CLEAN SKY
RESEARCH and TECHNOLOGY DEVELOPMENT PROJECTS
(CS-RTD Projects):

DESIGN OF INNOVATIVE CROR BLADE AND PYLON

Acronym: DINNO-CROR

- DELIVERABLE 0.5 -

Final report

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I. INTRODUCTION

This document summarizes the management and technical activities performed in the framework of the DINNO-CROR project. The global objective for NUMECA and VKI (the two partners in this project) is to develop innovative CROR low noise concepts. The four next chapters deal with the four work packages that were defined in the description of work. The DINNO-CROR project was kicked-off on March 1st 2010 for an original period of 19 month, but was extended by 6 months. The activities of DINNO-CROR have been adapted during the course of this project, in agreement with Airbus Industrie. In the next chapter dedicated to the project management (WP0), we summarize the changes that have been made with respect to the original description of work.

II. PROJECT MANAGEMENT (WP0)

The main tasks of this work package consisted in

- Maintaining the contacts with the EC and the CLEANSKY SFWA-ITD teams.
- Monitoring the progress and risks associated to the scientific and technical work, including the reporting and the meetings with the SFWA-ITD partners
- Ensuring the financial management of the project.

The kick-off meeting was held by Airbus Industrie in Toulouse on February 25th – 26th 2010. NUMECA presented the NLH method and the acoustic prediction tool based on the FW-H approach. It was decided to start the project with an initial assessment report on each innovative concept (porous blade surface and plasma control concept) to review and reorient the activities if necessary.

A first progress meeting was held by Airbus Industrie in Toulouse on September 30th 2010, gathering all associates and partners of the work package 2.2.2.1 - Innovative CROR blade & Pylon design (SFWA ITD, Clean Sky Project). NUMECA presented a CFD and CAA analysis on the generic CROR configuration of work package 2.2.2.1. VKI presented an initial assessment of plasma actuation and porous airfoil concepts.

The activities related to the plasma control concept have been monitored by Airbus through various conference calls. In February 2011, it was decided to stop the activities related to this concept as preliminary studies did not show promising results.

The next progress meeting took place in Braunschweig, Germany on June 15th 2011, again gathering all associates and partners of the work package 2.2.2.1. NUMECA presented aerodynamic and aero-acoustic results for isolated and installed configurations (in presence of an upstream pylon). VKI presented the experimental setup for their studies on porous blade designs as well as preliminary results.

In the summer of 2011, it was decided to extend the DINNO-CROR project by 6 months. Since the task JTI WP 2.2.2.1 itself encountered some delays, it was deemed necessary to extend the duration of the DINNO-CROR project in order to continue beneficiating from the interactions between the different partners of task JTI WP 2.2.2.1. Moreover, since the scope of the project had been adapted, new activities had therefore to be defined which required an adaptation of the schedule.

The final meeting was held in Toulouse on February 1st 2012 where the last results related to the DINNO-CROR project were presented.

The content of the deliverables has also been adapted during the course of the project reflecting the changes in the activities for each work package. The list below summarizes the actual content of each deliverable. These deliverables have all been uploaded on the online participant portal of the DINNO-CROR project, hosted by the European Commission (https://webgate.ec.europa.eu/sesam-fp7/projectHome.do).

- D0.1 Project management means

- D0.2 Fifth-month progress report

- D0.3 Mid-term periodic report

- D0.4 Fifteenth-month progress report

- D0.5 Final report

- D1.1 Intermediate report. Description of the experiment, CAD of the model, list of test cases and definition of the post-processing procedures for the porous blade surface low noise design.

- D1.2 Final report on the experimental database for the porous blade surface low noise design.

- D1.3 Final report on the implementation of the passive actuator in the numerical approach. This deliverable actually contains the additional CFD/CAA simulations performed by NUMECA for the AI-PX7 CROR configuration. The large scatter of numerical data among the SFWA partners indeed raised some questions regarding the numerical methodology to predict the emitted noise from CROR configurations. This led Airbus Industrie to redirect the man-months of NUMECA within the first work package to additional CFD/CAA simulations of the AI-PX7 CROR configuration.

- D1.4 Final report on the passive low noise blade concept for the CROR configuration.

- D2.1 Intermediate report. Description of the experiment, CAD of the model, list of test cases and definition of post-processing procedures for the active blade surface design.

- D2.2 Final report on the experimental database for the active blade surface design.

- D2.3 Final report on the implementation of the actuator in the numerical approach.

- D2.4 Final report on the feasibility of the active concept for the CROR configuration.

- D3.1 Final report on the pylon boundary layer absorption for the CROR configuration.

- D3.2 Final report on the non radial pylon orientation concept for the CROR configuration. In agreement with Airbus Industrie, it was decided to focus the scope of the deliverable on the basic aerodynamic and aeroacoustic effects of a pylon placed upstream of a CROR configuration.

- D4.1 Report on the integration of the DINNO-CROR results into the SFWA ITD objectives.

III. POROUS BLADE SURFACE FOR LOW NOISE DESIGN (WP1)

The objective of the activities related to porous treatment in DINNO-CROR were aimed at assessing experimentally whether porous liners located on the downstream blades of the CROR have a potential for significant noise reduction. A scaled-down mock-up has been designed, manufactured and assembled, with dimensions and operating parameters yielding a fair similarity with the full scale application (e.g. with regard to the reduced frequency of the incoming disturbances). However, not all parameters (e.g. Reynolds number and Mach number) could be preserved. The test rig is presented in Figure 1.

Figure 1. Rotor,airfoil and balance general view (left) and airfoil detailed view (right).

The results showed that a strong correlation could be established between the wall surface pressure and far-acoustic fields. The aerodynamic balance measurements, primarily intended to measure static forces, proved to respond fast enough in order to provide integrated force spectra as well. These spectra correlate well with the unsteady pressure spectra obtained by means of electrets microphones. This opened interesting perspectives for assessing the effect of porous liners by looking directly on the wall pressure spectra and correlating them with the measured acoustic fields, that should be consistent with the integrated force spectra.

The results indicate that in order to observe a reduction of the noise above the measurement uncertainty, the porosity of the liners must reach quite high values (of the order of 25%). Such perforations are likely to cause unacceptable performance loss for the present model. This has been later confirmed by measurements obtained with the aerodynamic balance. For illustration purposes, Figure 2 shows a comparison of the noise measured by a B&K microphone at 0.6m distance from the airfoils/flat plates, which highlights the limited effects of the porosity on the emitted noise.

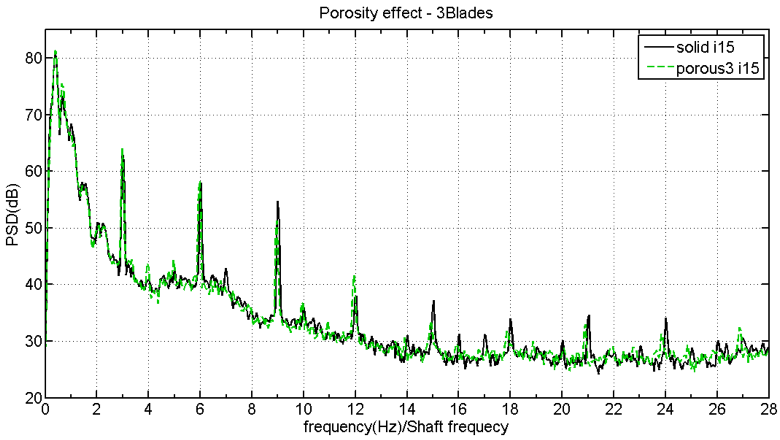

Figure 2. . Solid/porous flat plate comparison for 3 blade case.

IV. ACTIVE BLADE SURFACE FOR LOW NOISE DESIGN USING ACTUATORS (WP2)

WP2 deals with the use of DBD actuators for low noise CROR design. A state-of-the-art report on DBD actuators and their potential use for CROR has been written. Preliminary CFD computations have been performed to assess the effects of a DBD plasma actuator placed at the trailing edge (blunt) of the front blade in a CROR configuration. The effect of the plasma actuator is modeled as a new type of boundary condition on the blunt side of the airfoil where a 5 m/s velocity is imposed. (Maximum velocities of this order have been experimentally measured above DBD actuators.) As shown in Figure 3, the modeled plasma actuation causes no significant change in the wake behind the airfoil. This confirms that the DBD technology has a very limited potential for tone noise attenuation in realistic CROR configuration. Therefore, it was decided to stop the activities related to this concept. The remaining man-months have been redirected to WP1 and WP3.

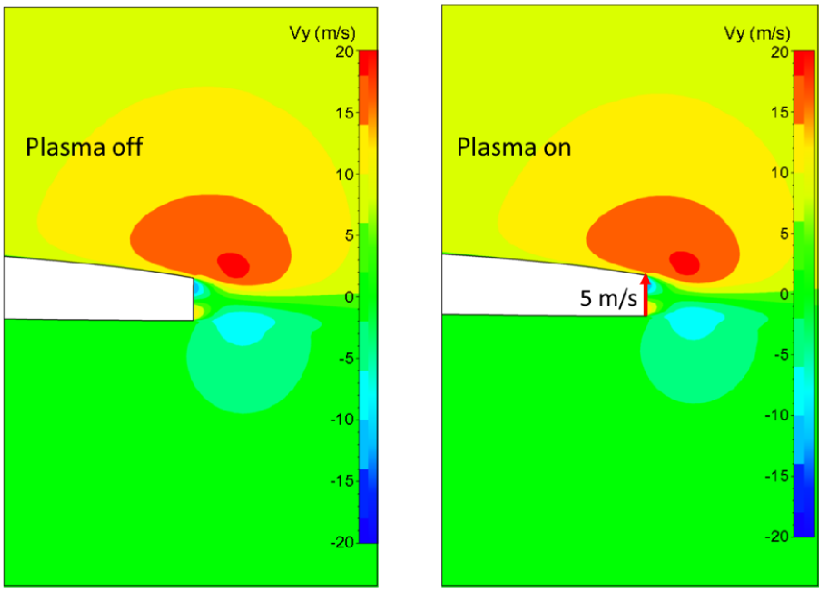

Figure 3. Transverse velocity profile with and without the plasma actuation

V. INNOVATIVE PYLON CONCEPTS FOR LOW NOISE DESIGN (WP3)

Aerodynamic and aeroacoustic simulations were carried out by NUMECA for the Airbus AI-PX7 CROR configuration at take-off conditions with the inclusion of an upstream pylon. The presence of the pylon marginally affects the global aerodynamic performance characteristics of the front and aft blades in our computations. As illustrated in Figure 4, the NLH method showed its limits in capturing the thin wake of the pylon through five or eight harmonics.

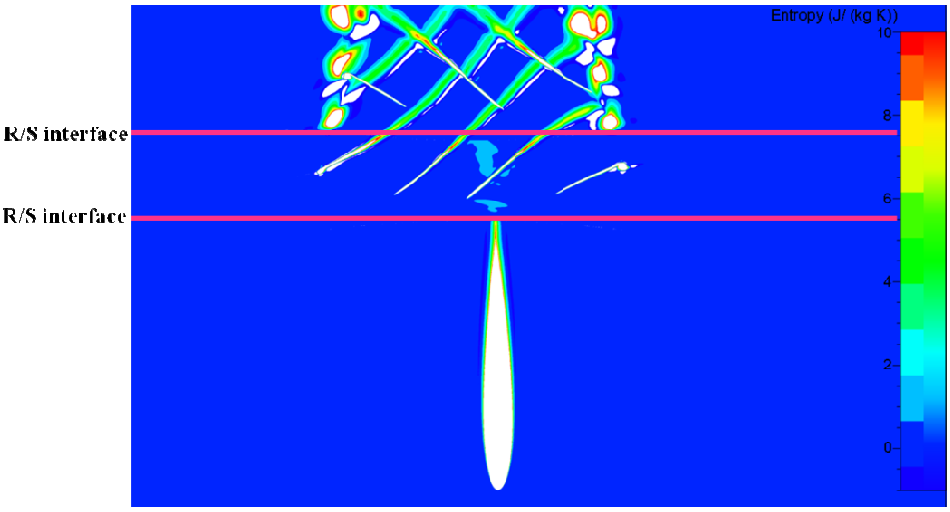

Figure 4. .Entropy wakes from pylon and rotor blades at midspan (computation performed with 8 harmonics)

The directivity of the emitted noise for the rotor-alone tones from the front rotor was found to be significantly affected by the presence of the pylon, with a significant increase in SPL in the upstream direction (shown in Figure 5).

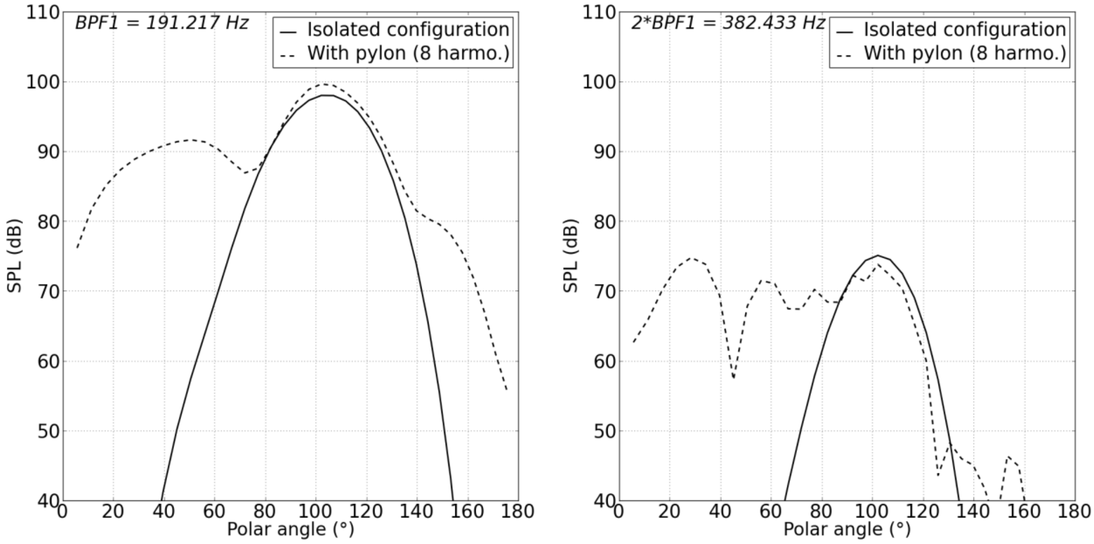

Figure 5. Comparison of the noise directivity in the polar direction between the isolated and installed configurations. The frequencies correspond to the rotor-alone tones from the front rotor.

Since studies from other partners within SFWA showed that the scooping concept is unpractical due to the large mass flow rate and large power needed to run the scooping system, it was decided to stop the activities related to the boundary layer absorption concept.

VI. INTEGRATION AND USERS SPECIFICATIONS FROM THE SFWA-ITD TEAMS AND OBJECTIVES (WP4)

During the course of the project, we developed a close collaboration with Airbus Industry and the rest of the SFWA-ITD partners. Meetings took place on a regular basis (Toulouse, Feb 2010; Toulouse, Sept. 2010; Braunschweig, Jun. 2011; Toulouse, Jan 2012). These meetings were open to the SFWA-ITD partners and guaranteed an efficient interface between the project and the SFWA-ITD team. It allowed Airbus Industry to closely monitor the work performed during this project and to adapt the scope of the project according the latest information and results available.

Our studies led to a better fundamental understanding of the aerodynamics and aero-acoustics of CROR configurations for the end users of the DINNO-CROR project which are the SFWA-ITD partners. Clear guidelines have been formulated on how to simulate CROR configurations to produce accurate aerodynamic and aero-acoustic results. The innovative low noise concepts considered in this project did not appear promising for CROR configurations. This allows nonetheless the SFWA-ITD partners to restrict the field of investigations for future concepts which should be further developed to higher TRL for limiting the aero-acoustic impact of the CROR.

There is no doubt that this project will support the global CLEANSKY objectives towards greener aircrafts. It should be noted that the promising results regarding the numerical simulations of CROR configurations led to a new Clean Sky project for NUMECA Int. (Clean Sky NAA-CROR, Call identifier: SP1-JTI-CS-2010-3). The collaboration with the SFWA-ITD partners therefore still continues in the framework of work package 2.2.2 (Innovative power plant integration), task 6 (CROR assessment).