Quantitative Computer Simulations of Extraterrestrial Processing Operations

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Abstract

Three specific projects were initiated with late starting dates. The first and second projects, "Automatic Control of a Propellant Mixer" and "Computer Simulation of Engineering Processes," were started January 15, 1989, and the third project, "Control for Chaotic Mixing," was started February 1, 1989.

The first project is concerned with the automation of a small, solid-propellant mixer located on campus in the AME labs building. Temperature control is under investigation. A numerical simulation of the system is under development and will be tested using different control options. Control system hardware is currently being put into place.

The second project deals with the construction of mathematical models and simulation techniques for understanding various engineering processes. Computer graphic packages will be utilized for better visualization of the simulation results.

The third project is concerned with understanding and, hopefully, improving the mechanical mixing of propellants. Simulation of the mixing process is being done in conjunction with the second project. We will use this simulation capability to study how one can control for chaotic behavior to meet specified mixing requirements. An experimental mixing chamber is also being built. It will allow visual tracking of particles under mixing. The experimental unit will be used to test ideas from chaos theory, as well as to verify simulation results. This third project in the basic research category has clear applications to extraterrestrial propellant quality and reliability.

Introduction

In the production of solid propellants, components must first be mixed under specified conditions in order to produce a uniform product. To date, the batch processing of propellants is still largely a process with a human operator in the control loop. Not only is this unacceptable for space applications, but it makes it difficult to meet precise specified conditions.

Project I was initiated not only to automate processing, but to guarantee that the specified mixing conditions will be precisely met. Temperature control of the propellants is critical and was taken as the first automation task. During mixing, a specified temperature profile must be met.

Project II will be based upon some of the existing knowledge and capabilities of computational simulation of engineering processes. The algorithms and simulation software that will be compiled during the course of this project will be provided to any research participant in the NASA Center. At the start of this project, the main objective has been focused on the computer simulation of the entire mixing process.

Project III is concerned with the actual mechanical mixing of the propellants. Ultimately, one must be able to quantify the mixing process. Otherwise, how does one compare two mixtures? We must then seek out dynamical processes which yield "good" mixing in accordance with our definition.

Approach and Results--Project I

Two hot water tanks are currently in use with the University of Arizona mixer. One is set at 160°F and the other is set at 140°F. Currently, the operator draws water from one tank or the other to meet two temperature set points. This open-loop approach is undesirable, not only from the point of view that it requires an operator, but the temperature in the two tanks may vary considerably. Our approach is to continue to use the two tanks but with one set >160° and one set <140°. Two control valves will regulate the amount of water drawn from each tank, thereby maintaining a constant flow rate and allowing for control of the specified temperature set points.

A proportional plus integral controller has been investigated using a numerical simulation and has been shown to be satisfactory. Actual control for the mixing system will be by means of a small digital computer with A/D and D/A interfaces. Thermocouple readings will be read into the computer and the control algorithm will, in turn, send a signal out through the D/A channel to set the valves. The computer system and one thermocouple are already in place. The control valves are on order and some replumbing will be required.

Approach and Results--Project II

Until we acquire a workstation for computer graphics and simulations, we are using the Silicon Graphics Workstation at the Computer-Aided Engineering Laboratory (CAEL). Since this is a Unix-based system, transition to another Unix-based system, such as a SUN workstation, should be rather easy. The first problem that we have considered for computer simulation is the formation of the mixing process of Project III.

Approach and Results--Project III

There is a close relationship between chaos and mixing. Indeed, the "baker map" used to explain chaos is a mixing tool (stretch then fold). This presents us with an

inverse problem in controls. Rather than designing a controller to produce uniform stable motion, our objective is to introduce controls into a system to make the behavior as random as possible. How does one design a controller so that the controlled system map will be one which will guarantee mixing? As with most progress in chaos theory, a great deal of simulation is required. We are currently working with some maps which should produce good mixing. These will be tested against a mixing definition so that a comparison of maps can be made. We will then examine the control dynamics to produce the maps. These will be examined both numerically and with an experimental mixing chamber. The first chamber has already been built and will be tested shortly.

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