www.onera.fr

POST-DOCTORATE PROPOSAL

Title : Pressure field measurements on rotating blades using pressure sensitive paints

Reference : **PDOC-DAAA-2022-02.**
(to be recalled in all correspondence)

Start of contract: December 2022 – February 2023	**Application deadline:** 15th November 2022

Duration: 24 months

Keywords

Pressure sensitive paints, Thermometry, Rotating blades, Open Fan

Profile and skills required

- PhD in Mechanical Engineering or related discipline
- Experience in the development of sensors or imaging systems

Presentation of the post-doctoral project, context and objective

ONERA has a wide variety of wind tunnel facilities dedicated to the evaluation of industrial aeronautical programs and to the scientific study of flow phenomena. Nowadays, dense and unsteady measurements are essential to characterize complex dynamics of fluid flow and further improve aerodynamical performances by reducing drag, noise footprint or improving the maneuverability of aircrafts. They are also of great interest for validating simulations or enhancing them with data-assimilation techniques. Since the pressure in a turbulent flow varies in space and time, fast distributed measurements over a surface are required. Pressure sensitive paint (PSP) is such a pressure imaging technology developed and used since the 1990´s at ONERA. It makes use of luminescent molecules embedded into a painted surface. The interaction of oxygen molecules present in the air and the luminescent molecules of the paint affects the intensity of the luminescence emission, a phenomenon called oxygen quenching [1]. Airflows are considered to have a uniform oxygen mole fraction. The number density of oxygen molecules is therefore directly related to the local static pressure of the flow so this technique delivers local pressure information. An example of dense surface pressure measurements on a wing placed in a transonic wind tunnel is shown in Fig. 1. The pressure map show a clear pressure step (blue to green boundary) due to the presence of a shock, known as the transonic buffet phenomenon.

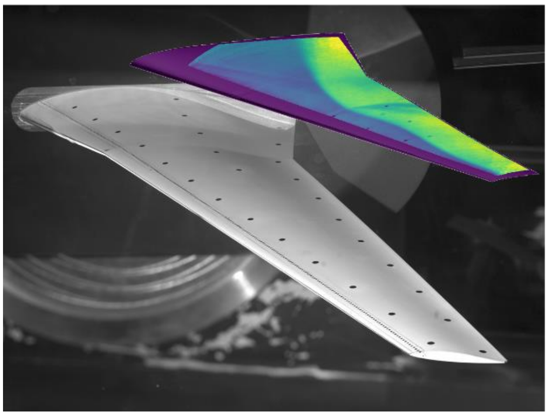

Fig 1: Pressure sensitive paint measurements on a wing performed in the ONERA S3Ch transonic wind tunnel, clearly showing the transonic buffet phenomenon.

In this project, the objective is to develop and demonstrate the ability to obtain dense yet accurate pressure measurements on rotating blades prior to large test campaigns on an open fan model at S1MA, the world largest transonic wind tunnel. It is shown in Fig. 2 (left). Open Fans are the next generation of aircraft propulsion systems, offering improved fuel economy compared to ducted turbofans. The challenges for the application of PSPs on fast rotating parts are numerous. Short illumination is necessary to avoid motion blurring. Advanced motion-capturing PSP techniques must also be used to correct for the effect of blade deformation. Finally, due to the strong radial velocity distribution, compressible effects lead to strong temperature inhomogeneity across the blade. Unfortunately, temperature also influences the luminescence intensity through thermal quenching, so the local temperature must be known to extract local pressure information. Simultaneous 2D temperature measurements are therefore necessary, adding for example pressure insensitive but temperature sensitive luminescent materials to the paint formulation.

The postdoctoral researcher will be in charge of developing, implementing and testing technical solutions to the above-mentioned challenges. This includes the use of pulsed laser illumination, advanced recording techniques and improved PSP formulations capable of deformation and temperature corrections. After benchmarking those solutions in laboratory experiments, demonstration measurements will be performed in a rotor test-rig shown in Fig. 2 (right).

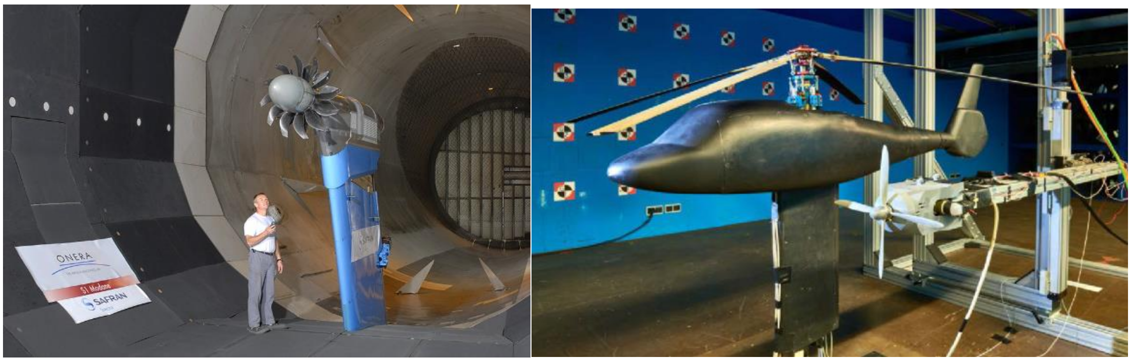

Fig 2: Left: Contra-Rotative Open Rotor (CROR) engine tested at ONERA S1MA the world largest transonic wind tunnel, Right : Rotor test bench at ONERA Lille.

[1] J. I. Peterson et R. V. Fitzgerald, «New technique of surface flow visualization based on oxygen quenching of fluorescence,» *Review of Scientific Instruments,* vol. 51, p. 670–671, 1980.

Host laboratory at ONERA

Department Department of Aerodynamics, Aeroelasticity and Aeroacoustics (DAAA)

Location (ONERA centre): Meudon

Contact: : Benoît Fond / François Nicolas

Phone: +33 1 46 23 51 47 / +33 1 46 23 50 65 Email : benoit.fond@onera.fr, francois.Nicolas@onera.fr