Innovative Rotor Blades – Innoblade

THE CHALLENGE

During the last few decades the cost of wind energy has decreased, to a significant part due to component and system improvements in aerodynamics, materials and structures, at present reaching an almost constant cost per m² rotor swept area. Further cost breakthrough can only be achieved by introducing new innovative improvements.

Sectional blades will be required for multi-megawatt machines as the blade transportation cost over land increases for blades over approximately 46 meters length and even more dramatically for blades over 60 meters length. The transportation costs become prohibitive unless length is limited by splitting the blades. Thus, sectional blade means dividing one blade in sections in order to ease handling and transportation works and consequently will reduce costs.

This work package (WP) focuses on the design and validation of a sectional blade specimen aimed at global cost of energy reduction and larger turbines development. This blade will include all the new technological advances regarding blade design and manufacturing.

WP Innoblade focuses on the following specific objectives:

- Development of a concept for joining the sections of a sectional blade;
- Implementation of new aerodynamic and structural design features;
- Utilisation of innovative materials and processes;
- Advanced blade instrumentation and monitoring;
- Development of a fully modular blade concept.

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RESULTS AND EXPECTATIONS

The following results have been achieved:

- Main characteristics of the blade structure and joint section of the blade, including the associated maximum loads at this section;
- Study of the state of the art in sensor and monitoring techniques. Evaluation of different wireless alternatives;
- Blade functional specification that defines specific sectional blade design requirements, blade design implementation plan;
- Various alternatives for joining blades and trade-off matrix that supports the selection of the joint concept;
- Concept design of a blade root fairing element.

When the WP is finalised it is expected that the following achievements will be realised:

- Definition and assessment of blade requirements to be fulfilled by a sectional blade, evaluation of different concepts and materials for blade joints;
- Study of the dynamic behaviour and aero-elastic considerations for a sectional blade in operational conditions. Improvement of large blade aerodynamics by means of a blade root fairing device;
- Blade sectional design concept, which is fully validated;
- Wireless sensor monitoring system adjusted to a sectional blade. Viability study for monitoring the stress and strains in different areas and specifically at the blade joint. The design criteria will also include the evaluation of a possible integration within the blade in order to provide data over the lifetime of the blade.

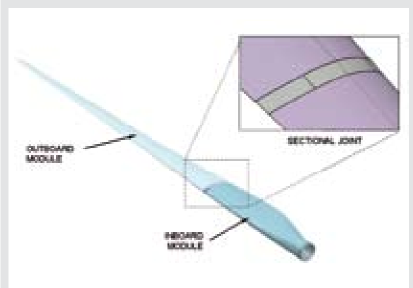

Figure 4: Blade preliminary design.

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SIXTH FRAMEWORK PROGRAMME

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- Fundación Robotiker

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THE RESEARCH ACTIVITIES

The WP comprises of the following tasks:

AERODYNAMIC DESIGN AND LOAD CALCULATION

This task includes aerodynamics design, aero-elastic design and loads consideration, making use of current practice methodologies and innovative methods that are not yet commonly used, such as:

- Profile design for efficient energy production as a design option, in relation to the Sirocco project in which both Gamesa Innovation and Technology and ECN are involved. For an optimum design and performance, materials and structural design improvements will be considered;
- Contribution of aero-elastic analysis, with the results from FP5 projects Dampblade and Stabcon;
- Aerodynamics design taking into account blade deformation;
- The use of the blade joints and their effect on modal shapes;
- Integration of the control system in the aerodynamic design and loads calculation, considering blade monitoring and load mitigation strategies;
- Optimisation criteria and design optimisation procedures.

The application of such methods however entails certain risks and careful consideration are being made in selecting and applying these methods.

MATERIALS SELECTION, STRUCTURAL DESIGN AND STRUCTURAL VERIFICATION

This task includes two elements:

a) Materials Selection. In order to obtain a cost effective design, special effort must be made on appropriate materials selection, lay-out of the blade and laminates lay-up definition analysing the important parameters. Fundamental understanding and behaviour of materials, use of new

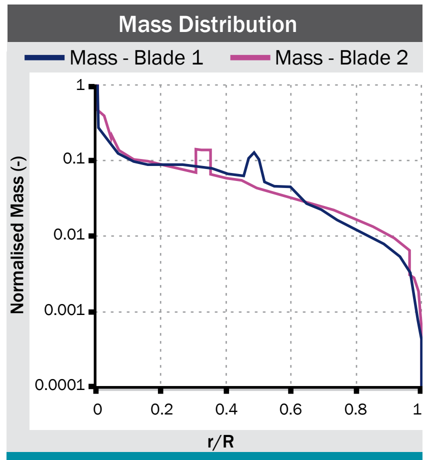

Figure 1: Sectional blade normalised mass distribution.

design tools based on extensive fundamentals knowledge of materials, usage of new databases for materials selection and consideration of tolerant design concepts in the specimen structural design are key activities.

The use of different types of joints, specifically metallic fasteners, adhesive joints between and composites are also considered. The evaluation of the behaviour of different combination of materials is assessed as well.

b) Structural Design and Structural Verification. From the structural point of view, this activity consists of a definition of the complete blade structure and preliminary study of a blade root fairing using the aerodynamic surface defined in the previous task and the type of material proposed. The preliminary assessment of the mechanical structure will show whether there is a need for cost increasing features like internal ribs, webs, stiffeners, bearing in mind the weight and special manufacturing processes.

SENSOR MONITORING WITH RESPONSE ACTIONS

This task is directed towards the achievement of a wireless sensor system specially designed to provide data about the behaviour of joints and modules during on field testing of the sectional blade concept.

The ultimate goal is to determine whether or not to integrate the wireless sensors in the blade, in order to provide data over the lifetime of the blade. Wireless communication and auto-feeding capabilities will be kept as constraints with the purpose of achieving a non-intrusive integration. A basic test campaign of a wireless system will be implemented in a blade to determine a further feasibility.

BLADE JOINT

This task consists of the development of the appropriate intermediate joint between composite laminates. It includes research on bonded or bolted joints, taking into account the complex stress states generated in the proximity to the joint. It also includes a study to evaluate the impact of the sectional joint in the blade mass and stiffness distribution, on blade aerodynamics and on blade dynamic behaviour to identify possible risks and constraints.

Different joint alternatives are considered and compared resulting in a trade-off matrix. The comparison is done, among others in terms of cost, weight, assembly, and modularity. Thus, the most appropriate joint concepts are preliminary sized in order to support a final decision for the optimum concept. As a complementary task the preliminary structural design of the section is to be completed in order to fulfil requirements like stiffness, weight and cost. Other important criteria such as failsafe concept, assembly and disassembly easiness, accessibility, reduced steps and other aerodynamic requirements, reduced maintenance schedule and leadtime, structural integrity, reparability, will be also regarded. A complete study will be performed for the integration of all the systems through the joint (lightning, sensors, draining, etc.).

The task includes a plan for validation of the joint concept.

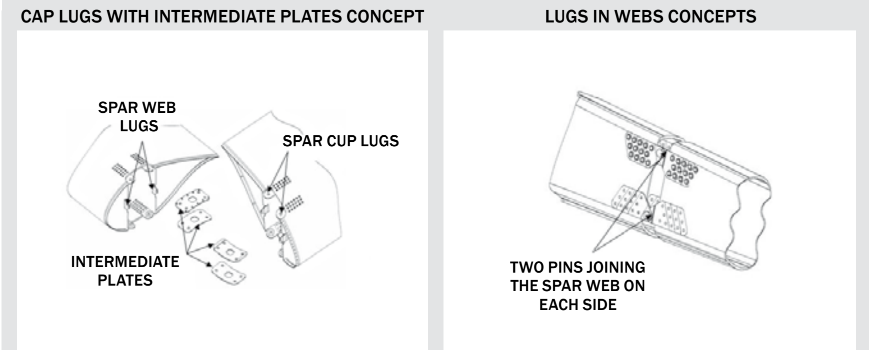

Figure 2: Different concepts used in the blade sectional joint trade-off decision matrix.

JOINTS AND MATERIAL TESTING

Joints and materials testing constitute a fundamental issue. In order to evaluate different joint alternatives and to support the selection of the one that best fits within this application, a campaign of subcomponents testing is to be carried out. This task includes static and fatigue tests for the different joint alternatives. This task will be followed with the blade specimen testing task described later on.

PROCESS / TOOLING

The sectional blade requires a thorough evaluation of innovative production technologies in order to select and implement the most appropriate one. This evaluation will be done by means of a comparison-matrix including different manufacturing process and materials selection. Other criteria such as assembly and disassembly easiness and maintenance will be kept in mind.

BLADE SPECIMEN MANUFACTURING

All the experiences and results obtained in the different tasks are to be integrated through the construction and validation of a blade design demonstration specimen. The aim of the blade specimen construction and testing is validation of the new concept.

BLADE SPECIMEN TESTING

The validation of the sectional blade is to be done not only by means of the subcomponent testing but also by means of a full-scale test. The full-scale test serves as the validation of the structural design.

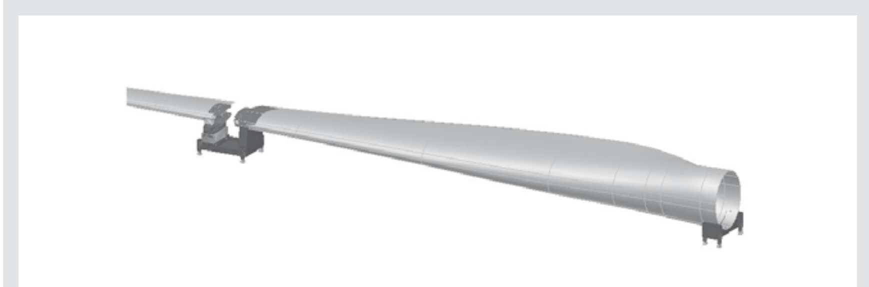

Figure 3: Blade manufacturing and assembly assessment.