Development of an unmanned aerial vehicle UAV for air quality measurements in urban areas

Patrick Haas[1], Christophe Balistreri[2], Piero Pontelandolfo[2], Gilles Triscone[3]
University of Applied Sciences Western Switzerland, hepia, Geneva, Switzerland

Hasret Pekoz[4]
Université Pierre et Marie Curie, Paris, France

and

Antonio Pignatiello[4]
Bologna University, Bologna, Italy

Based on an existing UAV platform from fly-n-sense, a system for air quality measurement is developed. The system is able to measure PM10 (SPM), O_3 and NO_2 (see Fig. 1 and 2). The wind speed is also determined by the use of the stabilization system and based on the pitching angle obtained under wind conditions. Detailed maps of pollution concentration can be done. The phenomenon related to particle movements or pollutant diffusion can be outlined. The main objective of the UAV measurement campaign is to determine boundary conditions for CFD calculations at the borders of a city. The aerodynamic development of the UAV includes CFD simulations, wind tunnel experiments, in flight measurements and finally, the sensors selection, integration and validation.

Nomenclature

CA	=	Aerodynamic center
CG	=	Mass center
F_A	=	Aerodynamic force generated by the wind, the UAV translation and the propeller air flow on structures
F_D	=	Drag force (projection of F_A on thespeed vector)
F_L	=	Lift force (projection of F_A at 90 grad of the UAV speed vector)
F_S	=	Sustentation force generated by the propellers
G	=	UAV weight
M_S	=	Moment generated by the propellers

I. Introduction

Based on an existing UAV platform, a system for air quality measurement is developed. The system is able to measure PM10, O_3 and NO_x (see Fig. 1 and 2). The wind speed is also determined by the use of the stabilization system and based on the pitching angle obtained under wind conditions. Detailed maps of pollution concentration can be measured. The phenomenon related to particle movements or pollutant diffusion can be outlined with a positioning tolerance smaller than one meter. The main objective of the UAV measurement campaign is to analyze *in situ* the pollutant distribution, to validate CFD simulation results, and to determine boundary conditions for CFD calculations at the borders of a city or a calculation domain.

[1] Professor, hepia-cmefe, patrick.haas@hesge.ch, AIAA Senior Member
[2] Research Assistant, hepia-cmefe, AIAA Member
[3] Research Coordinator, hepia
[4] Master Student

The development of the UAV includes the following chapters:

- The aerodynamics using CFD simulations, wind tunnel experiments and finally in flight measurements
- The sensors selection, integration and validation
- The UAV performances evaluation in real situations

Figure 1. The hepia UAV equipped with the metallic oxide NO_2 payload.

Figure 2. The metallic oxide NO_2 payload with 16 bits digitalizer and 2.4 GHz data link to ground station.

II. UAV aerodynamics – Wind tunnel study

The aerodynamics of the UAV was first studied in wind tunnel. The system was installed on a six-component balance at the top of a 2m profile (Fig. 3 and 4). The study parameters are the wind speed, the propeller speed and the pitch angle. The forces and moments are recorded to describe completely the UAV aerodynamics. These data describe the behavior of the UAV in flight.

The dynamics of such aircraft is complex (Fig. 5). Fs and Ms are the resultant force and moment generated by the propellers. These last can have different rotational speeds if a motion of the UAV on an axis shall be done. The relative motion of the fluid around the structure gives an aerodynamic force F_A applied to the aerodynamic center CA. F_A can be decomposed in a drag F_D and a lift F_L.

In the case the UAV is stationary and the wind is constant in direction and amplitude, the situation is simple and a direct relation between the pitch angle and the wind speed exists. From the measurements in wind tunnel we extract the situations when the sustentation force Fsz is equal to the UAV weight G, and the horizontal force measured by the balance is zero. In this situation, we obtain a direct estimation of the wind speed and direction as a function of the inclination angle. This angle is a combination of the pitch and roll angles. The results of this analysis are given hereafter (fig. 6).