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A THERMO-FLUID-DYNAMIC MODEL FOR A SMALL-SCALE SPACE-BASED GREENHOUSE

Abstract

High Plant Cultivation Chamber (HPPC) will be an essential element of Closed Loop Environmental Control Systems for future extra-planetary manned outpost. In fact for long permanence of crew inside these habitat, it is not feasible the transport from ground of all the resources needed to sustain the life. The HPPC represent the last compartment of the complex bio-regenerative loop aimed at the transformation of the crew metabolism's products absorbing CO2, purifying water and producing fresh food and O2 . In this context the vegetation is an intrinsic element of the control system and shall be managed in a way similar to gas exchanger or combustion chamber active in other control loop, a real challenge to be achieved.

This paper summarizes the activity performed at the Department of Aerospace Engineer of University of Naples "Federico II" in collaboration with the MARS Center to study the transport processes inside a small plant chamber, in preparation of future developments for modeling and controlling HPCC environment. A small sealed experimental chamber has been developed to establish controlled temperature and humidity conditions in a typical range of interest for plant cultivation; in particular the temperature can be controlled in the range 15-25C and the relative humidity in the range 50-90%. Preliminary experiments have been carried out to evaluate the performances of the experimental apparatus.

A computational fluid dynamics model is applied to predict and study the transport processes inside the small plant chamber, in preparation of future developments in large scale for modeling, design and controlling the environment inside Space greenhouses. The CFD analyses are carried out considering the vegetation canopy, modeled as a porous region characterized by exchanges of momentum, energy and humidity with the airflow. An advanced model of plant photosynthesis process for the prediction of the CO2 absorption, as a function of the leaf temperature, photo-synthetically active radiation (PAR) and other thermo-fluid-dynamics parameters has been considered.

The paper describes the experimental system, the fluid dynamic modeling and the plant models, as well as the results of parametrical analyses considering different boundary conditions. Experiments will be carried out under specific conditions to test the numerical model and to provide numerical-experimental correlations.