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Procedia Engineering 185 (2017) 91 – 96

Procedia Engineering

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6th Russian-German Conference on Electric Propulsion and Their Application Investigation of a hydroxylammonium nitrate thermocatalytic thruster on "green propellant"

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Abstract

A transition from hydrazine to less environmentally hazardous monopropellants with higher specific characteristics is considered to be perspective for thermocatalytic thrusters which are used for spacecraft attitude control and station keeping. Such propellants are commonly named as "green propellants". Hydroxylammonium nitrate can be used as a basis for such a propellant. Hydroxylammonium nitrate-based propellant has a higher density, higher specific impulse and a lower freezing temperature compared to hydrazine. The high combustion temperature of the propellant (above 1800 ^{0}C) and strong oxidation properties of the combustion products impose specific requirements to the thruster design materials used.

A laboratory model of the K100E thruster has been developed. The product operating capability with high dynamic characteristics has been demonstrated.

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Peer-review under responsibility of the scientific committee of the 6th Russian-German Conference on Electric Propulsion and Their Application

Keywords: Green propellant - hydroxylammonium nitrate - thruster - laboratory model

1. Introduction

"Green propellant" is an aqueous solution of a high-energy oxidizer (hydroxylammonium nitrate and others) and a fuel of different composition such as alcohols, glycerin, etc. [1,2]. "Green propellant" has some advantages in a higher density, lower freezing temperature and high specific characteristics. Such mixtures are classified as low-toxic substances, while hydrazine is highly toxic. This is why the use of the "green propellant" as a monopropellant for thermocatalytic thrusters for spacecraft attitude control and station keeping is of interest.

The combustion temperature of such fuels can reach 1800 ^{0}C. Water vapors, carbon dioxide, carbon monoxide and nitrogen are combustion products of the "green propellant". Therefore, exceptional requirements are set for the structural materials which have to be resistant to a high-temperature oxidizing environment. Similar requirements are set on the catalyst which has to ensure the propellant ignition and maintain its burning.

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Peer-review under responsibility of the scientific committee of the 6th Russian-German Conference on Electric Propulsion and Their Application
doi:10.1016/j.proeng.2017.03.297

2. Investigation of "green propellant" on hydroxylammonium nitrate

Hydroxylammonium nitrate was chosen as a basis of the “green propellant”. Fuel and solvent (water) are added in a defined ratio to hydroxylammonium nitrate. The fuel’s energetic properties depend on its basis, however, the output characteristics are highly affected by the water content in the mixture.

Figures 1-2 present the dependence between the specific impulse and combustion temperatures for various fuels.

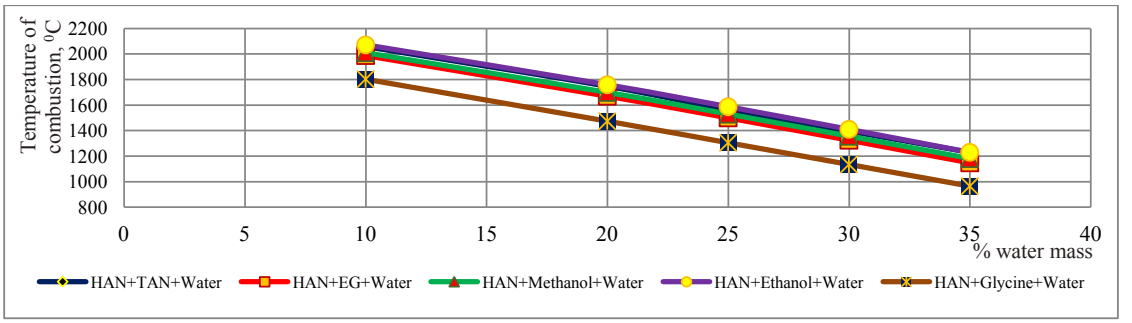

Fig. 1. Fuel combustion temperature versus water mass

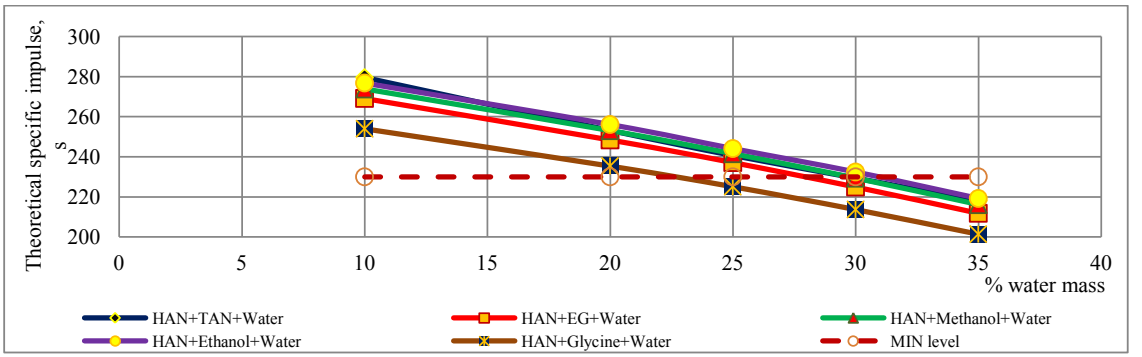

Fig. 2. Theoretical impulse versus water mass

The content of the oxidizer for the mixtures given in Figures 1 – 2 exceeds 50%. Combustion temperature and specific characteristics are reduced by increasing water content.

An optimal water content in the “green fuel” mixture is in the range of (15 – 25) %. In comparison with hydrazine the specific impulse is (10 – 20) % higher and density is (1.2 – 1.4) times higher.

The formula of the “green propellant” based on hydroxylammonium nitrate has a theoretical specific impulse of about 260 s at the expansion factor of 50:1 and a theoretical specific impulse of about 265 s at the expansion factor of 100:1.

Studies of the experimental samples of the developed fuel have demonstrated the following characteristics:

- mixture density is about 1350 kg/m^3;
- freezing temperature is below minus 40 ^{0}C;
- warranty storage period under normal environment conditions is more than 15 years.

The preliminary studies have demonstrated that the fuel can be transported by land, sea and air.

3. Investigation of "green propellant" on hydroxylammonium nitrate

3.1. *Laboratory model of the K100E thruster*

Figure 3 presents the external appearance of the laboratory model of the “K100E” thermocatalytic thruster on “green propellant”.

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