UpWind

WP1B1: Innovative Rotor Blade

Contract SES6-CT-2006-019945 Project UPWIND

Mid-term UPWIND Workshop 9th of October, Brussels

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WP1B1 Innovative Rotor Blade: Overview of Work Package Tasks

- Task WP1B1.1 Aerodynamic Design and Loads Calculation
- Task WP1B1.2 Materials Selection, Structural Design and Structural Verification
- Task WP1B1.3 Sensors and Monitoring Technologies
- Task WP1B1.4 Blade Joints Design
- Task WP1B1.5 Sub-component Testing
- Task WP1B1.6 Manufacturing and Assembly Processes
- Task WP1B1.7 Specimen Prototypes Manufacturing
- Task WP1B1.8 Specimen Testing

WP1B1 Innovative Rotor Blade: Work Package Task #1 (in progress)

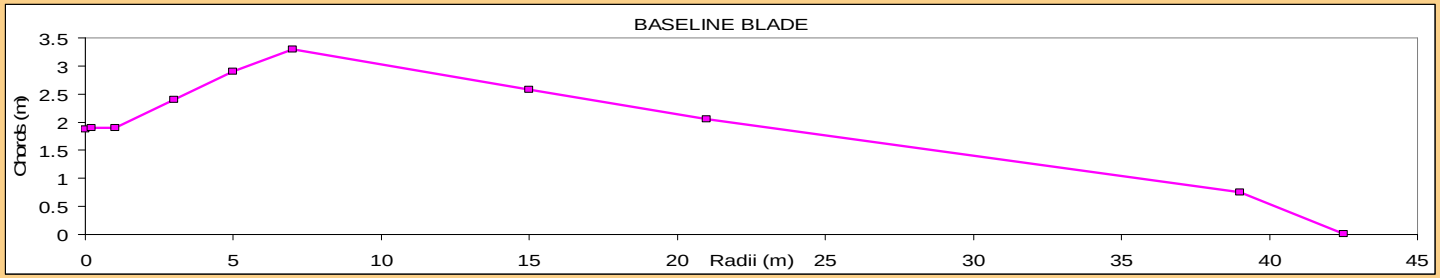
TASK WP1B1.1 AERODYNAMIC DESIGN AND LOADS CALCULATION
PARTICIPANTS: CRES, NTUA, TUD, ECN, GAMESA

- PART I. AERODYNAMIC AND LOADS DESIGN: SCOPE & OBJECTIVES

  The main objective is the design of a large, sectional **Proof of Concept Blade**.

  Considering the risks for directly design and manufacture such blade, it is convenient to start with a reliable, well-known, non-sectional, 42.5m blade (called baseline blade), in which several improvements can be applied an conceptually studied.

  The **Baseline Blade** has been already designed by Gamesa, including aerodynamics design and loads calculations:



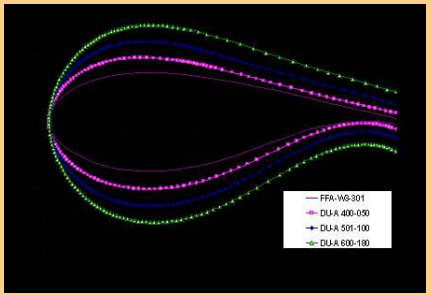
WP1B1 Innovative Rotor Blade: Work Package Task #1 (in progress)

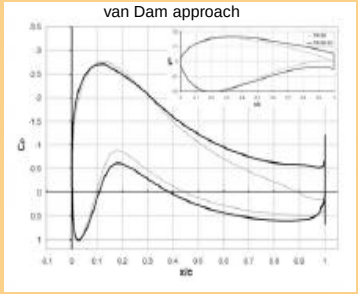
TASK WP1B1.1 AERODYNAMIC DESIGN AND LOADS CALCULATION
PARTICIPANTS: CRES, NTUA, TUD, ECN, GAMESA

- PART I. AERODYNAMIC AND LOADS DESIGN: SCOPE & OBJECTIVES

  One of the relevant improvements to be included in the baseline blade is the design of a "foot fairing "for improving the aerodynamic performance:

  - 2D airfoils design (considering thick TE) is currently finished (DELFT):





  - 3D aero design is finished in conceptual phase (GAMESA) and detailed design phase is currently ongoing (ECN).
  - Structural design is currently ongoing (UPATRAS)

WP1B1 Innovative Rotor Blade: Work Package Task #1 (in progress)

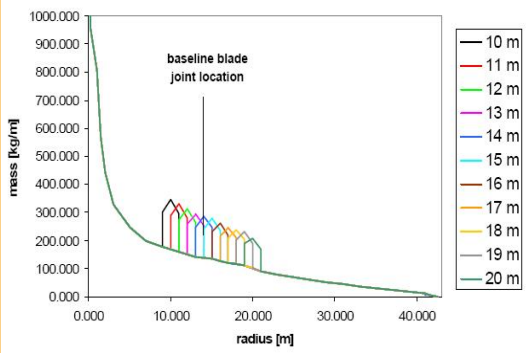
TASK WP1B1.1 AERODYNAMIC DESIGN AND LOADS CALCULATION

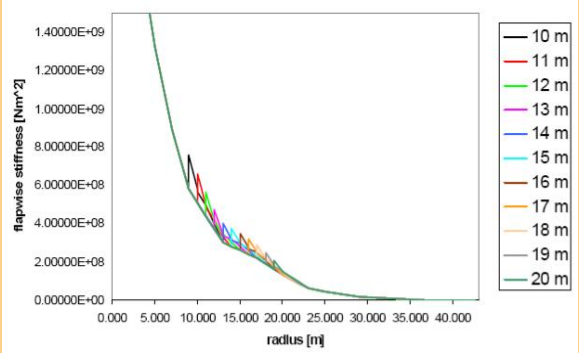
PARTICIPANTS: CRES, NTUA, TUD, ECN, GAMESA

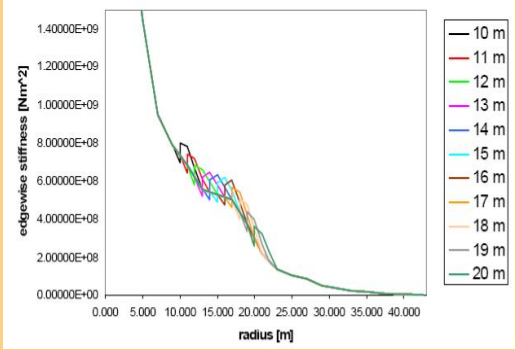
PART II. AEROELASTIC DESIGN IMPROVEMENTS: SCOPE & OBJECTIVES

Several aeroelastic calculations are currently ongoing over the baseline blade, including:

1. Positioning of Sectional Joint Study (Deliverable 1B1-1.2A, finished by CRES/NTUA):







2. Blade Damping Study, including the study of *"Negative damping effects for high angles of attack on stopped wind turbines "*(abstract submitted to EWEC 2009) and the *"Study of Influence of Similar Edge and Flap Natural Frequencies ",* both currently ongoing by CRES / NTUA / ECN.

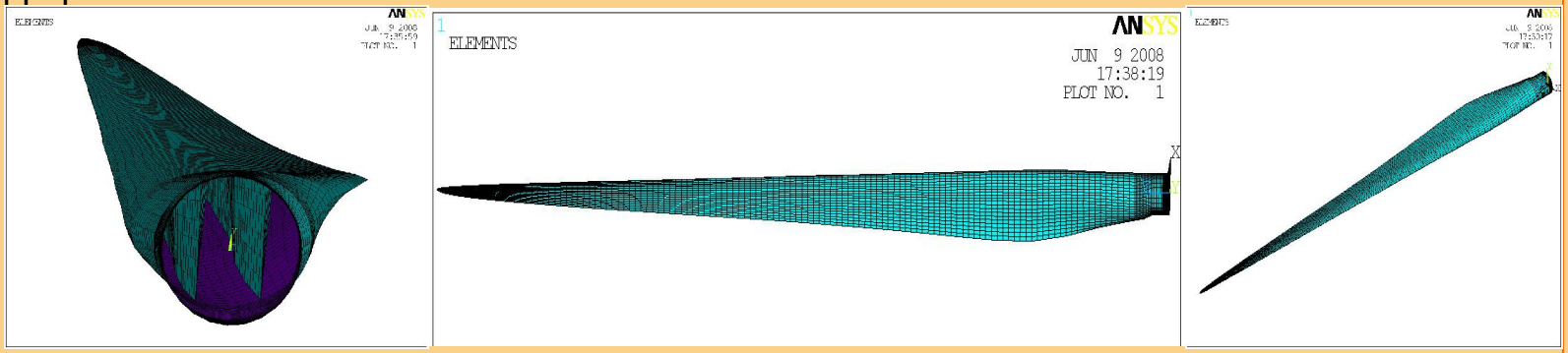
WP1B1 Innovative Rotor Blade: Work Package Task #1 (in progress)

TASK WP1B1.1 AERODYNAMIC DESIGN AND LOADS CALCULATION

PARTICIPANTS: CRES, NTUA, TUD, ECN, GAMESA

- PART II. AERODYNAMIC DESIGN IMPROVEMENTS: SCOPE & OBJECTIVES

3. Blade Deformation Study, which includes the computation of the *"Torsion Deformation"* and a potential *"Loads Reduction by Stiffness and Geometry Combination."* The task is currently ongoing by NTUA / CRES / ECN, and a FEM model is already developed by UPATRAS for the baseline



4. Effects on Loads of Having Three-Dimensional Modal Shapes, which includes the investigation of improved structural models for the blades instead of Euler-Bernoulli beams that are used by conventional commercial aero-elastic codes. Comparisons of the performance of these models (usually beam models due to calculation time restrictions) with detailed FE models based on shells.

WP1B1 Innovative Rotor Blade: Work Package Task #2 (in progress)

TASK WP1B1.2 MATERIALS SELECTION

PARTICIPANTS: UP, WMC, GAMESA

- **Selection of Materials**
  - Parameters such cost, weight, structural integrity and manufacturing, among others, are evaluated to develop cost-effective wind blades.
  - **Materials selection for large blades.** Identification and evaluation of potentially interesting materials from current available materials and promising innovations.
  - **Materials selections for blade joints.** Identification and evaluation of different types of joints (hence materials): metallic fasteners, adhesive joints between composites and composite-metallic materials, etc.

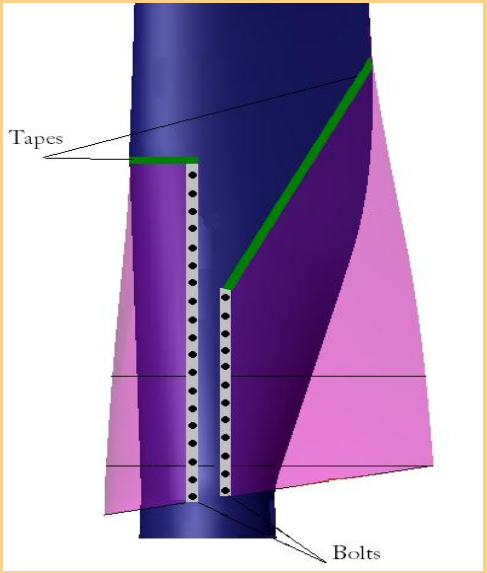
WP1B1 Innovative Rotor Blade: Work Package Task #2 (in progress)

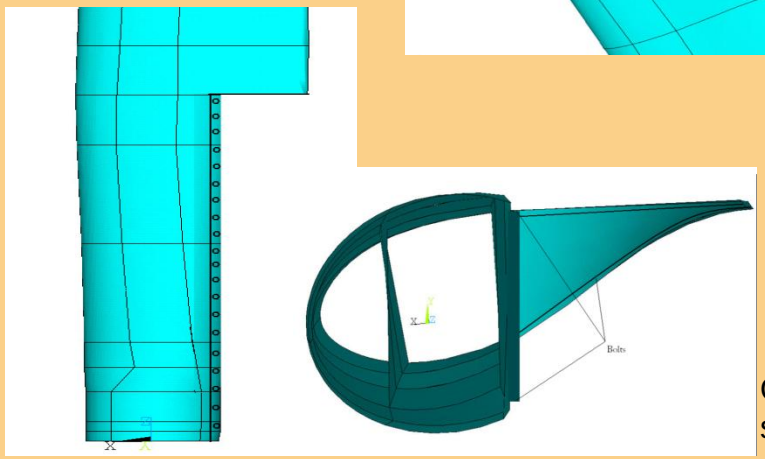
TASK WP1B1.2 MATERIALS SELECTION

PARTICIPANTS: UP, WMC, GAMESA

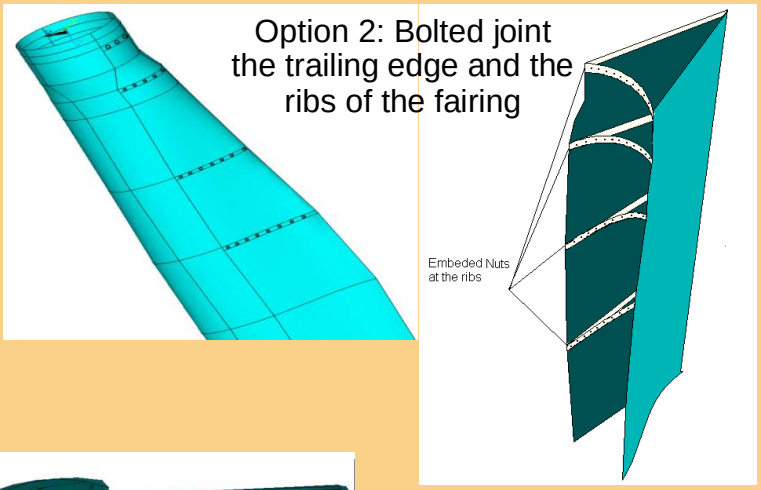
- Fairing Joining Concepts

Option 1: Bolted joint at the spar cups of the blade





Option 2: Bolted joint the trailing edge and the ribs of the fairing



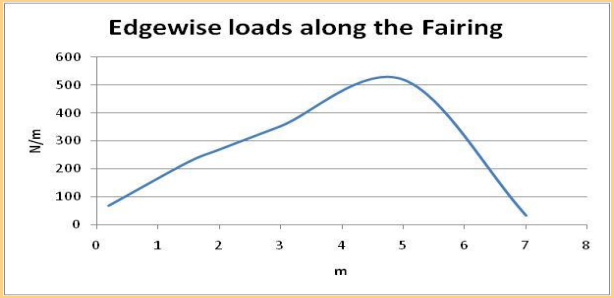
Option 3: Bolted joint at a specially shaped blade

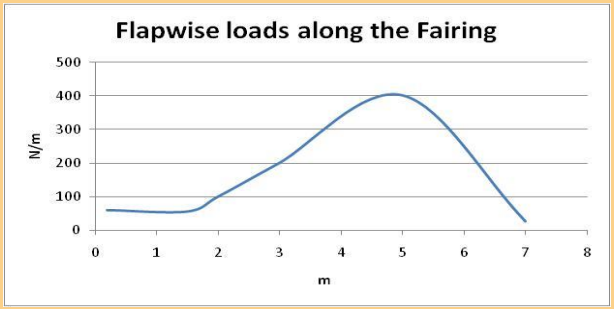
WP1B1 Innovative Rotor Blade: Work Package Task #2 (in progress)

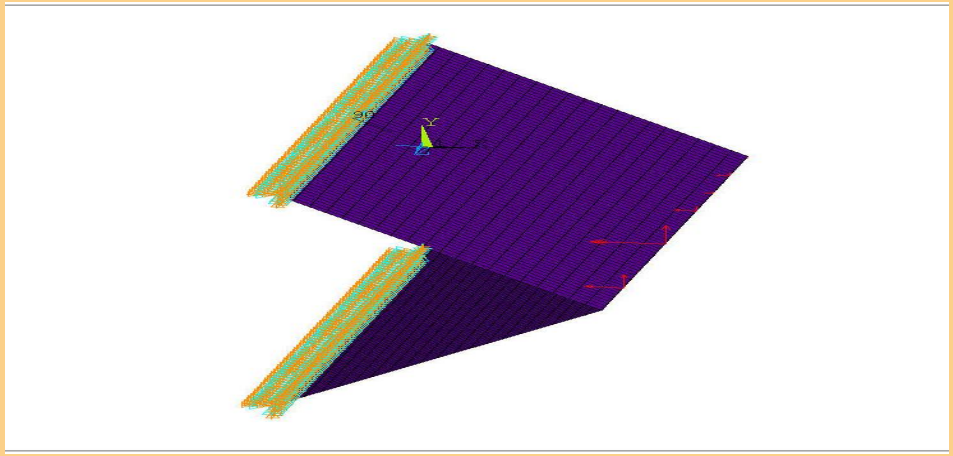
TASK WP1B1.2 MATERIALS SELECTION

PARTICIPANTS: UP, WMC, GAMESA

- Fairing Joining Preliminary Calculations







Preliminary calculations indicate that the load to be carried by all the bolts of the joint does not exceed 2.5 kN.

WP1B1 Innovative Rotor Blade: Work Package Task #3 (in progress)

TASK WP1B1.3 SENSORS AND MONITORING TECHNOLOGIES
PARTICIPANTS: ROBOTIKER

- Test campaign of a monitoring wireless system (successfully finished):
  - Location of wireless systems (receiver and transmitter)
  - Successful behaviour in glass and carbon fibre blades
  - Low power consumption
  - Low duty cycle
- Test report (in progress)
- Detailed specification of sensors and monitoring system (in progress)

WP1B1 Innovative Rotor Blade: Work Package Task #4 (in progress)

TASK WP1B1.4 BLADE JOINTS DESIGN

PARTICIPANTS: GAMESA

- **Activities to be accomplished under Task #4:**
  - Research on bonded or bolted joints, taking into account the complex stress states generated in the proximity to the joints.
  - Research to evaluate the impact of the joint in blade mass and stiffness distribution, blade aerodynamics and dynamic behaviour.
  - Asssessment and comparison of different joint alternatives in terms of cost, weight, failsafe, assembly and modularity.
  - Preliminary sizing of the optimum blade joint concepts.
  - Structural design of the blade joint.
  - Integration of secondary systems through the joint (lighning system, sensors, drainage system, etc.).

WP1B1 Innovative Rotor Blade: Work Package Task #4 (in progress)

TASK WP1B1.4 BLADE JOINTS DESIGN

PARTICIPANTS: GAMESA

- DEFINITION OF MODULAR BLADE JOINTS DESIGN REQUIREMENTS:

1- Functional Requirements
- Loads
- Aerodynamic Requirements
- Structural Integrity
- Mass and Stiffness Distribution Limits
- Dynamic Requirements
- Weight

2- Material Requirements

3- Supportability Requirements
- Assembly on Site & Interchangeability
- Reliability
- Mainteinability
- Fail Safe

4- Validation and Certification

5- Secondary Systems
- Drainage System
- Lightning System

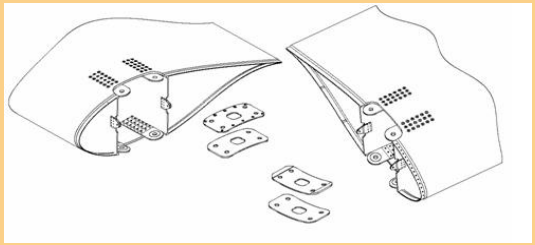
6- Manufacturing
- Assembly in Factory
- Tolerance
- Toolings
- Materials

WP1B1 Innovative Rotor Blade: Work Package Task #4 (in progress)

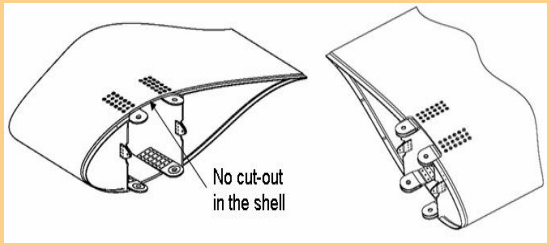
TASK WP1B1.4 BLADE JOINTS DESIGN

PARTICIPANTS: GAMESA

- VARIOUS ALTERNATIVE DESIGN SOLUTIONS PRE-SIZED AND EVALUATED:

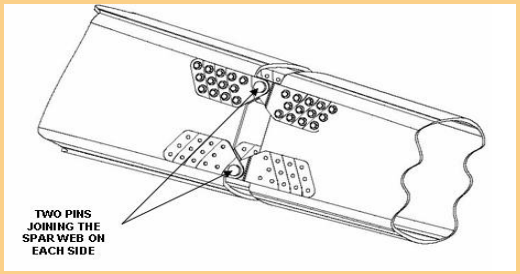


Cap Lugs with Intermediate Plate

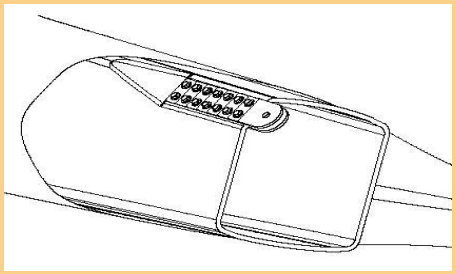


Cap Lugs without Intermediate Plate

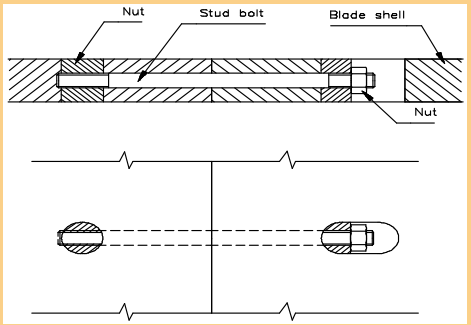
Carbon Tube



Lugs in Webs



Lugs in Corners



T-Bolts

WP1B1 Innovative Rotor Blade: Work Package Task #5 (in progress)

TASK WP1B1.5 SUB-COMPONENT TESTING

PARTICIPANTS: WMC

- Tests to be accomplished aimed to validate design assumptions:
  - Static and fatigue testing of joints sub-components.
  - Static and fatigue testing of materials

WP1B1 Innovative Rotor Blade: Work Package Task #6 (in progress)

TASK WP1B1.6 MANUFACTURING AND ASSEMBLY

PARTICIPANTS: GAMESA

- **Manufacturing process for Large Blades :**
  - Evaluation of State of the Art in Composites manufacturing technologies. Description Pros/cons for each process.
  - Process comparative and selection for Large Blades manufacturing (Prepregs + Vacuum bag versus **Infusion**)
- **Manufacturing process for Root Fairing (WIP)**
  - Focus of the aforementioned study for the most suitable process for the manufacturing of the root fairing.
- **Blade Assembly requirements and considerations**

WP1B1 Innovative Rotor Blade: Vision

- In order to support feasibility of a specific blade joint solution with a certain margin of confidence a very deep work is required.
- Such innovative blades will allow in the future for many other additional features, such as elements to increase energy production, etc.
- Development of sensoring is essential for such blades.

Thank You for your Attention