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Combustion in Heterogeneous Media, Solid and Hybrid Rocket Engines

Theme

The paper describes the results of measurements made in the flame zone above the burning surface of a composite solid propellant. The results are compared to other similar experimental results as well as to current theoretical results.

Content

Temperature measurements in the gaseous reaction zone close to the surface of a burning composite solid (polysulfide-AP) have been made using a modified line reversal pyrometer. In conjunction with the pyrometer, a servo-controlled feedshaft was employed to drive the strand of propellant toward the temperature measurement region at the same rate at which the strand burned. The results of the temperature measurements showed that the gaseous reaction zone cannot be presented by a one-dimensional temperature profile. It was also found that the gaseous reaction zone extends up to a distance of approximately 1 mm from the surface for pressures from 1 to about 15 atmospheres. It is concluded that the gaseous reaction zone alone does not supply sufficient energy to the surface for sustaining the controlling surface reactions.

Composite Propellant Combustion

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Temperature measurements in the gaseous reaction zone close to the surface of a burning composite solid propellant have been made using a modified line reversal pyrometer. In conjunction with the pyrometer, a servo-controlled feedshaft was employed to drive the strand of propellant toward the temperature measurement region at the same rate at which the strand burned. The results of the temperature measurement showed that the gaseous reaction zone cannot be represented by a one-dimensional temperature profile. It was also found that the gaseous reaction zone extends up to a distance of approximately 1 mm from the surface for pressures from 1 to about 15 atmospheres. It is concluded that the gaseous reaction zone alone does not supply sufficient energy to the surface for sustaining the controlling surface reactions.

Introduction

ONE of the most widely debated issues regarding the steady-state combustion of composite solid propellants concerns the contribution of the heat generated in the gaseous reaction zone to the total heat necessary to sustain the controlling surface reactions. Indeed, the flame structure above the burning surface is not well understood and has been approximated as follows: a) occurring adjacent to the burning surface such that almost all of the energy required by surface decomposition reactions originates from the gas phase reactions[1]; b) occurring at an intermediate distance from the burning surface whereby only a fraction of the heat necessary to sustain surface decomposition reactions comes from the gas phase reactions[2–4]; and c) occurring at a distance from the burning surface great enough that the surface decomposition reactions must depend on surface and subsurface exothermic reactions for their sustaining energy.[5,6]

The prime reason for the confusion is the lack of agreement in the results of experiments which are designed to determine the structure of the flame zone. Results have been obtained which show that the adiabatic flame temperature of the gas phase reaction occurs very close to the burning surface,[7] while other results[8,9] have shown that the reaction zone is two orders of magnitude larger than that reported in Refs. 1 and 2.

As a result of the discrepancies of the previous experimental work and the importance of determining the contribution of the energy feedback from the gas phase to the propellant surface, it was deemed important to attempt to reconcile the differences reported in the literature.

Experimental Study

Approach

In all of the previous experimental approaches,[7–9] the procedure followed has consisted of fixing the temperature measurement point at a location below the future burning surface of the propellant sample. After the propellant is ignited, the surface burns past the measurement point such that a single temperature scan of the gaseous reaction zone is obtained.

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