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Theoretical analysis of ammonium-perchlorate based composite propellants containing small size particles of boron

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Abstract

One of the main goals for the scientific/ military rocket industry is to increase the operational burning time, thus the specific impulse. New homogeneous and heterogeneous propellants were tested and metallic fuels were added in the mixture to obtain best performance. To study heterogeneous propellant, containing large amount of fine boron and ammonium perchlorate, it is appropriate to estimate the combustion products to evaluate/obtain the values of the specific impulse, density, Mach number and mass flow of the mixture. Several composite propellant mixtures, ammonium perchlorate, nitramides (RDX – Cyclotrimethylene trinitramide), were defined with or without addiction of small particles of Boron and modeled. The energetic properties of boron and progress of boron particles on the burning surface of the ammonium perchlorate based composite propellants was modeled used a numerical algorithm. This paper reports the analysis of the influence of boron in the performance parameters for ammonium perchlorate based composite propellants.

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Keywords: Propellant; RDX; rocket engine; specific impulse

1. Introduction

The aerospace industry is always looking for new energetic materials to use as solid rocket propellants. One of the nowadays trends to improve solid propellants is to introduce metallic fuels on the grain. There has been a need

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for development of new and improved binders and metal fuels to increase the specific impulse, such as aluminum [1] and titanium [2].

Nomenclature

Ai	molar concentration of i species
C_p	Specific heat at constant pressure (J/kg.K)
K	Equilíbrium constant
N	Number of moles
P	Pressure (Pa)
R	Gas constant (J/mole.K)
t	Time (s)
T	Temperature (K)
V	Volume (m^3)
M	Molecular weight (g/mole)
$\Delta G0$	Gibbs free energy (J/mol.K)
ΔH	Molar enthalpy (J/mol)
Φ_S	Stoichiometric mixture ratio

Another known fact about solid propellants is that the specific impulse increases when traditional aluminum powders are changed into nano aluminum [3]. Several authors had studied the effects of the mixture of thin and ultra-thin aluminum and titanium [4-10].

Babuk et al. [3] studied the effect on nano aluminum as propellant for rocket motors and concluded that the nano aluminum appreciably influences the burning rate of the propellant.

Stephens and Petersen [2], determined parameters of the flame stabilization and sensitivity of the flame, having concluded that titanium was the best stabilizer.

Arkhipov et al. [11], observed the effect of ultra-fine aluminum in solid propellants at sub-atmospheric pressures, and they concluded that the dual oxidizer AP/RDX has better performance at the higher ranges of sub-atmospheric pressures due to the influence of aluminum. Promising propellants contains a double-based oxidant ammonium perchlorate and nitramides (RDX and HMX) and up to 20% aluminum powder. The partial exchange of AP by HMX/RDX increases the specific impulse and reduces the danger of environmental release of hydrogen chloride present in the combustion products to the atmosphere. The burning rate is influenced by the aluminum particle size.

Li et al. [12] conducted a study that characterized solid propellants thermochemical characteristics as well as the behavior of the combustion in case of nitramides and found that the composite propellant which had metal fuel in the matrix generated a superior performance unlike those who lacked metal fuel.

Ao et al. [13] studied the ignition kinetics of Boron in primary combustion products. The experimental results show that the ignition time of boron particles in primary combustion products was 20 ~ 30 ms under 1673-1873 K. It was verified that the boron surface was coated with carbon particles, the boron particle size and the boron oxide layer thickness increases.

Hsieh et al. [14] studied combustion characteristics of boron/poly (BAMO/NMMO) fuel rich solid propellants for solid-fuel scramjets. Vigorous pyrolysis characteristics for dispersing boron particles from surface reaction zones into the main reaction zone was verified. Burning rates of boron/poly (BAMO/NMMO) fuel rich propellants were found to depend strongly upon boron weight percentage and pressure.

Liu et al. [15] analyzed the effect of magnesium on the burning characteristics of boron particles, it was concluded that both flames exhibit the same type of flame. It was verified that the boron combustion increases with increasing magnesium addition. The mixture shows the maximum boron combustion efficiency of 64.2%.

Chen et al. [16] analyzed an ignition and combustion model of a single boron particle for ramjet engines. Effects of gas temperature, gas pressure and oxygen mole fraction of boron ignition and combustion were studied and were considered useful for ramjet engine design.