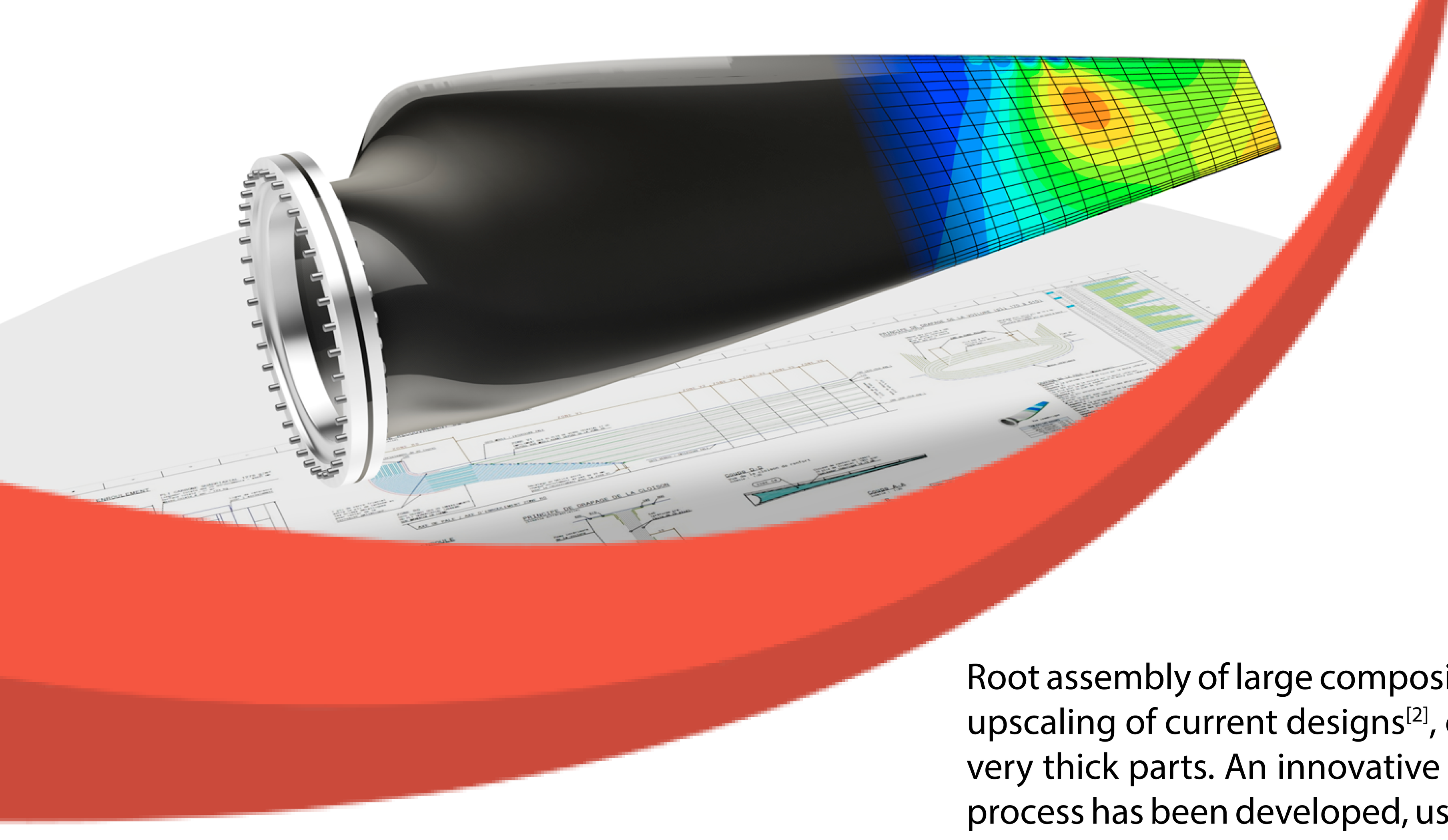
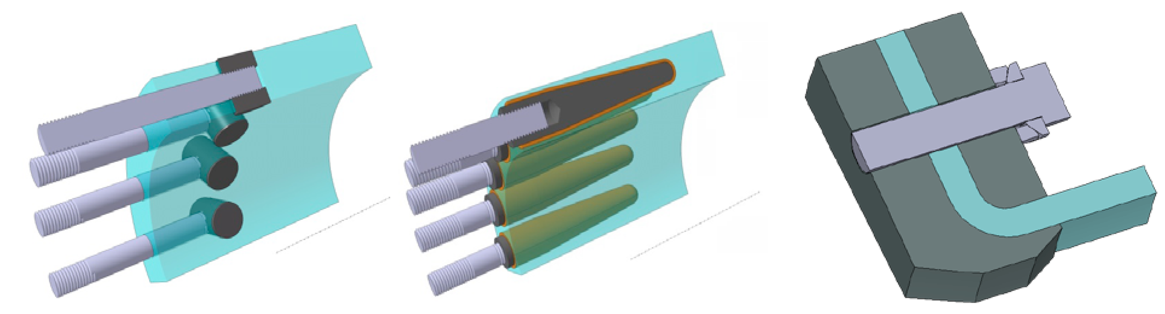


Méca

Reliability Approach to the Design of an Innovative Large Blade Root

Root assembly of large composite blades is a critical issue to the upscaling of current designs[2], due to the complexity of curing very thick parts. An innovative root design suited to light RTM process has been developed, using reliability analysis principles to handle the uncertainties regarding environment, material, and manufacturing conditions.



Common root connectors[1] : T-Bolts / Bonded inserts — *Innovative root design suited to light RTM process*

Environmental Conditions
Wave, Current, Turbulence

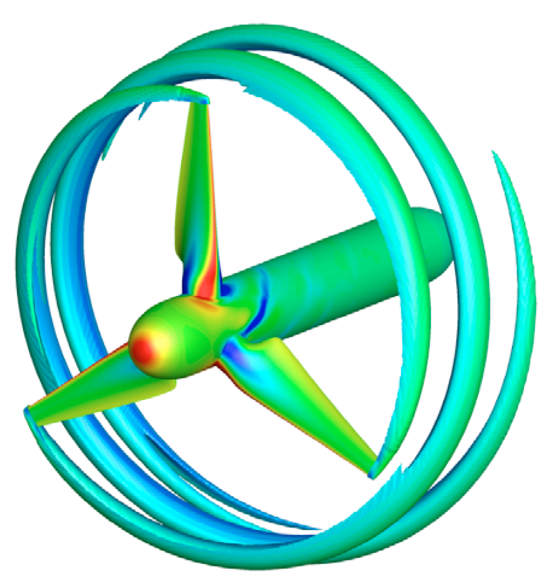
Material parameters
Strengths

Design parameters
Thickness, Radius

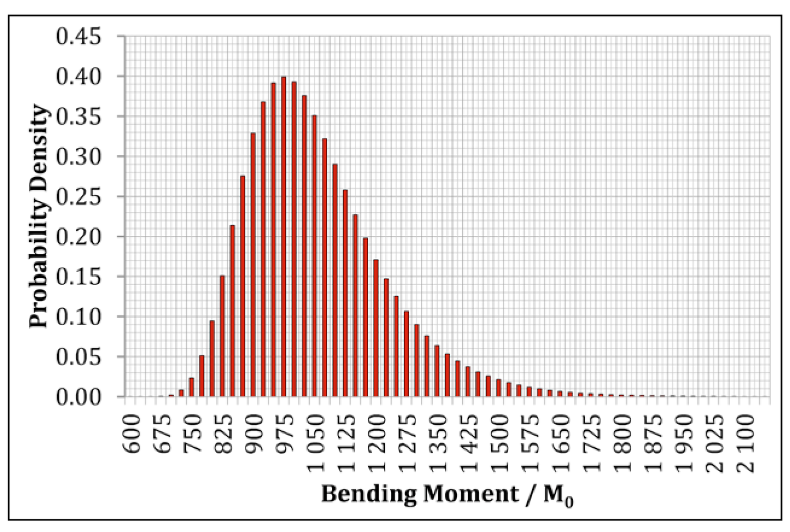
Process parameters
Tightening, Friction

Propagation of uncertainty

From sea state measurement, the hydrodynamic analysis leads to statistics for load components on the root.



Hydrodynamic simulation

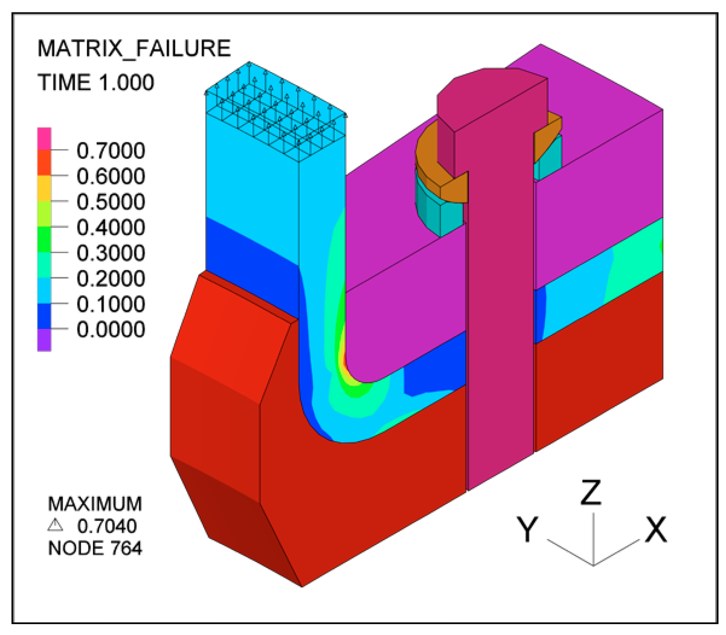


Extreme bending moment statistics

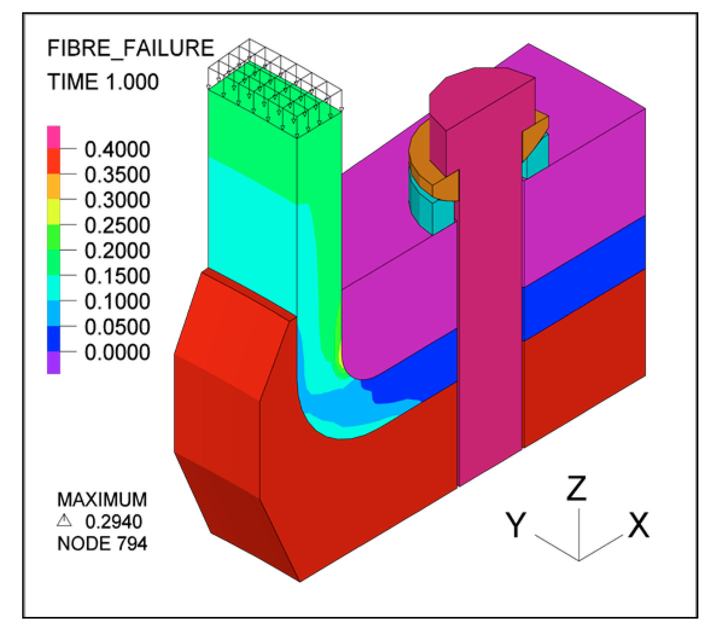
Composite strength assessment using advanced composite modeling

The 3D Puck failure theory[3], which distinguishes matrix and fiber modes, is well suited to the integration of stochastic material properties.

Bolt tightening dispersion and contact friction can be taken into account by using a detailed finite element model with 3D orthotropic properties.



Puck Matrix Failure exposition factor



Puck Fibre Failure exposition factor

VERIFICATION

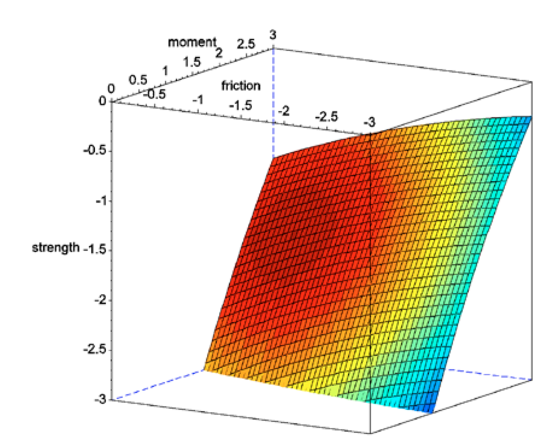
HYDRODYNAMIC ANALYSIS

Blade root load statistics
Bending, Shear

STRUCTURAL ANALYSIS

Model reduction is achieved by fitting an analytical expression of the failure limit surface to appropriate numerical experiments

$$H(u) = \exp(\lambda_R + \zeta_R u_R) - f_E(u_F, u_\mu, u_M)$$



Quadratic response surface

MANUFACTURING PROCESS ANALYSIS

Material mechanical properties deviation

Process parameters deviation

RELIABILITY ANALYSIS

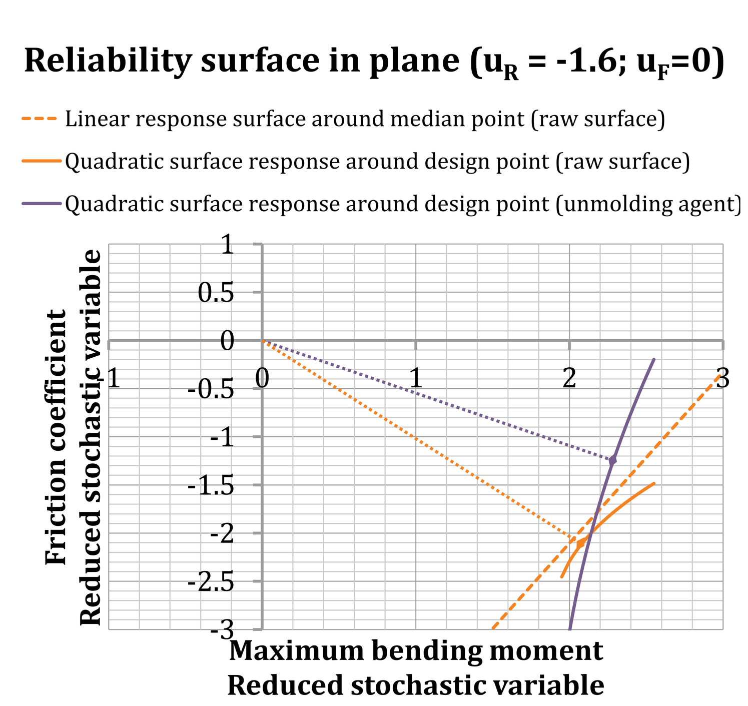
IDENTIFICATION OF CRITICAL PARAMETERS TO MONITOR

Reliability analysis is a support to structural design and manufacturing.

The reliability procedure provides insight into most probable failure modes.[4]

Parameter sensitivities orient process solutions and monitoring.

The target reliability criterion based on DNV-GL standards is derived into design variables optimization (thickness, manufacturing radius).



Most probable failure points

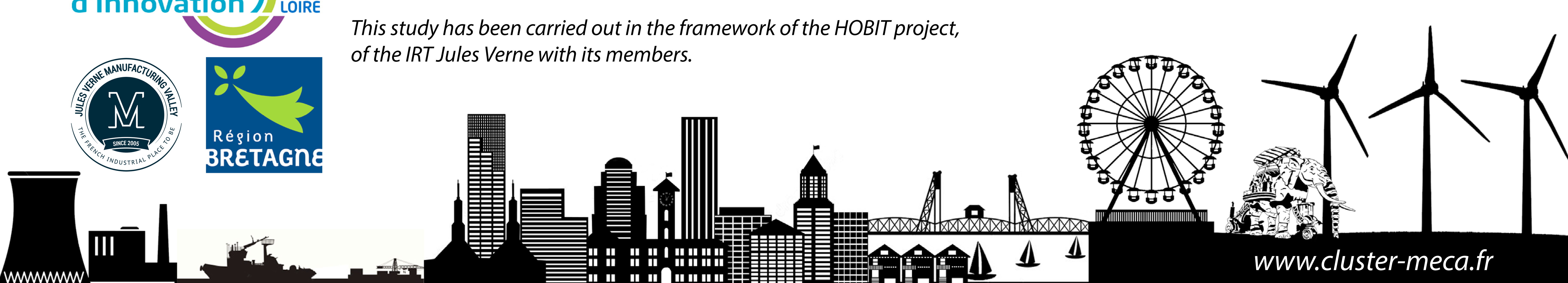
EXPERIMENTAL VALIDATION

1/7th scale prototype

COMPARISON BENCHMARK WITH OTHER DESIGNS

[1] Briggs et al. « Study on T-Bolt and Pin-Loaded Bearing Strengths and Damage Accumulation in E-Glass/epoxy Blade Applications ». Journal of Composite Materials 49, n° 9 (1 avril 2015) : 1047-56.
[2] Grogan et al. « Design of composite tidal turbine blades ». Renewable Energy 57 (septembre 2013) : 151-62
[3] Deuschle, « 3D failure analysis of UD fibre reinforced composites : Puck's theory within FEA ». Universität Stuttgart, 2010.
[4] Lemaire, Maurice, Alaa Chateauneuf, et Jean-Claude Mitteau. Fiabilité des structures : couplage mécano-fiabiliste statique. Paris : Hermès Science Publications, 2005.

This study has been carried out in the framework of the HOBIT project, of the IRT Jules Verne with its members.



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