Project WENEMOR
Call Identifier: SP1-JTI-CLEAN SKY-2010-4

Wind tunnel tests for the evaluation of the installation effects of noise emissions of an open rotor advanced regional aircraft

WENEMOR - Overview

The main objective of the WENEMOR project was the establishment of an experimental database for open rotor noise emission.
The project was completely successful is achieving it's scientific and technical objectives.

The database is being utilised to:

- Validate numerical codes
- Develop advanced data analysis techniques for source separation
- Develop future aircraft designs in the GRA program

Figure 1 : Aircraft in Pusher-E U-tail configuration

WENEMOR - Overview

The project utilised a proposed design for an advanced regional aircraft configuration, developed within the Green Regional Aircraft project.
The aircraft model was manufactured at 1:7.5 scale and was designed to be parametric following a modular approach.

The project consisted of 7 partners:

Trinity College Dublin [Co-ordinator]	**Ireland**	**HEA**
Eurotech SAS	Italy	SME
Universita Politecnica delle Marche	Italy	HEA
Pininfarina SPA	Italy	LE
Teknosud SRL	Italy	SME
MicrodB SA	France	SME
Paragon S.A.	Greece	SME

WENEMOR – Project Structure

WENEMOR consisted of five work packages:

WP1 –Multi-Configuration Model Design

- This work package produced designs for the a/c model, wind tunnel interface and engine simulators

WP2 - Multi-Configuration Model Manufacturing

- This work package manufactured all elements of the wind tunnel models

WP3 – Wind Tunnel Test Campaign

- This work package defined and conducted the test program at the Pininfarina wind tunnel facility

WP4 – Aeroacoustic Measurement Analysis

- The near and far field noise measurements were analysed in this work package to identify the optimum low noise aircraft configuration

WP5 Management and JTI GRA Interaction

- Project management and dissemination activities were overseen in this work package

WENEMOR – WP1

WP1 –Multi-Configuration Model Design

The objective of this task was the design of:

- The wind tunnel aircraft model of at 1:7.5 scale
- The instrumented and non-instrumented engine simulators

The design consisted of 16 aircraft configurations with take-off and approach settings for each.

The model was controllable for angle of attack changes.

The engine simulators featured take-off and approach settings by varying for engine speed and blade pitch

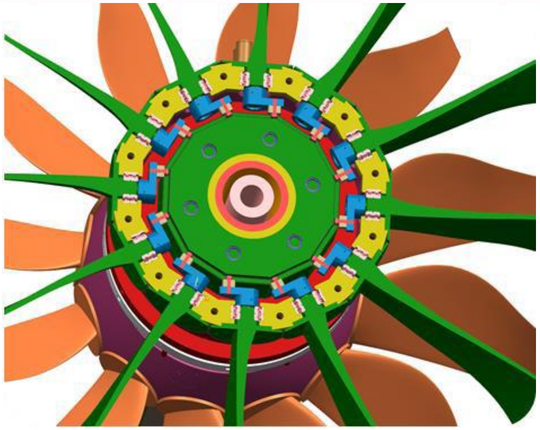

Figure 3 – Engine simulator hub with blade pitch control

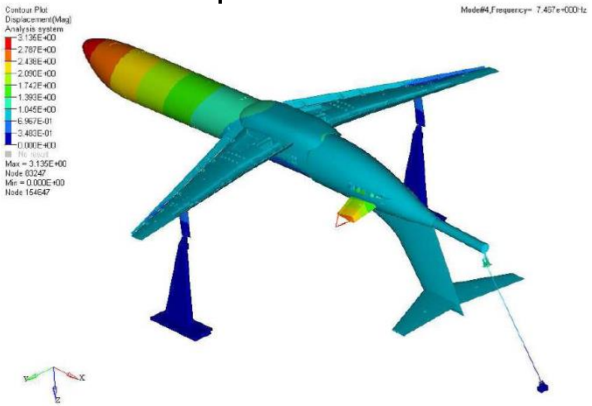

Figure 4 – FEM analysis

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WENEMOR – WP1

WP1 –Multi-Configuration Model Design

The modular design of the aircraft model allowed for fast changes between aircraft configurations.

The innovative engine simulator design that was achieved in the project allowed for easy adjustments of the blade pitch for take-off and approach conditions.

The blade design was done according to a profile agreed with GRA and suggested by SNECMA, so the model's representativeness is well assured.

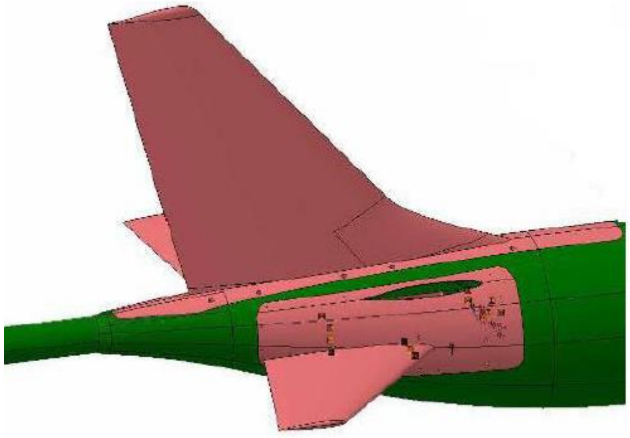


Figure 5 – Model L-tail with removable panels for configuration changes

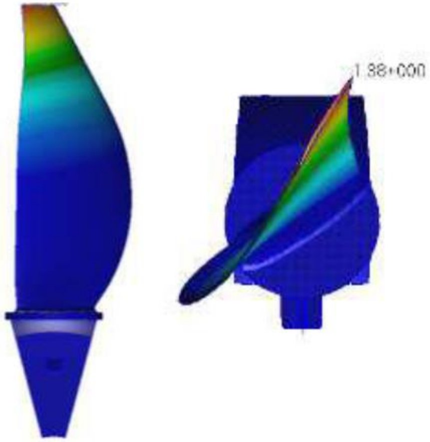


Figure 6 – Analysis of blade tip displacement at 3300 rpm

WENEMOR – WP2

WP2 - Multi-Configuration Model Manufacturing

The objective of this work package was the manufacturing of model subcomponents and model assembly. This included:

- The modular wind tunnel model
- The wind tunnel interfaces
- The engine simulators

Each model configuration was instrumented with an array of 20 fuselage pressure sensors centred on the front blade plane. One engine simulator was instrumented with kulites embedded in the front and rear blade row for a total of 24 sensors at different locations between 15%-70% of the blade chord.

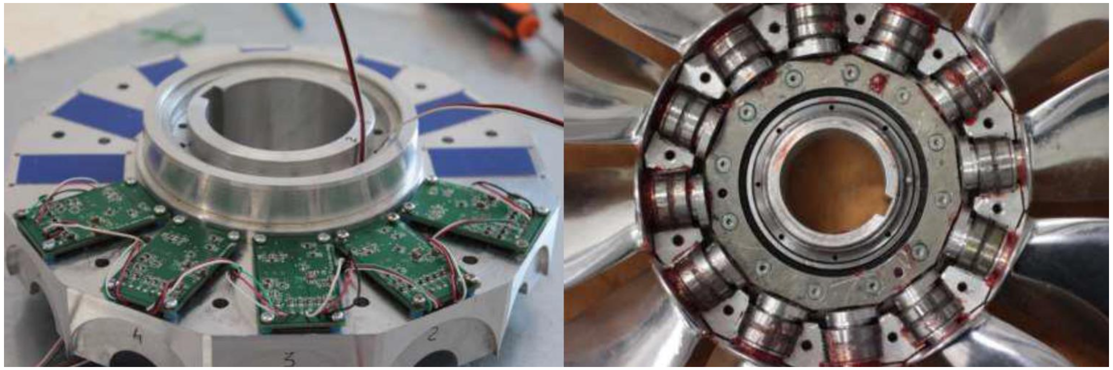
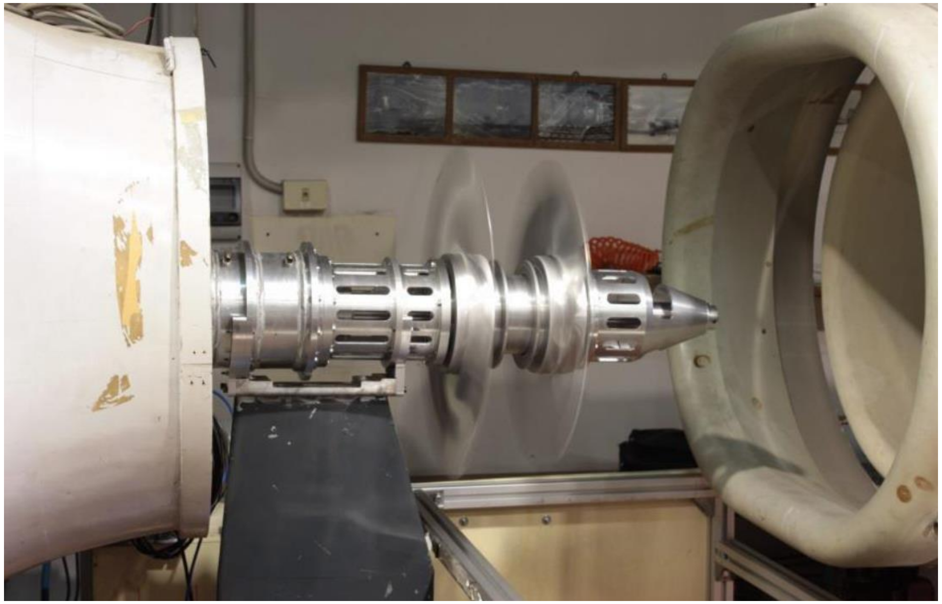


Figure 7 – Instrumented engine hub and pitch control system

WENEMOR – WP2

WP2 - Multi-Configuration Model Manufacturing

The blade pitch settings for take-off and approach conditions were determined experimentally in order to exactly match the scaled aerodynamic load on the blade during wind tunnel testing.



This was achieved through an engine calibration producing an accurate evaluation of the thrust of engine as function of blade pitch angle and wind tunnel speed.

Figure 7 – Experimental calibration of engine simulator

WENEMOR – WP3

WP3 – Wind Tunnel Test Campaign

The object of WP3 was to execute wind tunnel tests and aero-acoustic measurements of noise emitted by the scaled model of the CROR aircraft.

This work package defined the test program, instrumentation setup, data analysis procedures as well as the experimental validation and characterization of the test articles.

Figure 8 – Aircraft model in wind tunnel with microphone arrays

Installation effects due to the reflective action of the aircraft body were to be investigated together with behaviour variation due to different geometric configurations. Wind tunnel test were performed at the Pininfarina wind tunnel, Turin, Italy.

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WENEMOR – WP3

WP3 – Wind Tunnel Test Campaign

Near field noise measurements:

- A microphone array on a traversing arm
- 22 kulites sensors on both the front and rear blade rows
- 20 fuselage mounted pressure sensors

Far field noise measurements:

- 3 microphone beam forming arrays
- Far field linear array

In total over 250 sensors were deployed for 106 configurations during the test campaign. The data produced have been used to generate the most comprehensive database of installed and isolated CROR noise emission currently available.

Figure 9 – Lateral, forward and linear far field microphone arrays with the near field traversing arm

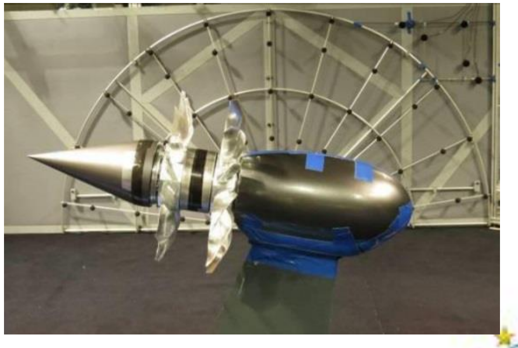

Figure 10 – Single pylon

WENEMOR – WP4

WP4 – Aeroacoustic Measurement Analysis

The object of WP4 was to execute the processing and the organization of data collected during the WENEMOR test campaign. The output of the test program was a very large and extensive database of CROR noise emission.

The principle output of the data analysis was a database of linear and A-weighted OASPL and 1/3 Octave Band and narrow band spectra on all sensors.

Additional processing was conducted through beamforming analysis for source identification on the wind tunnel models

The combined databases were used to identify the best performing aircraft configuration through a parametric study of the noise emission

WENEMOR – WP4

WP4 – Aeroacoustic Measurement Analysis

The conclusions of the parametric study are quite clear:

- The pusher engine configuration has a lower noise emission than the tractor (5-7dBA reduction)
- The pusher E U-tail configuration has been identified as the best performing low noise configuration (further 5dBA reduction from baseline pusher)
- For the pusher engine configuration the lower noise emissions were achieved through the use of longer engine pylons, higher angles and a U-tail design

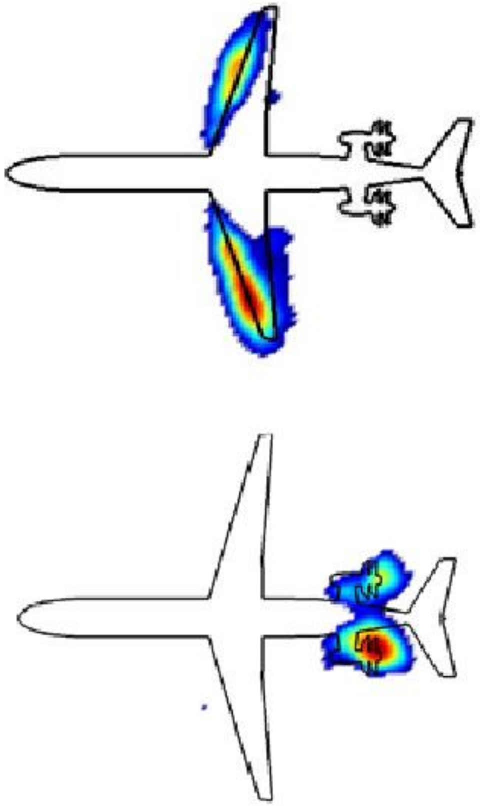

Figure 11 – Beamforming source identification with and without engine simulators activated

WENEMOR – WP5

WP5 Management and JTI GRA Interaction

The project was managed within this work package.

The results of the WENEMOR project will integrate with research activities in the wider Clean Sky and Green Regional Aircraft programs and pave the way for flight testing of the demonstrated low noise technology.

In addition, the project will serve to sustain the momentum of a number of national programmes in Ireland, France, Italy and Greece from which the consortium partners have been drawn.

The initial results of the first pusher test campaign were presented at the AIAA/CEAS conference in Berlin, May, 2013.

WENEMOR – Dissemination

Current publications are listed below:

WENEMOR: Wind Tunnel Tests for the Evaluation of the Installation Effects of Noise Emissions of an Open Rotor Advanced Regional Aircraft , Gareth J. Bennett, John Kennedy, Petr Eret, Filippo Cappadona, Antonello Bianco, Raffaele Letizia, Davide Danise, Lucille Lamotte, Christophe Picard, Arthur Finez, Paolo Castellini, Paolo Chiariotti, Francesca Sopranzetti, Demosthenis Tsahalis, Haralabos Tsahalis, Vassilios Moussas, Antonio Paonessa Francesco Amoroso, Massimiliano Di Giulio, 19th AIAA/CEAS Conference, Berlin, May 2013

The application of advanced beamforming techniques for the noise characterization of installed counter rotating open rotors, John Kennedy, Petr Eret, Gareth Bennett, Francesca Sopranzetti, Paolo Chiariotti, Paolo Castellini, Arthur Finez, Christophe Picard, 19th AIAA/CEAS Conference, Berlin, May 2013

A parametric study of installed counter rotating open rotors, John Kennedy, Petr Eret, Gareth Bennett, 19th AIAA/CEAS Conference, Berlin, May 2013

New open rotor Aircraft Configuration: Wind tunnel tests for the evaluation of Engine Installation Effects on Emitted noise, Leonardo Lecce, LMS Aerospace Conference, Toulouse, 2013

A coupling of computational methods for CROR installation effects, Laurent Sanders, Daniel Mincu, Williams Denis, Pier Luigi Vitagliano, Mauro Minervino, John Kennedy, Petr Eret, Gareth Bennett, 20th AIAA/CEAS Conference, June 20, 2014

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