Simulation of the Aerodynamic Effects on an Actuated Pendulum with the Actuator Volume Method

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EXTENDED ABSTRACT

1 Introduction

Nowadays, it is accepted by scientists and sportsmen that aerodynamics plays a very important role in cycling performance. From the position on the bike to the design of the helmet, everything must be done to minimize the aerodynamic drag. The power developed by the cyclist is, among others, related to this drag force, that can be noticeably influenced by the body motion. In particular, legs rotation around the crank induces a drag that varies of about 20% over a pedal stroke cycle, while the front area does not vary more than 2% [1].

Unfortunately, the aerodynamic of a complex three dimensional geometry in a non static configuration (i.e. legs rotation) remains a very difficult problem. Some other studies have been made about the change in the aerodynamic drag due to the change in position of the legs but only experimentally, or numerically in static or quasi-static cases [1]. They found that there are two major flow regimes varying with the crank angle. The symmetrical low-drag flow regime occurs for an horizontal crank and the asymmetrical high-drag flow regime for a vertical crank.

Because of this complexity, another numerical method has to be used to simulate the flow. This paper presents the Actuator Volume method applied to a simplified problem (still unsteady with complex three-dimensional geometries) in order to validate it. Another goal is to make the junction between multibody dynamics and aerodynamics, that could be coupled for different situations.

2 Method

Usually, the Actuator Line method is used to simulate the flow around profiled objects, such as blades. This method cannot be adopted for a complex three-dimensional object like a cyclist. Thus, with a moving object (i.e. rotation of the legs around the crank axis), another method has to be chosen. Computational Fluid Dynamics (CFD) method is not a good solution because of its price in terms of computation time. The purpose is to find a method that gives a good approximation of the solution and that is not too expensive in terms of calculations.
Thus, the idea is to implement the Actuator Volume method, which means that the real bodies are replaced by simplified volumes (such as cylinder). The boundary layers cannot be captured but vortices and turbulence phenomenons might be well approximated.

This first approach will be based on a simpler study case because of the complexity of the whole cyclist-bike system. From the whole legs rotation of the cyclist problem, a simple actuated pendulum will be considered in order to compare the results of the model with an experimental setup, and hence to validate the Actuator Volume method for unsteady aerodynamics.

3 Experiments

The experimentation will be done in a wind tunnel in our laboratory. As depicted in Fig 1, the experiment will be composed of a force sensor, an actuator and the pendulum itself. The force sensor will allow to compute the aerodynamic forces (drag and lift) and the actuator will control the pendulum in order to impose its kinematics. The minimum and maximum angle α can be computed based on a bike dimension and the anthropometry of a human body or thanks to Sanderson [2]. Also, the imposed speed can be obtained on the basis of minimum and maximum crank rotation speed [3].
The geometry and the material of the pendulum will be chosen such that it corresponds to a real leg.

By measuring the forces on the pendulum, the aerodynamics will be simulated using the Actuator Volume method that requires to know the lift and drag forces. Then the flow will be simulated and the actuator torque will be estimated and compared to the real one measured in the experiment.

The model will be made with the Robotran multibody program [4] coupled to a CAD software such as Solidworks®. The purpose of this model is to apply the Actuator Volume to simulate the flow around the bodies and hence to obtain the large-scale aerodynamic effects. This method does not require a huge mesh as it would be necessary for a CFD method. As depicted in Fig

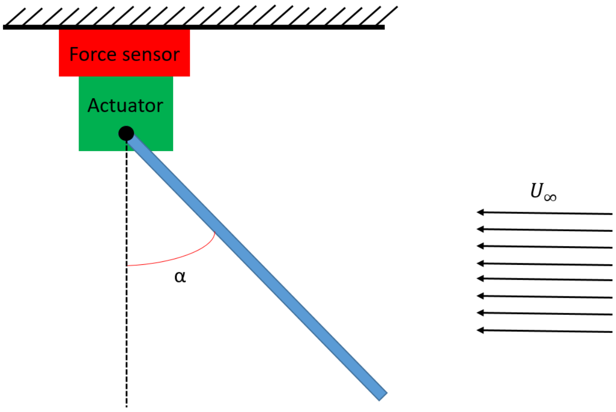

Figure 1: Schematic of the legs rotation simplified problem, i.e. the simple pendulum submitted to an air flow.

2 and Fig 3, a CFD mesh requires a very fine mesh while the Actuator Volume method requires only a coarse Cartesian mesh, meaning that the computations will be much faster and much cheaper but of course less accurate.

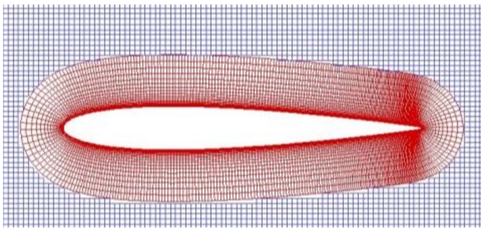

Figure 2: Usual CFD mesh for a airfoil application [5]

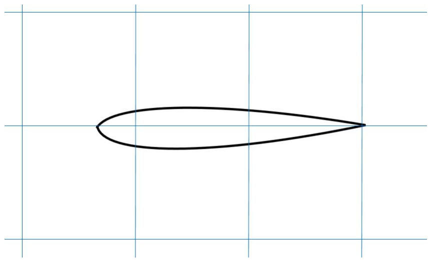

Figure 3: Usual Actuator Volume mesh for an airfoil application

4 Expected results

The main purpose of the experimental results is to verify if the Actuator Volume method can be used to estimate the aerodynamic effect on a complex, i.e. not profiled like blades, three-dimensional geometry in an unsteady case with an acceptable accuracy. Experimentation are planned at the beginning of 2019 so that preliminary results could be presented and discussed in the full paper as well as during the oral presentation.

References

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