Master REST, Wind Energy

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February 22, 2021

The work can be done by groups of two people.

1 Introduction

The aim of this activity is to show how a Computational Fluid Dynamics (CFD) tool can be used to modelize a wind turbine farm and to study the interaction between several windturbines. The software that will be used is StarCCM+. The presence of a wind turbine in a flow of air will be modelized by a "Virtual Disk" method, using the "1D momentum" approach that is imlplemented in StarCCM+. The idea is to simulate the flow in a large domain (a box) with a prescribed infinite incoming velocity and to replace the wind turbines by singularities of circular shape in the domain that will add source terms in the momentum balance equation for the fluid; these source terms being prescribed functions of the incoming wind just upstream of the active disk. The axial thrust is modeled as a body force that is distributed on the disk,and the mechanical power is used to compute a torque that is modeled as a distributed angular momentum source. The wind turbine we are going to study has the following characteristics:

- Outer radius: $R_{tip} = 150$mm
- Three blades
- Rotation rate: $N = 1909$rpm
- Maximal power: $P_{max} = 35W$ (for air of density $\rho = 1.2$kg.m^{-3})
- Minimum wind speed 6m.s^{-1}, Maximum wind speed 14m.s^{-1}

A picture of it is visible in Fig. 1. The curves giving the power and the thrust coefficient C_T as a function of the wind speed are displayed in Fig. 2.

2 Simulation

The first day will start with a tutorial on the software. The main steps are the following:

- Creating a box of sufficient size to simulate the flow domain (typically we need a region of five diameters upstream and on the sides of the first wind turbine and of ten diameters downstream)
- Prescribing boundary conditions
- Defining the physics of the problem
- Creating active disk(s) modeling the wind turbine(s) and assign properties to them
- Meshing the domain

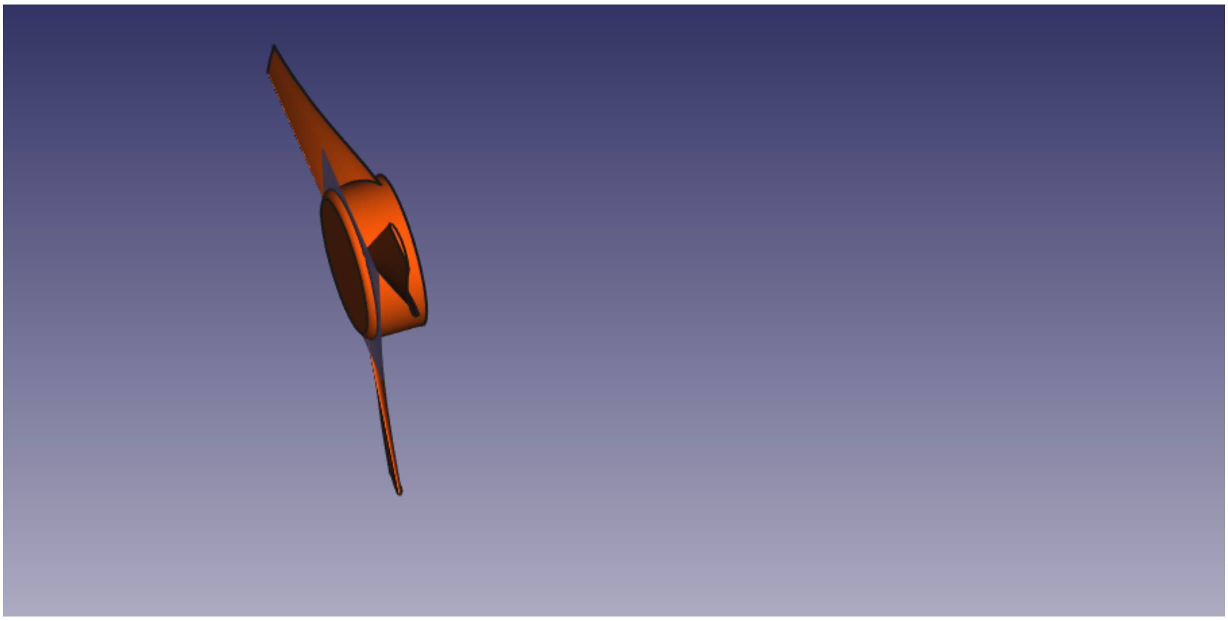

Figure 1: CAD of the wind turbine

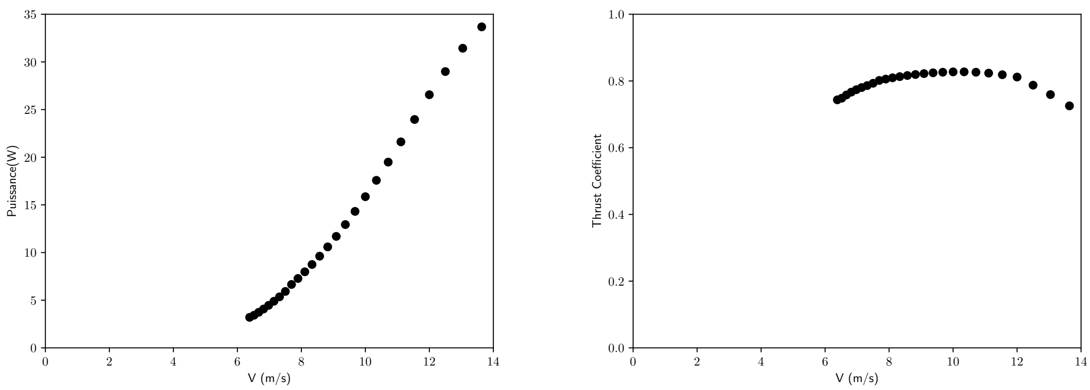

Figure 2: Power and thrust coefficient C_T as a function of the wind speed, for $\rho = 1.2 \text{kg.m}^{-3}$ and $N = 1909 \text{rpm}$

- Simulating
- Treating the data

The results of the first five steps will look like what is shown in Fig. 3, and an example of solution for the velocity field is displayed in Fig. 4.

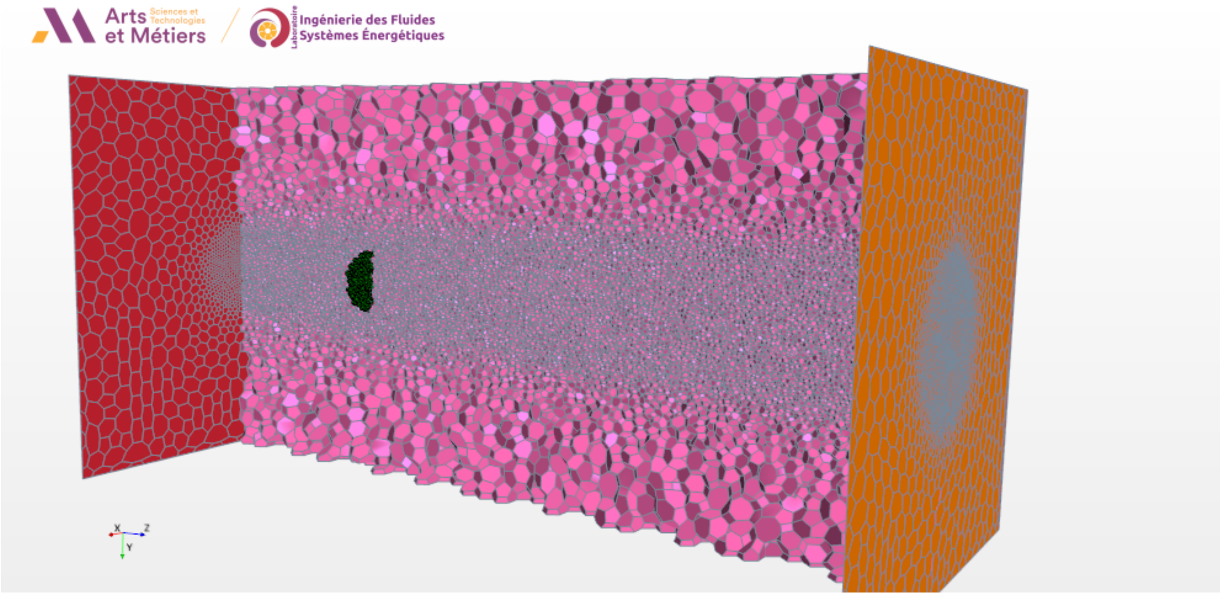

Figure 3: Typical mesh of a domain with one active disk

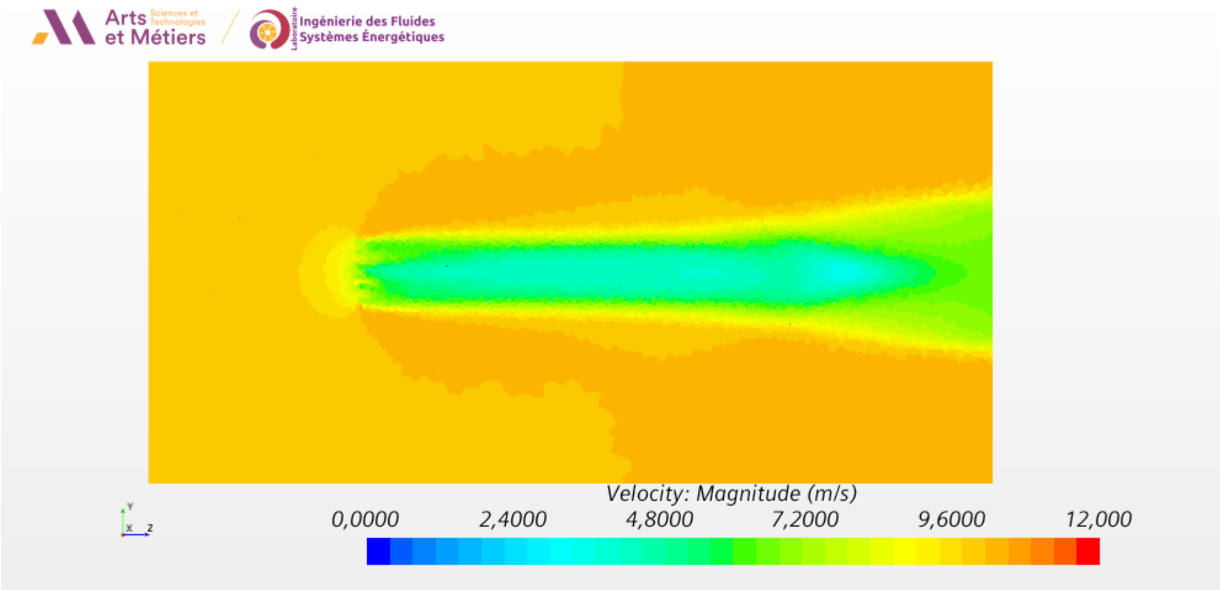

Figure 4: Typical result of a CFD with one active disk

During this tutorial you are advised to read the online help of StarCCM+ dedicated to the 1D momentum model, in "StarCCM+ → Simulating Physics → Virtual Disk Model → 1DMomentum Method". The file which contains the necessary data is available on the web site: `http://florent.ravelet.free.fr/Perfos_FlorentTripaleLambda3.csv`.

3 Work to do

- On the wind turbine: deduce from the data that are given the power coefficient Cp as a function of the tip speed velocity Λ and make all the comments you may imagine about this wind turbine.
- With the software, study the power loss of a wind turbine downstream of another as a function of the distance and of the upwind velocity. You can have a look at the PhD thesis of Munif Jourieh `https://tel.archives-ouvertes.fr/pastel-00003390`, chapter 5, to help getting ideas. You can also explore 3D effects by positioning several disks in a staggered way.

A brief report has to be sent by email to florent.ravelet@ensam.eu within the week that follows the last course.