HYDRODYNAMIC MEASUREMENTS AROUND MOVING PROFILES: FLAPPING FLIGHT, WATER TURBINE, AND OSCILLATING PROFILE.

Laurent David, Anthony Bernard, Ludovic Chatellier

P' Institute, CNRS- University of Poitiers - ENSMA, UPR 3346, France

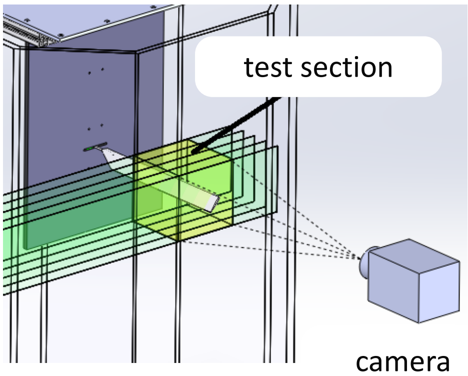
In the field of the fluid mechanics, the team HYDEE (Hydrodynamics and Environmental flow section) of the institute Pprime is involved in the understanding of flows around moving profiles for environmental applications, the maritime transport, the renewable energy production, The research interests cover fundamental aspects of unsteady flows with moving structures, turbulent free-surface flows, environmental flows and mixing through different national and European programs. Fundamental contributions to optical flow measurements include PIV stereoscopy PIV measurement techniques and recently free surface measurement and volumetric measurement techniques have been obtained.

During this session, different experimental devices and measurement techniques will be presented in the context of the flow analysis around moving profiles. Direct dynamic measurements such as loads, torque or pressure are often coupled with kinematic measurements like velocity. Optical non-intrusive measurements are developed in the lab and allow accurate and local measurements of the flow around profiles.

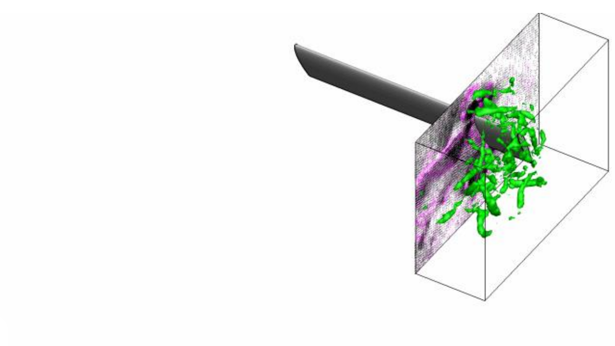
Three examples will be presented:

- An experience of a flapping wing in hover:

A flapping wing with a revolving motion is studied with different kinematics by simulation and experimental measurements to better understand the interaction between the wing and the main flow structures. The objective is the optimization of the efficiency (ratio between the lift coefficient and the drag coefficient) by playing on the kinematic of the wing. For the experimental measurements, a scanning tomography PIV is applied to measure a flow volume of about 85 mm in depth (David, Jardin, Braud & Farcy, 2012).



(a)

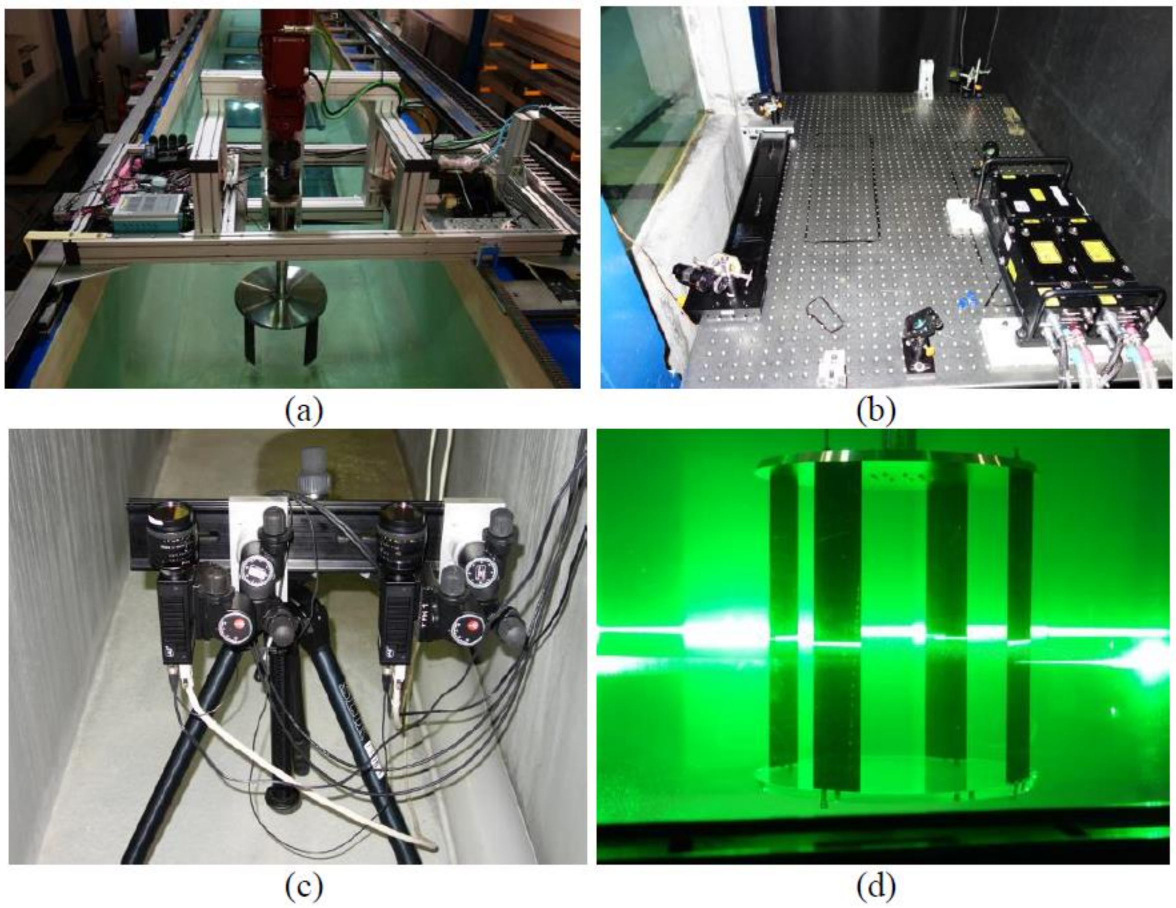


(b)

(a) Acquisition of the flow around a flapping wing; (**b)** λ_2 criteria, pressure and velocity measurements from TR PIV.

- A vertical axis water Turbine:

As a part extensive research in the development and application of renewable energy sources in the built environment, the experimental studies are conducted on a Darrieus turbine model with four-blades. This study used PIV technique with advanced timing coordination between turbine rotation, its linear motion, laser illumination, PIV system and torque measurement. In order for the field-of-view of the experiment to cover the entire rotation of the turbine, a dual camera system was used. Series of PIV measurements were conducted for tip speed ratios leading to optimal and non-optimal operating conditions. Depending on the flow configuration, 50 to 160 pairs of PIV images were used to analyze the velocity and vorticity distributions. Phase-locked measurements of each flow configuration conducted in this study were used to quantify the time evolution of the flow structures in the observation plane and learn about the exact location and timing of the vortex shedding from the blade. The unsteady behaviour of the fluid flow around the model is related to the varying incidence (θ) of the blade and the local Reynolds number (Gorle et al., 2014).

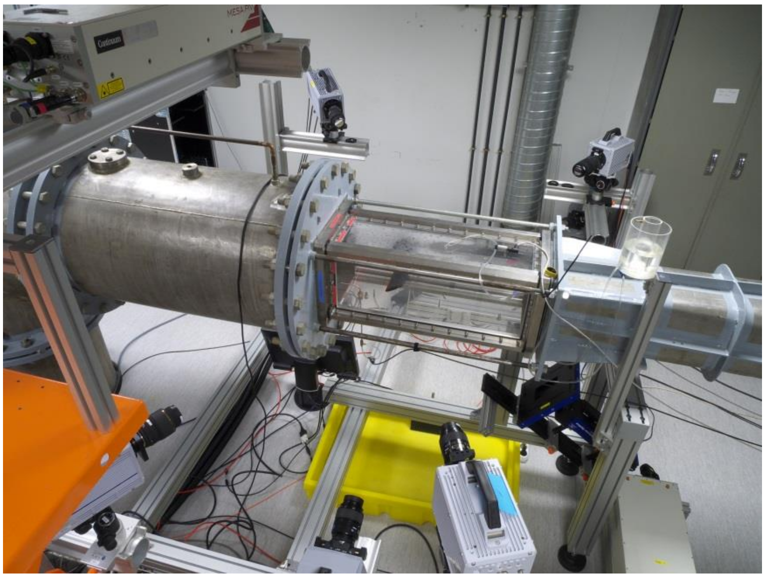


(a) Turbine model in the starting zone of the towing tank; **(b)** Optical arrangement for laser beam separation **(c)** CCD cameras; **(d)** Instantaneous laser sheet on the mid-plane of the turbine

- An oscillating profile at high Reynolds number.

An application to the fully detached flow around an oscillating NACA 0015 airfoil of chord c=80mm with a range of angle of attack varying between $\alpha=\pm30°$ and a Reynold number $Re=10^5$ is studied to understand the effect of the kinematics of the wing on the lift and drag coefficients during a cycle of motion.

The time-resolved velocity and pressure measurements allow the calculation of pressure and loads from the momentum equation to optimize the motion with the objective of the efficiency maximization. These new tools are developed in the framework of the European project FP7 NIOPLEX.



Simultaneous TomoPIV-pressure measurements of the flow around an oscillating wing with six cameras

David L., Jardin, T., Braud, P. & Farcy, A. (2012). Time-resolved scanning tomography PIV measurements around a flapping wing. *Experiments in Fluids*, Vol 52, n°4, 857-864.

Gorle, J.M.R., Bardwell, S., Chatellier, L., Pons, F., Ba, M. & Pineau, G. (2014). PIV investigation of the flow across a Darrius water turbine. *17th International Symposium on Applications of Laser Techniques to Fluid Mechanics Lisbon*, Portugal, 07-10 July, 2014.

www.nioplex.eu (7th Framework Program of the European Commission under Grant Agreement 605151).

Workshop on Non-Intrusive Measurements for unsteady flows and aerodynamics, http://nim2015.conference.univ-poitiers.fr/