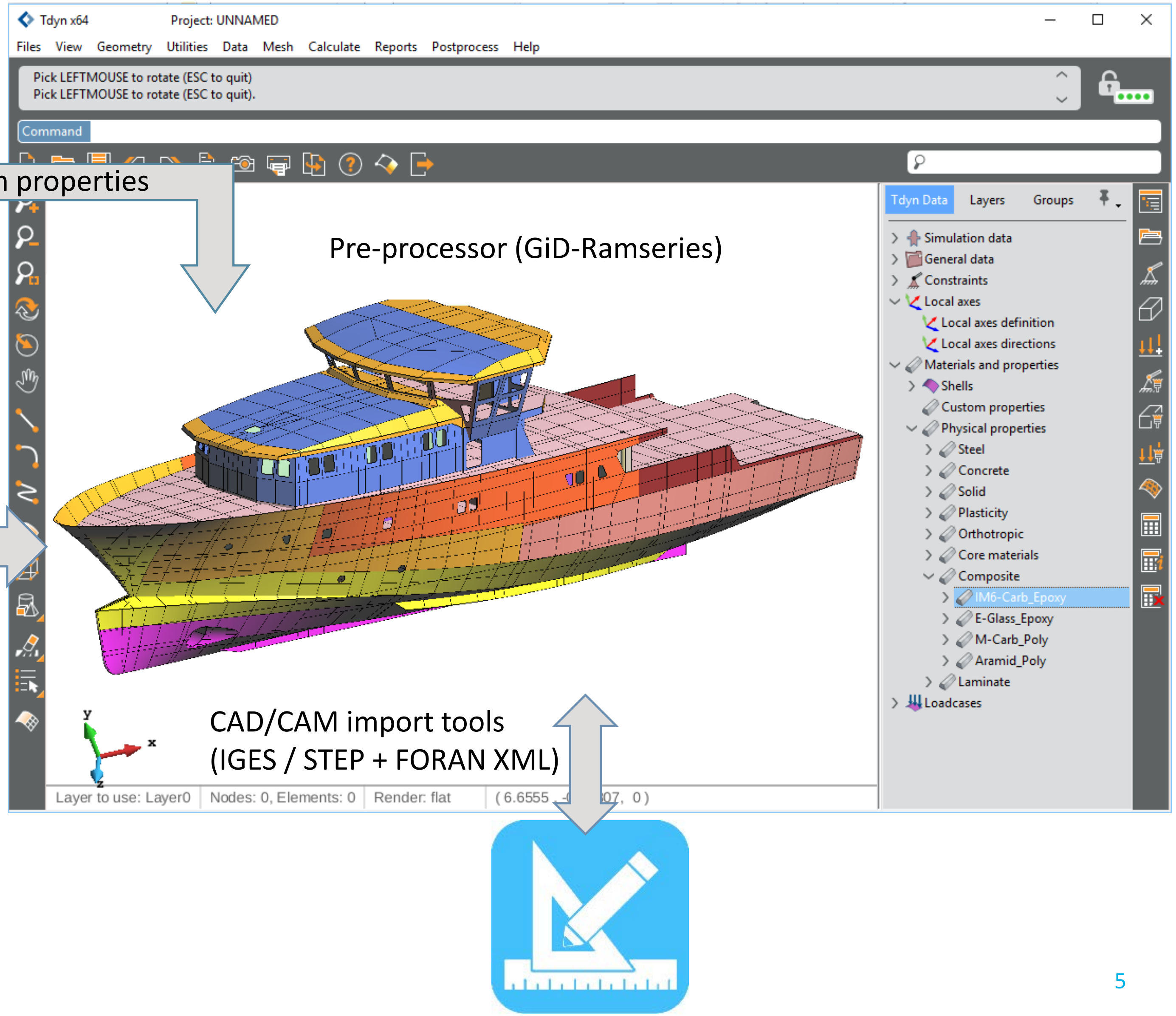
Definition of FRP laminates



Constitutive model for FRP materials

Definition of structural FEM model





Solution:

- Hull girder model (basic component for fatigue assessment and health structural monitoring tools).
- Long term analysis (fatigue assessment) tool for FRP structures.

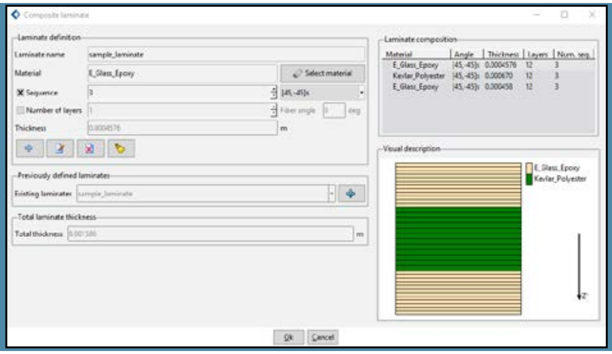
Objectives:

- To implement a time-domain coupled hull girder – seakeeping analysis tool (linear/non-linear – 1^{st} order/2^{nd} order) and a 1D to 3D FEM interface.
- To implement a fatigue damage formulation which reduces the strength capacity of the material based on energy dissipated in each load cycle (load cycle is a variable of the model).

Components: GiD, Tdyn-SeaFEM, Tdyn-Ramseries, fatigue damage model (new).

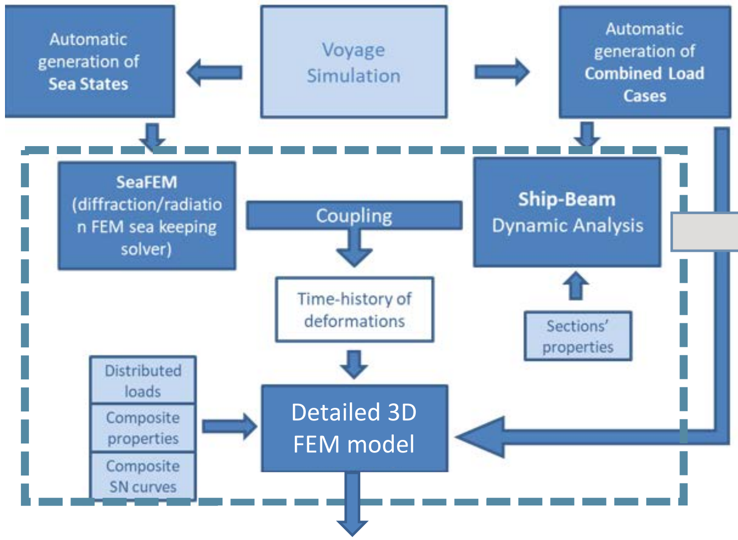
Other characteristics: Hull girder to 3D FEM model interface, Reduced computational cost, Usability (new GUI), Practicality.

Hull girder model

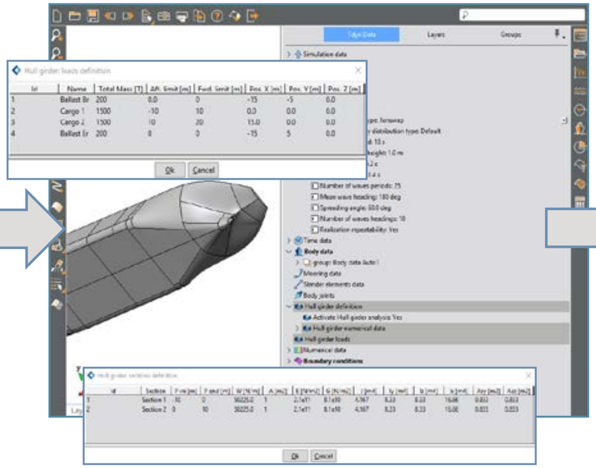


Hull girder model

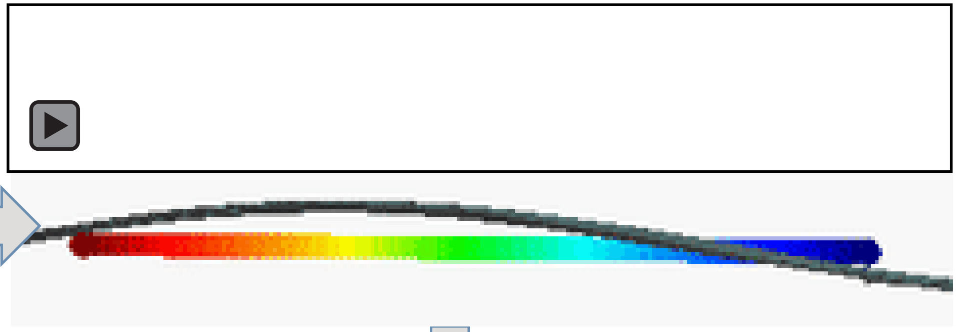
Definition of FRP laminates



Hull girder model definition

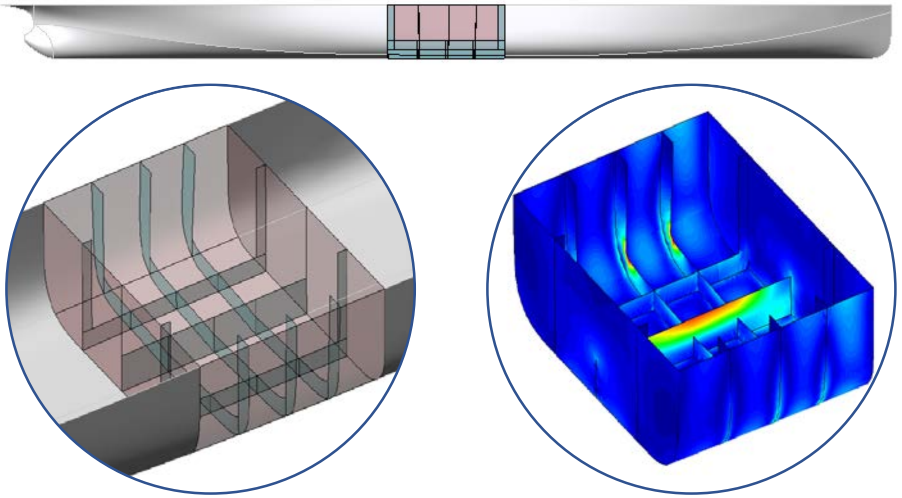


Coupled hull girder – seakeeping analysis



1D to 3D interface

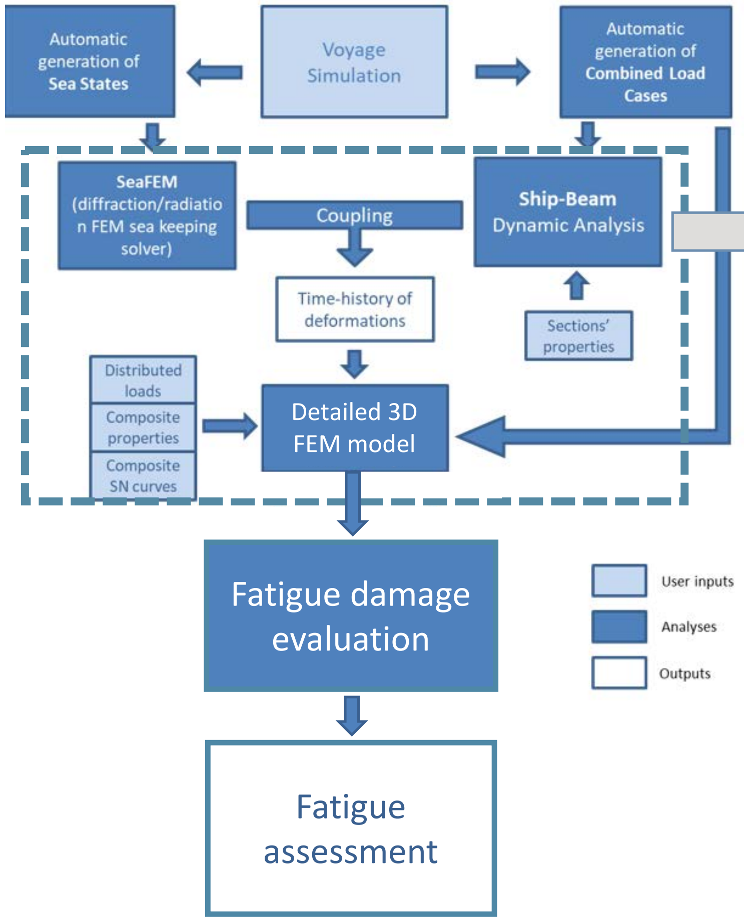
3D FEM dynamic analysis



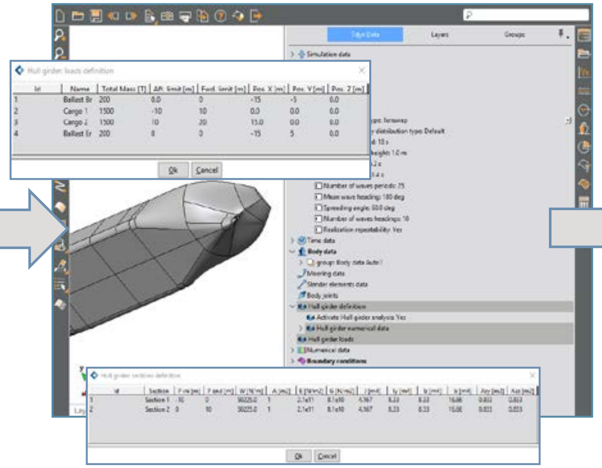
- Transfer of (time-domain) seakeeping wave loads
- Imposed hull girder displacements at the boundaries of the 3D section under analysis
- 3D FEM model offers local displacements and stresses using SP-RoM model

Hull girder model

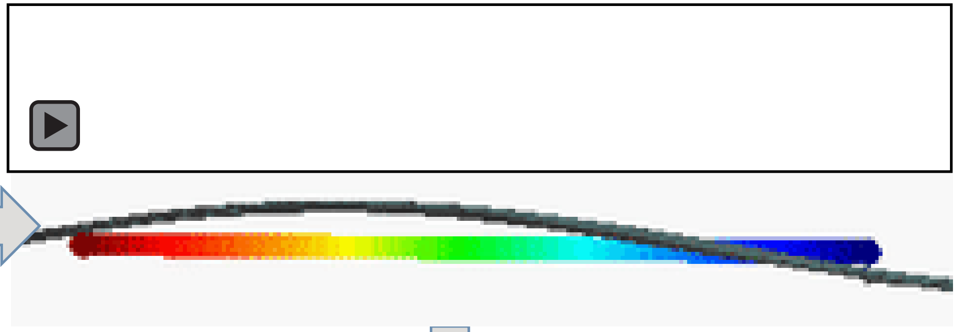
Definition of FRP laminates



Hull girder model definition

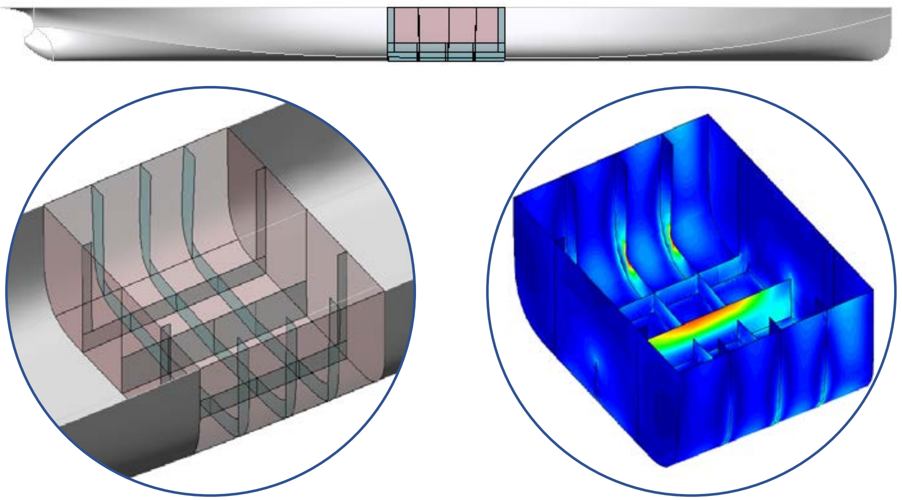


Coupled hull girder – seakeeping analysis



1D to 3D interface

3D FEM fatigue analysis



- Fatigue damage formulation reduces the strength capacity of the material based on energy dissipated in each load cycle.
- The computational analysis is based on the number of cycles applied to the structure, instead of the load history.

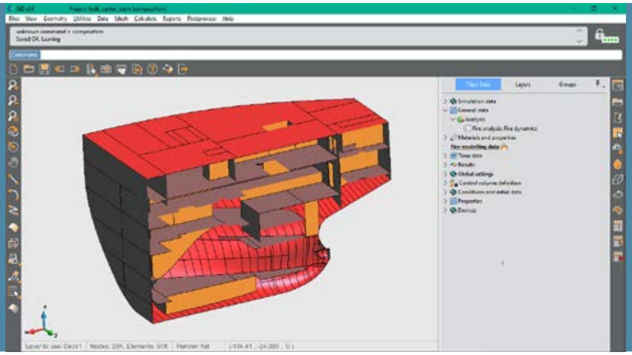
Solution: Fire simulation & collapse assessment tool

Objectives: Coupled computational analysis solution for fire and smoke propagation (fire dynamics and fire propagation) and collapse assessment of FRP composite structures (thermo-mechanical FEM).

Components: CFAST, FDS, GiD, Tdyn-Ramseries / Abaqus, S/P thermomechanical model (new), 1D-2D pyrolysis model (new).

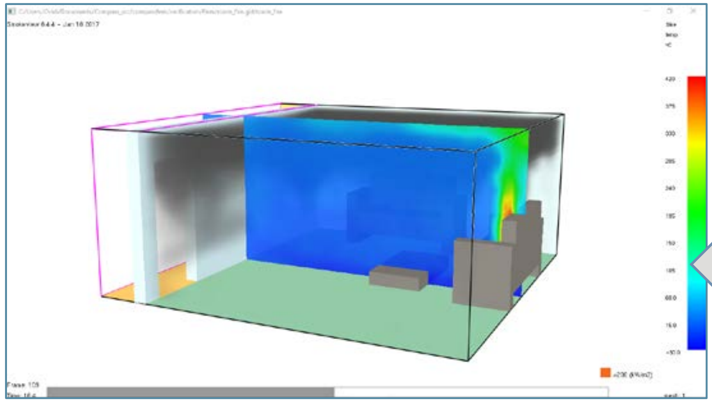
Other characteristics: Usability (included integrated GUI), Import/Export tools, Practicality (Fire propagation vs Fire dynamics).

Fire/smoke propagation & collapse assessment tool



Fire simulation & collapse assessment tool

FDS GUI (based on GiD-Ramseries)



SOME CHARACTERISTICS

- new GUI tools allow to define the main namelist groups of FDS (obstacles, vents, reactions, fire events ...) directly in GiD-RamSeries and to run FDS solver.
- Geometrical information is shared with the structural model and can be used for the definition of the FDS model.
- Importation tools (STEP and IGES, including XML's FORAN data)

Fire specification, ship compartments configuration, wall thermal properties...

Fire dynamics analysis (FDS)

Fire propagation analysis (CFAST)

Temperature time evolution curves

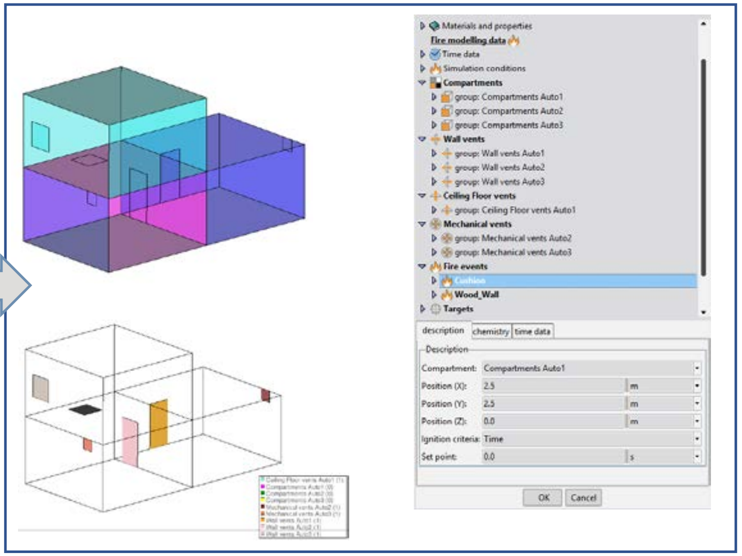
Beams and shells thermal analysis (RamSeries)

Pyrolysis model (through thickness temperature)

Beams and shells structural analysis (RamSeries)

Collapse risk assessment

CFAST GUI (based on GiD-Ramseries)

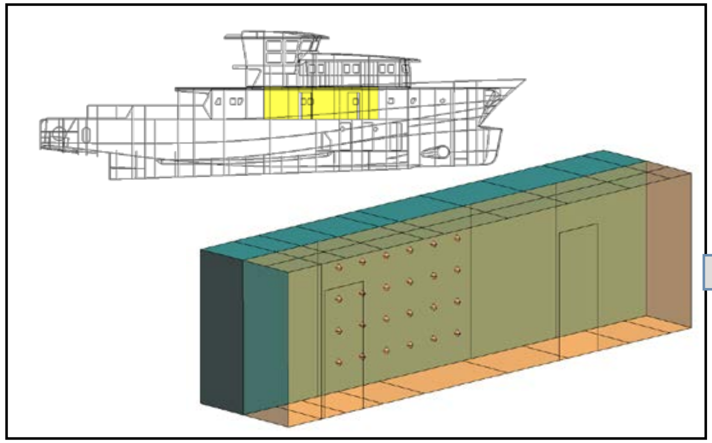


SOME CHARACTERISTICS

- New GUI tools also allow to define compartments, vents, fire events and targets directly in RamSeries and to run the CFAST solver.
- Geometrical information from the structural model can be used for the definition of the CFAST model if necessary..
- Importation tools (STEP and IGES, including XML's FORAN data)

Fire simulation & collapse assessment tool

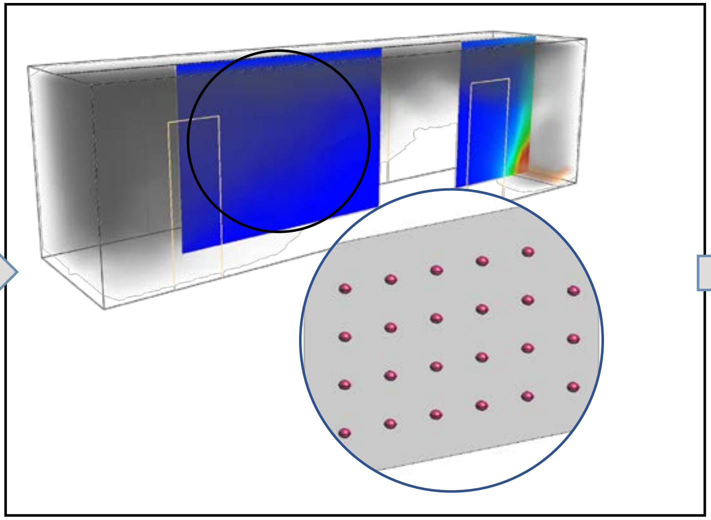
FDS / CFAST GUI ()



SOME CHARACTERISTICS

- FDS: Temperature maps over structural components (beams, decks and bulkheads) are calculated
- CFAST: Two-zones temperature evolution is calculated.
- FDS/CFAST: Furthermore, time evolution of (adiabatic) temperature in a distributed network of control points

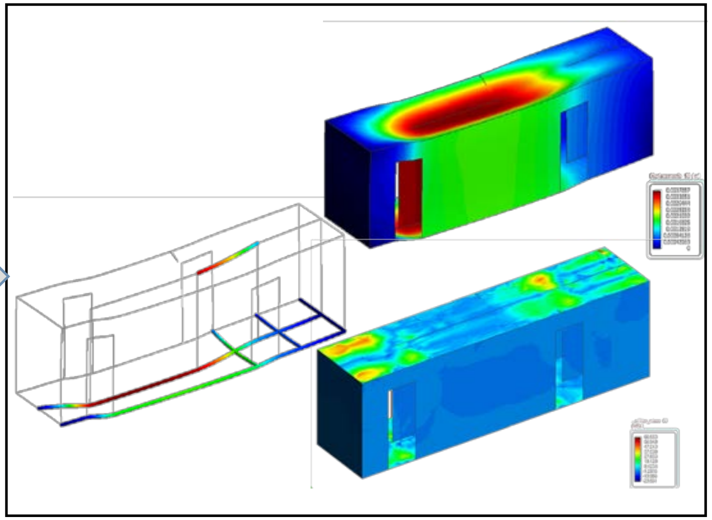
1D/2D Pyrolysis model



SOME CHARACTERISTICS

- Transfer temperature (heat flux) information from control points to the structural solver.
- The structural solver includes a pyrolysis model for composites (1D -through thickness- model for shell elements and a 2D model for beam elements), which calculated temperature distribution (per layer).

Thermo-mechanical analysis



SOME CHARACTERISTICS

- Displacements, strains and stresses are calculated on structural components using a thermo-mechanical composites constitutive model (collapse of the structure is assessed).

Full 3D hydroelastic solver

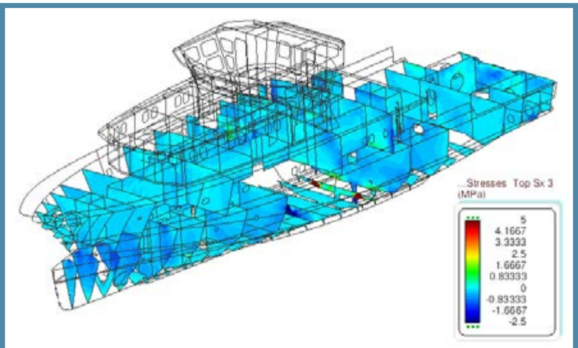
Solution: Full 3D hydroelastic solver (ultimate strength assessment).

Objectives: To implement a coupled time-domain radiation/diffraction seakeeping analysis solver and dynamic FEM structural solver based on the SP-RoM constitutive model.

Components: GiD, Tdyn-Ramseries, Tdyn-SeaFEM, SP-RoM model (new).

Other characteristics: Integrated GUI, Monolithic coupling, Import/Export tools.

Full 3D hydro-elasticity solver



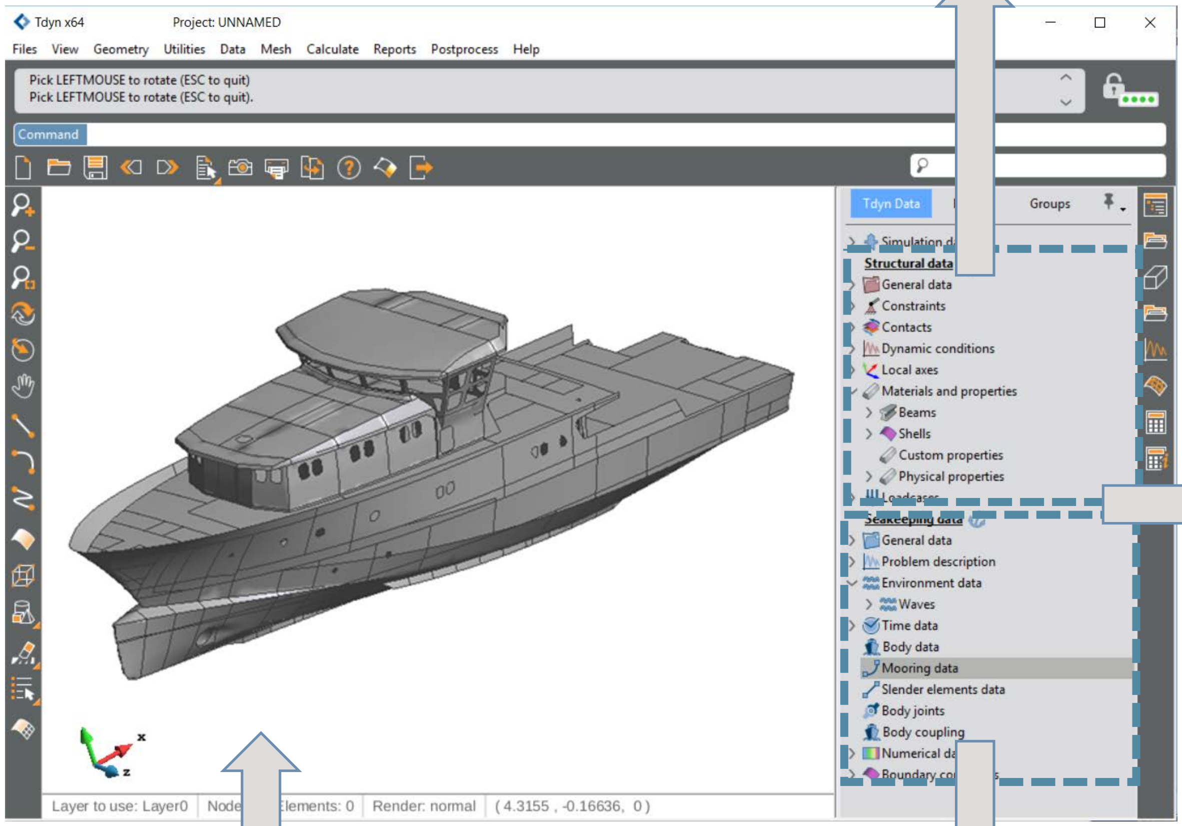
Full 3D hydroelastic solver

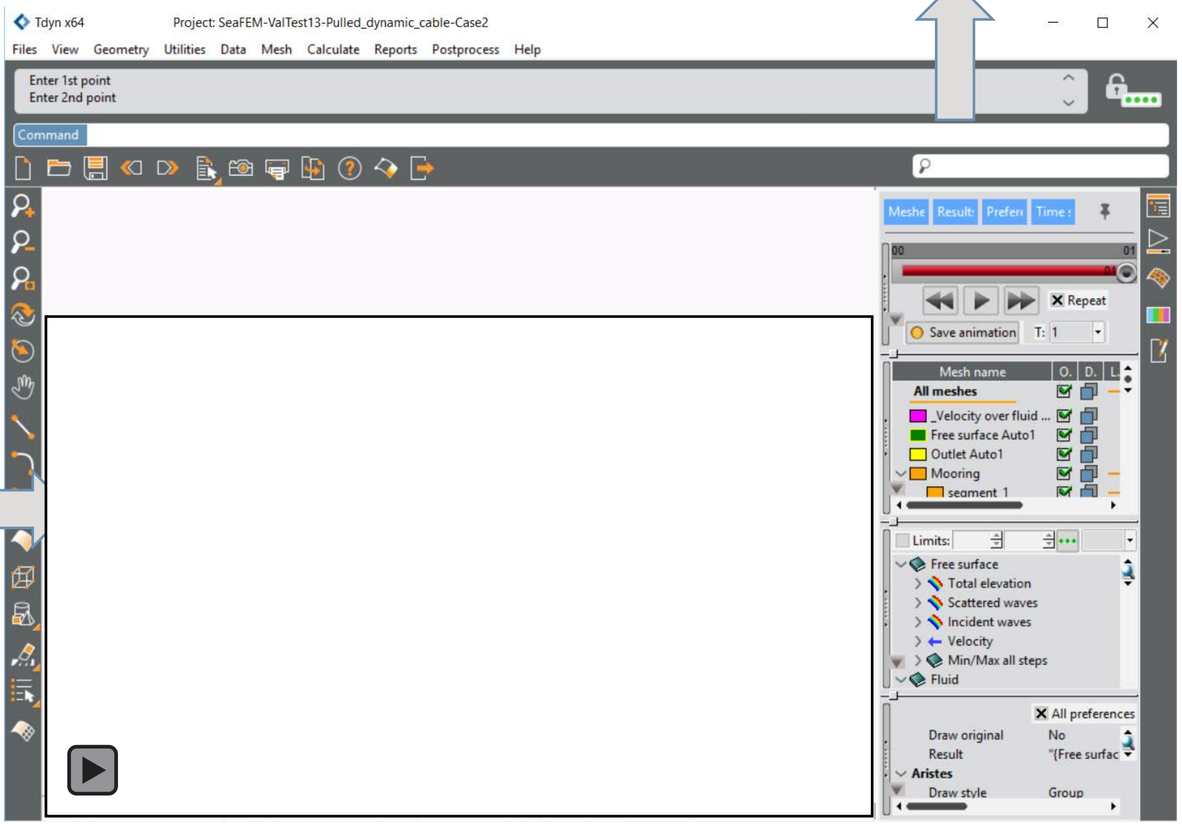
FEM structural solver data

- Linear / Non-linear dynamic solver
- SP RoM constitutive model

Hydrolelastic solver

- Monolithic coupling





Importation tools

STEP and IGES, including XML's FORAN data

FEM seakeeping solver data

- Time domain
- 1st and 2nd order

Inverse Finite Element Updating Method

Solution:

- Inverse Finite Element Updating Method (basic component).
- Structural health monitoring solution.
- Non-destructive testing tools.

Objectives:

- To implement an Inverse Finite Element (iFEM) Updating Method based on the SP-RoM + explicit Kachanov-type damage model.
- To develop a Structural Health Monitoring system for large-length FRP-based ships.
- To develop a non-destructive testing (inspection) for structural elements.

Components: RMOP optimization platform, GiD, Tdyn-Ramseries, SP-RoM model (new), monitoring system (new).

Inverse Finite Element Updating Method

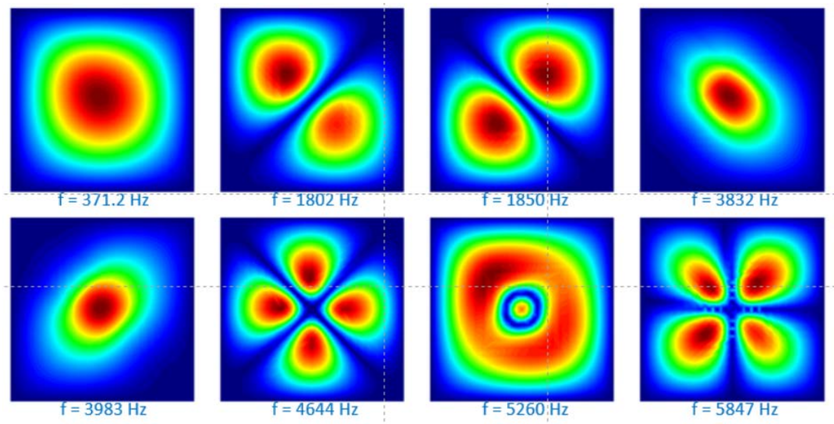
Problem statement

- Damage zones: FEM model topologically / heuristically divided into zones
- Design variables: Average damage on the different zones
- Objective functions: weighted differences between measured and calculated frequencies:

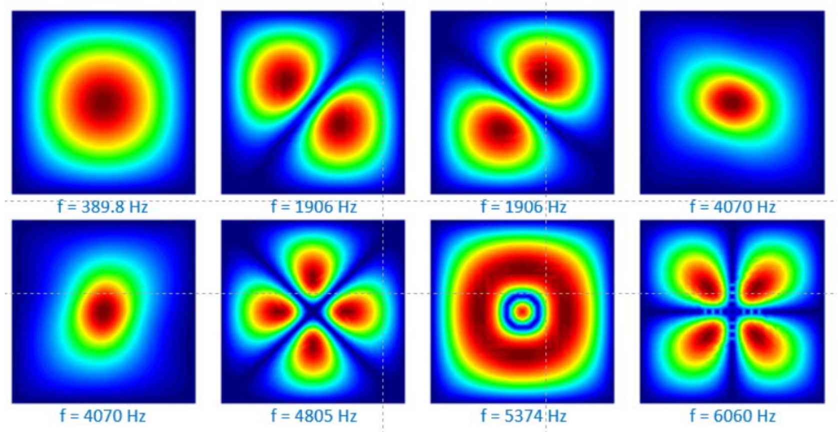
$$f_{obj} = w_i \cdot (f_{ref,i} - f_i)$$

- Strategy: Minimization of the objective functions by means of Newton-based methods
- FEM solver: SP-RoM + explicit Kachanov-type damage model

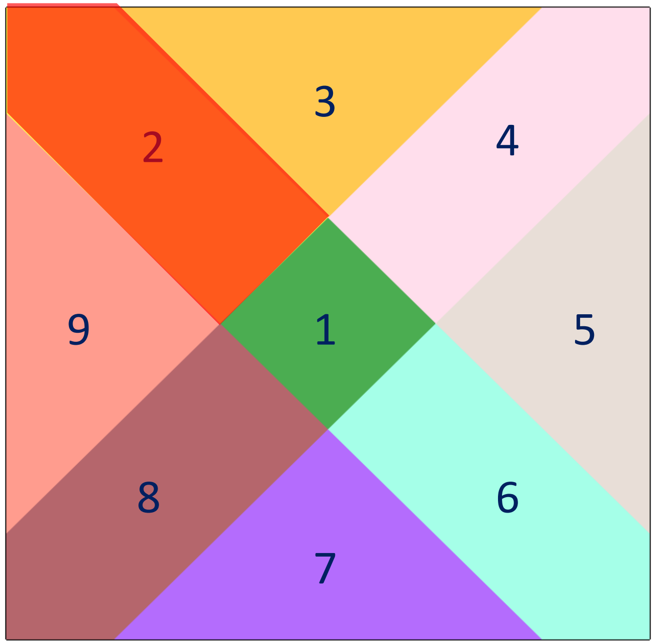
Normal modes / frequencies (zone 2 damaged)



Normal modes / frequencies (undamaged)



Squared shell panel divided into nine zones



Inverse Finite Element Updating Method

Structural Health Monitoring (SHM)

- Consist on:
  - A modal monitoring (testing) system
  - A model of the structure (global hull girder and local detailed models)
  - A processing unit (iFEM model)
- The collected data is used to feed the iFEM model, which estimates the damage map on the structure for the global hull girder and local detailed models
- The system is conceived to support decision making on maintenance plans

Non-destructive testing tools

- Consist on:
  - A portable modal monitoring (testing) system, including impact hammer.
  - A local model of the structural element (i.e. bulkhead)
  - A processing unit (iFEM model)
- The collected data is used to feed the iFEM model, which identifies possible defects in the structural element
- The tool is conceived for quality control and inspection on structural elements

Final comments / Open discussion

- **Work progress on track.**
- **Alpha version (of most) of the solutions expected by October 2018.**
- **Final versions (validated tools) to be delivered in May 2019.**
- **Validation based on a three-tier approach: small, medium and large scale experiments*.**

Final comments / Open discussion

- Questions? Ideas?
  - Are the specifications of the tools (approaches) correct?
  - Additional requirements / specifications?
  - Additional missing computational analysis tool will be required for large FRP ships?
  - How to validate the tools?
  - Integration / communication with existing design tools
  - Cooperation with teams of other projects
- Open discussion

This project has recived funding from European Union's Horizon 2020 research and innovation programme under grant agreement Nº 723360

THANK YOU

www.fibreship.eu