1. Publishable summary

MANOEUVRES

Manoeuvring Noise Evaluation Using Validated Rotor State Estimation Systems

State of the art - Background

Radiated noise is among the main factors that limit public acceptance of rotorcraft vehicles, hindering a wider diffusion of these unique machines that still exhibit a considerable growth potential in terms of performance, cost effectiveness and social usefulness at large. The problem is particularly felt when operating in proximity to the ground, as in approach and departure procedures, in densely populated areas.

Several European research projects have already dealt with identification of optimal rotorcraft trajectories, minimising the noise emitted nearby populate area. At the moment, all these developed noise optimization tools use static acoustic maps that neglect the influence of unsteady flight conditions. MANOEUVRES investigates these limitations and **seeks improvement** performing real-time noise estimation based on in-flight rotor flapping measurement. Furthermore, while actual blade flapping sensor systems are experimental applications, the MANOEUVRES system is **intended for application on production helicopters** (designed from the beginning tacking into account constraints and requirements of a possible future certification under CS 27/29), so design and development consider all relevant requirements, in particular regarding safety, operating and environmental conditions, human-machine interface and software implementation.

Objectives

The MANOEUVRES project aims to **study and develop enabling technologies** towards an **innovative approach** to **noise abatement in rotorcraft manoeuvres** by way of an enhanced **pilot noise awareness**. This is based on the real-time presentation of the emitted noise level, through a new cockpit instrument: the **Pilot Acoustic Indicator** (PAI). By monitoring the PAI, the pilot will be able to appropriately adjust flight controls, to avoid highly disturbing flight conditions, such as those when strong main rotor BVI (Blade-Vortex Interaction) occurs. Emitted noise is estimated through a **suited acoustic database** fed by information retrievable on-board (advance ratio, thrust coefficient) plus an innovative in-flight measurement of the main rotor tip-path-plane angle of attack. This measurement represents the core technology of the project and is performed through a **novel contactless sensor system** able to estimate the blade flapping angles.

Description of Work Performed

The MANOEUVRES consortium brings together two universities **Politecnico di Milano**, **Università degli Studi Roma Tre**, and two SMEs **Logic Spa**, **Vicoter.** Politecnico di Milano coordinated the project and led the activities related to innovative measurement system development and in-flight monitoring tool development. Università degli Studi Roma Tre was responsible for the acoustic prediction. Vicoter supported the activities on innovative measurement system development, focusing on mechanical installation, workbench design and Logic provided the necessary skills for the requirement definition phases of the activities.

In order to fulfil the project goals, MANOEUVRES was organised in three main research activities – **acoustic prediction**, **innovative measurement system development**, and **in-flight monitoring tool development** - plus an effort towards the development of **innovative control laws.**

The project is articulated in **5 Work Packages.**

WP1 is devoted to **acoustic prediction:** the acoustic prediction code has been upgraded to allow steady and unsteady computations and the development of the necessary database for the in-flight noise estimation algorithm has been started.

WP2 and WP3 are dedicated to the **flapping measurement system**: preliminary studies have been carried out to determine the most promising measuring strategies and a selection process identified two candidate solutions; preliminary design and analysis of these solutions were carried out and testing started in order to evaluate their characteristics and performance.

The exploitation of the flapping sensor to improve flight control aiming at reducing pilot workload in manoeuvring flight has also been investigated, providing preliminary versions of novel control laws.

WP4 concerns **in-flight noise monitoring**: a noise estimation algorithm has been developed and the PAI prototype has been designed and implemented. Finally, **project management**, **dissemination** and **exploitation** has been carried out in WP5.

Achieved results

The project involved the design, develop and testing of a **novel sensor system** intended to return run-time information on vehicle noise in non-steady conditions.

The MANOEUVRES system includes:

- an innovative on-board apparatus devoted to the measurement of main rotor flap angles;
- the necessary signal conditioning system;
- an estimation algorithm for main rotor angle of attack (AOA);
- an acoustic prediction algorithm;
- a graphical display (Pilot Acoustic Indicator) of the noise signal to the pilot.

Furthermore, the MANOEUVRES project provides an in-depth study of the non-steady effects of manoeuvring flight on noise prediction and innovative, reliable flight control laws capable to reduce pilot workload in manoeuvring flight

a) Timeline & main milestones

The project duration was 32 months.

Three technical work packages (WP1, WP2, WP4) were running since the beginning of the project. WP3 focusing on the flapping measurement system development is starting at Month 16. Support activities (WP5) were ongoing for the whole period.

The PAI solution has been chosen and implemented, and has been tested in the second year of the project.

Unsteady noise predictions and correlation with flight test data have been performed in the second period of the project. The MANOEUVRES sensor system has been integrated and tested on a ground test vehicle (AW139) in the last 6 months of the project for final validation and functional/performance assessment.

b) Environmental benefits

The MANOEUVRES system will significantly contribute to the reduction of rotorcraft environmental impact in term of noise emissions, including during non-stationary manoeuvring flight conditions, enhancing public acceptance of rotary wing operations in populated/environmentally sensitive areas.

c) Maturity of works performed

A full-scale integrated prototype of the rotor state measurement system has been installed on a ground test vehicle (AW139) and validated, demonstrating a level of maturity up to TRL6. The pilot acoustic indicator has been assessed through a test campaign on an industrial R&D flight simulator.

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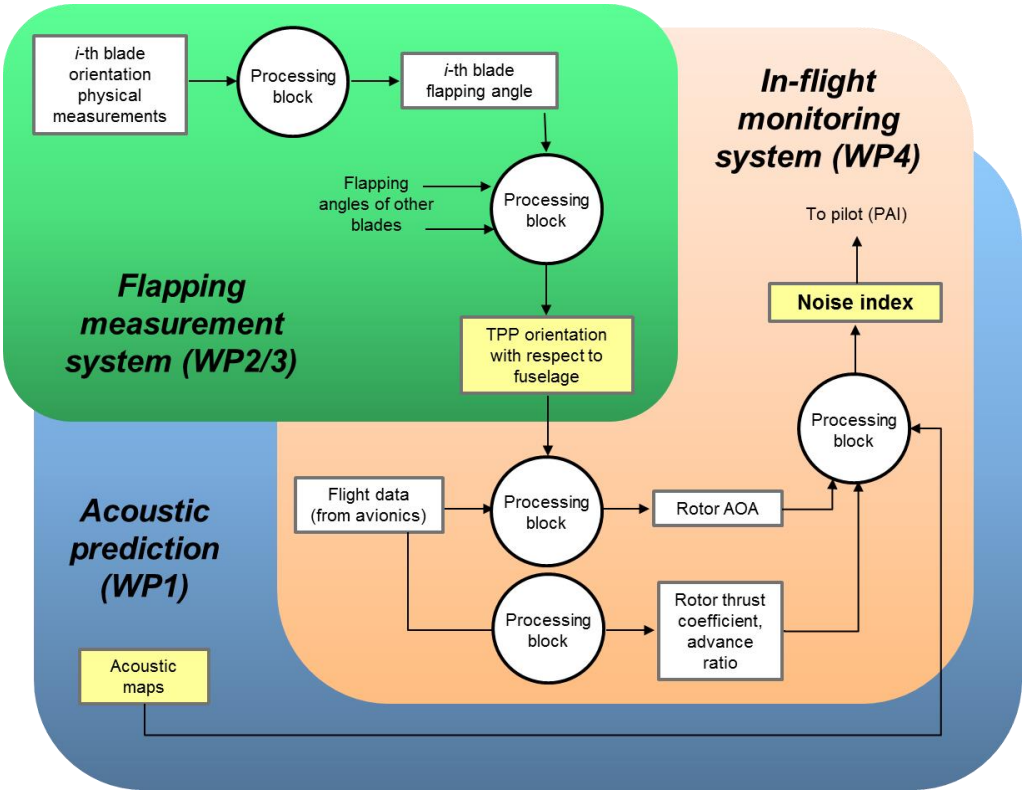

MANOEUVRES integrated concept layout