SUSTAINABLE Rotorcraft for the Future—
Rotor Blade Design for an Innovative European Tilt Rotor

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ABSTRACT

Summary
Preliminary structural design of an integrated rotor blade has been conducted as part of the NICETRIP (Novel Innovative Competitive Effective Tilt-Rotor Integrated Project) research programme. NICETRIP aims to determine the feasibility of applying various technologies to the Tilt-Rotor, and to develop the technical knowledge required to achieve a civil European tilt-rotor configuration similar to ERICA (Enhanced Rotorcraft Innovative Concept Achievement), with a first flight before 2020.

The specific challenges and solutions involved in the evolution of a structural design of a feasible integrated NICETRIP rotor blade are presented.

Background
In a constant drive to develop more efficient, sustainable rotorcraft and to overcome the speed limitations of the traditional helicopter, many different configurations have been considered. The tilt-rotor offers a platform optimised to combine the best attributes of the helicopter with those of the aeroplane. This makes the tilt-rotor more competitive than the conventional helicopter against fixed wing aircraft, especially when range is an important factor.

The concept of the tilt-rotor has been around for many years, but only recently have the required technologies and materials been available to make viable configurations (such as the V-22 Osprey and the BA609) a reality. Current tilt-rotors require the pilot to transition into helicopter mode to land due to the size of the rotor diameter. ERICA is different because the outboard portion of the wings are rotated to become vertical in the hover which reduces download on the wings and therefore increases system efficiency. The result is a reduced diameter rotor which offers enhanced safety compared to existing tilt rotors because it allows landing to be carried out in aeroplane mode.

The structural blade design was conducted in collaboration with other European NICETRIP partners who provided dynamic and loads analysis, and builds on previous research projects that considered a modular blade with a separate cuff. The aim of the integrated blade is to improve dynamic characteristics and achieve reductions in mass and manufacturing complexity.

Method
Two iterations of structural design were carried out, the first concentrated on defining the blade root and cuff regions. The second iteration was concerned with refining the design and included preliminary design of additional components (blade tip, root attachment, outboard support, balance
masses). Preliminary design of components was necessary to optimise dynamic characteristics, ease manufacturing and to obtain a more realistic estimation of total blade mass.

Starting from the external aerodynamic profile, 2-D sections were cut at 90° to the feathering axis at specific radial stations along the blade. Material properties and the ply lay-up were modelled using a combination of AgustaWestland developed software and Patran. Mass and stiffness properties were analysed and the make-up of the sections optimised to achieve the required dynamic characteristics. Strain analysis was conducted using a high speed limit load case to assess the structural integrity of the proposed design.

**Results**

Several interesting challenges arise from the concept of an integrated blade due to the mixture of characteristics form a helicopter blade and a propeller. Firstly, the high twist in the transition region from the root to the first aerofoil section presents a challenge because centrifugal loads need to be transferred through the blade cuff to the centrifugal force bearing at the root attachment. This is difficult due to limitations on the degree of twist which can be withstood by the unidirectional material. The solution to this was to start with a circular section which transitions into a D-spar through the cuff region, and provide the aerodynamic shape at the trailing edge with a foam fairing.

Secondly, the blade is attached to the hub via two brackets on the root end, and is supported by a bearing at the end of the yoke. Because the yoke extends into the blade, an internal space is required inside the cuff potion of the blade to allow movement of the yoke and blades without interference. For this reason it is proposed to manufacture the blade around a mandrel which is then removed to leave a hollow spar.

Thirdly, external clearance between the blade and the spinner was also necessary to take into account ±11° of flapping motion. This was accommodated by a cut-out section in the trailing edge at the blade root.

Carbon and glass unidirectional materials were chosen from an existing database to reduce the risk associated in certification of new materials.

**Conclusions**

An integrated NICETRIP blade that satisfies dynamic requirements while withstanding the required limit loads is feasible. It is possible to manufacture the blade from existing materials using a combination of well established techniques.

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