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EXPANDABLE GRAPHITE EFFECT ON SOLID PROPELLANT COMBUSTION

Abstract

This paper presents an investigation on a novel method for manipulating and controlling the burning of solid propellants by expandable graphite additive. Expandable graphite (EG) is a form of intercalated graphite. At elevated temperature it undergoes an increase in volume, forming elongated strings/fibers many folds longer than the original particles/flakes. When added in the matrix of a solid propellant, this property can result in different effects, sometime contradicting. On one hand the fibers forming and accumulating on the surface may act as a flame retardant, reducing and even extinguishing the propellant combustion. On the other hand the fibers protruding into the hot flame can act as an efficient heat conduction medium, increasing the propellant burning rate. Furthermore, the swelling effect at the surface layer may increase the effective surface area, hence further increasing the effective burning rate. Expandable graphite is available in different sizes (typically 100-400 micrometer) and exhibits different temperatures of onset of expansion. Our investigation revealed that selecting the appropriate EG type and fraction, one can control the burning rate. Adding up to 5 percent of EG with temperature of onset of expansion of 200-230C, revealed 2-folds and more increase in the burning rate of solid polymeric fuels. Furthermore, high-speed video photography showed outstanding and detailed dynamics of EG fibers protruding from the fuel matrix and growing at the burning surface. Using this EG type in ammonium perchlorate based solid propellants showed an increase in burning rate for small fractions of EG and a tendency to reduce burning rate at EG fractions higher than 3 percent. The application of other types of EG demonstrated substantial effect on the solid propellant combustion over a broad range of mass fractions. The paper includes a parametric investigation of the effect of EG fraction and type on the burning rate and surface phenomena, presenting empirical correlations and relating the findings to theoretical aspects. Movies and pictures from video recording (including high speed) of the burning surface are presented as well. The conclusion is that the use of expandable graphite is a significant novel means that can be fitted to control the burning of solid propellants.