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GENERALIZED PREDICTIVE THERMAL CONTROL OF A THERMAL-VACUUM CHAMBER FOR SPACE QUALIFICATION TESTS

Abstract

This work aims at increasing the effectiveness and efficiency of the temperature control in the thermal-vacuum chamber available at the Department of Aerospace Sciences and Technologies of Politecnico di Milano (Milan, Italy). The chamber has a cylindrical shape with both diameter and height measuring 1 m. It is used for qualification tests of spacecraft components and small satellites (mainly cubesats). To this aim, high vacuum conditions (pressure values below 1E-6 mbar) are guaranteed using an air pump and a turbo-molecular pump in cascade. Moreover, the thermal control system is designed to simulate thermal cycles in the range -75 C to 200 C. Cold conditions are achieved through a serpentine cooling circuit, whereas the temperature is increased using either electrical resistances or thermal lamps.

Temperature control is currently regulated using a Proportional-Integral-Derivative (PID) controller. Unfortunately, PID regulators tend to be inadequate to control the temperature during qualification tests. More specifically, PID is tuned to effectively control the baseplate temperature of the chamber. However, temperature requirements are usually provided on specific points of the component to be qualified. In addition, each component to be tested has its thermal behavior. Thus, transient duration and control accuracy strongly depends on the specific test, unless an exhaustive tuning of PID coefficients is carried out.

This work investigates the possibility of solving the above problems by applying the generalized predictive control (GPC) technique. GPC is based on a two-step procedure. First, linear system identification techniques are applied off-line to identify a thermal model of the overall system (including the thermal-vacuum chamber and the object to be qualified). Then, the control action is designed to minimize both the error with respect to the desired temperature profile and the cost of the control action. Thus, GPC is able to adapt to the specific conditions of the qualification test and to optimize energy consumption. In addition, system identification can be performed online to adapt the controller to system nonlinearities and possible variations of thermal behavior.

The numerical and experimental results presented in this work confirm the adequacy of the GPC method to meet temperature requirements and adapt the control action to specific tests. The effectiveness of the method is assessed by comparing its performances with the traditional PID control strategy.