Development of a Hydrogen-Peroxide Rocket-Engine Facility

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Introduction

In recent years, there has been a renewed interest in the use of hydrogen peroxide as an oxidizer in bipropellant liquid rocket engines as well as in hybrid rocket engines.[1-4] The renewed interest is due to the propellant's low toxicity, versatility, and high density-specific-impulse. Its use in hybrid rocket propulsion offers the versatility of operating the engine on a dual mode: a bipropellant mode (hybrid mode) for large thrust requirement and a monopropellant mode for small thrust application. A propulsion unit without a requirement for an external ignition offers a higher system-reliability. Hydrogen peroxide decomposes into superheated steam and oxygen to a temperature of around 1000K, leading to automatic ignition with the solid fuel in the hybrid-rocket mode. Thus, this versatility, with the additional advantage of automatic ignition, makes the hydrogen peroxide an attractive oxidizer. This is considered to be very appealing especially for the application in upper-stage propulsion of a space launch vehicle.

Considering the importance of this "green" and versatile hydrogen peroxide propellant, it is planned at Kyungpook National University to develop a test facility for research in the areas of hydrogen peroxide propulsion. The present paper includes some review information on physical and chemical properties of hydrogen peroxide. Also, it presents the design details of a small thruster. Once this monopropellant thruster is made operational, the future plan will be to realize a facility for research in hybrid rocket engines using hydrogen peroxide.

Properties of Hydrogen Peroxide

Pure, anhydrous hydrogen peroxide is a colorless, syrupy liquid. It blisters the skin and has a metallic taste. Hydrogen peroxide is manufactured in large amounts by the electrolysis of aqueous solutions of sulfuric acid or of potassium bisulfate. It is also prepared by the action of acid on other peroxides, such as those of sodium and barium.[5] Pure solutions of hydrogen peroxide are inherently very stable. When carefully purified and kept in clean

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non-reactive containers, the rate of decomposition is extremely slow. In general, the stability of very pure hydrogen peroxide increases with the concentration. The properties of hydrogen peroxide and the list of materials compatible with hydrogen peroxide are given in Tables 1 and 2 respectively.

Design of Engine

The hydrogen peroxide thruster is to produce about 100 N thrust at a chamber pressure of 0.2 MPa. The thrusting time may be in excess of 5 seconds with a provision of operating the thruster for short pulses of say 1 second duration.

By running the CEC71 code,[7] the calculated theoretical performance values of the thruster are as given in Table 3. Assumptions adopted on performance factors for the design calculations are given in Table 4. The values of these performance factors are estimated from References 8-11. Silver screens will be used for the catalyst bed. The assembly drawing of the thruster is given in Fig. 1.

Table 1 Properties of Hydrogen Peroxide

Properties	Information
Heat of formation	-187.7 MJ/k-mol
Auto-ignition temperature	90%: 210°C (in air), 169°C (in oxygen); 99%: 122°C (in air or oxygen)
Vapor pressure	At 30°C : 90%: 5 mmHg; 98%: 3 mmHg; 99%: 2.8 mm Hg
Boiling point	90%: 141°C; 98-99%: 149°C
Melting point	90%: -11.5°C; 98%: -2.5°; 99%: -1.5°C
Density	At 25°C: 90%: 1387 kg/m^3; 98%: 1431 kg/m^3; 99%: 1437 kg/m^3
Viscosity	Slightly above the viscosity of water (0.00085 kg/m-s)
Incompatible materials leading to violent reaction	Dirt, catalytic metals such as iron, copper, manganese, etc., organics, cyanides and combustibles such as leather, wood, cotton, paper, oils, etc.

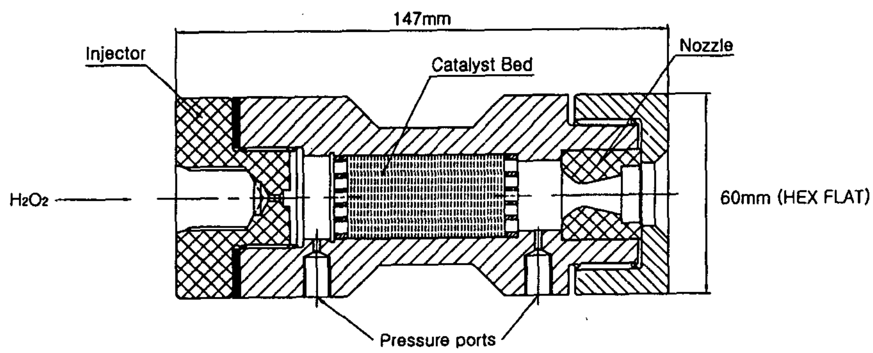

Fig. 1. Hydrogen peroxide thruster of 100 N.

Table 2 Compatible materials for hydrogen peroxide[6]

Material	Applications	Remarks
Aluminum	pipes, fittings, and storage tanks	Pickle thoroughly all components with 35 to 42% nitric acid to remove all surface impurities. Use extra pure aluminum rods with oxyhydrogen flame in gas welding or argon or helium shield in arc welding.
Stainless steels 304, 347, 316, 316Cb	valves, pumps, pipes, fittings, and storage tanks	Less resistant than aluminum. Special varieties of Low carbon content stainless steel (such as 304-ELC, 316-ELC) offer more resistance for corrosion. Pickle all components in nitric acid (35 to 42%) before use.
Tantalum	Structural material	Excellent resistance for corrosion. Very expensive.
Plastics (Teflon, polystyrene, polyethylene, and copolymers such as Tygon and Saran)	Tubing and gasket materials	--

Table 3 Theoretical performance of the hydrogen peroxide thruster

Characteristics	Values
Hydrogen peroxide concentration	0.9
Chamber pressure (MPa)	0.2
Adiabatic flame temperature (K)	1029
Molecular mass of combustion products (kg/k-mol)	22.1
Ratio of specific heats (chamber)	1.26
Characteristic velocity (m/s)	940
Nozzle pressure ratio	15
Thrust coefficient	1.338

Table 4 Performance factors assumed for the thruster design

Performance factor	Value
c* efficiency	0.9
Quality factor on thrust coefficient	0.95
Catalyst bed loading (mass flux of propellant through catalyst bed) (kg/m^2-s)	200
Average residence time in the catalyst bed (ms)	1.5

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