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Multiphase Flows: Hypervelocity Impact

Theme

This paper presents the results of an experimental study to determine particle impingment forces and damage produced on flat plate models located at several angles of impingement in a controlled two-phase flow.

Content

Tests were conducted in a blow-down type, two-phase, supersonic wind tunnel using helium carrier gas to accelerate micron-sized aluminum oxide particles to velocities ranging from 1300 to 2300 m/sec. The particle mass flux ranged from 0.4 to 2.6 g/cm^2 sec which corresponds to conditions typical of the near field of solid-propellant motors. A number of target materials were tested including stainless steel, teflon, carbon cloth phenolic, quartz cloth phenolic, ATJ graphite, and pyrolytic boron nitride. In order to determine the effect of angle of incidence on the nature of the particle-surface interaction, the targets were designed to provide information on impingement forces over the full range from grazing to normal impact. Specifically, impact angles of 90° (normal), 60°, and 20° were selected. Force measurements were made with a three component balance. The balance was instrumented to detect directly the axial force and two bending moments, where the latter could be resolved into the transverse component of force and a pure residual moment acting on the target. In addition, the flowfield surrounding the target was examined photographically, using schlieren and light transmission and scattering techniques.

For the range of experimental conditions, the particle impact was found to be inelastic for moderate to large angles of incidence and partially elastic for grazing incidence. The measured forces, which were observed to be independent of particle size, shock layer gas density and target material, were less than the theoretical forces by an amount dependent only on the angle of incidence. The most significant experimental result, however, was the discovery that a dense debris layer, comprised primarily of spent projectile material, formed immediately ahead of the target, partially shielding it from subsequent impact by oncoming particles. Although a large fraction of the incident particle momentum diffused through the layer and was transferred to the target, a significant fraction of the incident particle kinetic energy was absorbed by the impact debris with a corresponding decrease in target damage. The latter effect was accentuated with increasing particle mass flux where relative target damage, i.e., the ratio of target mass loss to mass of impinging particles, was observed to rapidly diminish.

Two-Phase Plume Impingement Effects

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The results of an experimental study to determine particle impingement forces and damage produced on flat plate models located at several angles of impingement in a controlled two phase flow are reported. Tests were conducted with a two phase, supersonic wind tunnel using helium carrier gas and micron-sized aluminum oxide particles accelerated to velocities ranging from 1300 to 2300 m/sec. The particle mass flux incident on the target ranged from 0.4 to 2.6 g/cm^2 sec which corresponds to conditions typical of the near field of solid-propellant motors. Target materials included stainless steel and several typical ablators. The most significant experimental result was the discovery that, for this range of mass flux, a debris layer formed immediately ahead of the target, partially shielding it from subsequent impact by oncoming particles. The test results, which were similar for all target materials, showed further that the impact debris was comprised primarily of spent projectile material. While a large fraction of the incident particle momentum diffused through the layer and was transferred to the target, a significant fraction of the incident particle kinetic energy was absorbed by the impact debris with a corresponding decrease in target damage. The latter effect was accentuated with increasing particle flux where relative target damage, i.e., the ratio of target mass loss to mass of impinging particles, was observed to rapidly diminish.

Introduction

DURING high-altitude operation of solid-propellant rockets, the exhaust flow from the rocket nozzle undergoes a large expansion and the resulting two-phase plume occupies a large volume in space. As a consequence, nearby vehicles which pass through the plume may be subjected to forces and moments which can seriously alter their flight characteristics. Depending on the local properties of the plume, these forces may be due to the gas flow around the

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