September 1971 Brief 71-10335

NASA TECH BRIEF

Langley Research Center

Flame Zone of a Composite Propellant Expanded by a Laser Source

A laser source can be used to heat the surface of a propellant in order to sustain combustion at greatly reduced pressures, expanding the flame zone to a scale large enough for studying its structure. The flame zone thickness of a composite propellant (an oxidizer such as ammonium perchlorate and a polymeric fuel binder) is normally so small that studying the thermal, compositional, and flow structures of the flame by macroscopic means such as probes becomes very difficult.

One approach to flame zone studies is to expand the zone to a more convenient scale by reducing the pressure in the combustion chamber. The combustion of the propellant, however, is sustained by heat conducted from the flame zone. Since the temperature gradient in the gas phase adjacent to the propellant surface decreases with expansion of the flame zone, quenching usually results before the flame zone can be expanded to a useful size.

A normal combustion environment for ammonium perchlorate propellants, composed of particles in the micron range, involves rapid regression rates (0.5 to 2.0 cm/sec) at pressures in the range of 1.01 to 10.1 MN/m^2. Under these conditions, vaporization of the solid is maintained by conductive heat feedback from a gas flame, whose distance from the propellant surface is also in the micron range. Since analytical probes cannot be miniaturized to the scale of such flames, their structures have largely been a matter of conjecture. With decreasing pressure, however, the flame zone thickness of premixed flames increases, increasing the feasibility of probing their structures. But decreasing pressure also means a diminished burning rate because the temperature gradient above the surface decreases as the flame zone thickness increases. Few propellants burn freely at pressures substantially below 0.1 MN/m^2. Even those propellants that sustain combustion at low pressures have particle radii so small that the characteristic diffusion length is still microscopic. Attempts to expand the flame zone by increasing particle radii have been unsuccessful, since the propellant soon ceases to burn freely, and extinguishes at some particle radius for which the flame zone is still too small for convenient probing.

The use of an external radiant CO_2 laser source to sustain and control the surface regression rate has resolved these scaling problems. The technique allows the heat input to the burning surface to be regulated, independent of ambient pressure. The pressure may then be lowered to the order of 0.01 MN/m^2, and the particle radii becomes macroscopic. Since the laser maintains the required heat input, the propellant continues to burn. In effect, this new technique scales the flame structure linearly with the gas kinetic mean free path, which increases two to three orders of magnitude as the pressure decreases a like amount. The kinetic and transport time scales are expanded in proportion so that the regression rates for the laser-induced flames are two to three orders of magnitude slower (0.02 to 0.04 cm/sec).

Note:

No additional documentation is available. Specific questions, however, may be directed to:

Technology Utilization Officer
Langley Research Center
Hampton, Virginia 23365
Reference: B71-10335

(continued overleaf)

Patent status:

Inquiries about obtaining rights for the commercial use of this invention may be made to:

Patent Counsel
Mail Code 173
Langley Research Center
Langley Station
Hampton, Virginia 23365

Source: Dr. M. Hertzberg, Dr. G. von Elbe,
Mr. E. McHale, and Dr. R. Friedman of
Atlantic Research Corporation
under contract to
Langley Research Center
(LAR-10660)