100N H_2O_2 Monopropellant 로켓 엔진의 개발

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Development of a Hydrogen-Peroxide Rocket Engine of 100N Thrust

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ABSTRACT

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. This is because hydrogen peroxide is a propellant of low toxicity and enhanced versatility. The present paper details the features of the designed engine of 100N thrust and its facility. Also explained is the arrangement of the distillation unit to be used to prepare rocket-grade hydrogen-peroxide propellant. Results of the simulated "cold" tests are presented.

Key Words : hydrogen peroxide(H_2O_2), monopropellant rocket engine, distillation unit

1. INTRODUCTION

In recent years, there has been a renewed interest in the use of hydrogen peroxide (H_2O_2) as an oxidizer in bipropellant liquid rocket engines as well as in hybrid rocket engines.[1-4] This renewed interest is because of the growing importance in using propellants of low toxicity and enhanced versatility. H_2O_2 is a propellant of low toxicity because it decomposes into a mixture of clean superheated-steam and oxygen. The decomposed products are of temperature of around 1000K. Looking at its versatility, the use of H_2O_2 in rocket propulsion offers the facility of operating the engine on a dual mode: a bipropellant mode (either as a bipropellant liquid engine or as a hybrid rocket engine) for a large thrust requirement; and a monopropellant mode for a small thrust application. A propulsion unit without a requirement for a separate ignition unit offers a higher system-reliability. The high-temperature decomposition-products of H_2O_2, containing oxygen, lead to automatic ignition either with a liquid fuel in a bipropellant engine or with a solid fuel in a hybrid-rocket engine. Thus, the versatility with the additional advantage of automatic ignition makes this "green" H_2O_2 an attractive oxidizer.

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Many developmental studies are in progress around the world in adopting H_2O_2 in rocket propulsion. These studies are towards developing H_2O_2-oxidized bipropellant liquid engines (mostly having kerosene as the fuel) and hybrid rocket engines. H_2O_2-oxidized kerosene liquid engines are among the few most-suitable propulsion-systems for reusable launch vehicles. Calculated values indicate that, in comparison with the semi-cryogenic LOX+RP1, the specific impulse of the earth storable H_2O_2+RP1 is less only by about 5%; but its density specific impulse is more by about 20%.[5] This higher density specific impulse will lead to a substantially lighter and more compact propulsion-system for the H_2O_2+RP1 combination.

Considering the importance of this "green" and versatile H_2O_2 propellant, it is planned at Kyungpook National University to develop a test facility for research in the areas of H_2O_2 propulsion. Initially it is intended to develop a small H_2O_2 monopropellant-rocket-engine that delivers a thrust of about 100N. As a next phase, the H_2O_2 decomposition products will form the gaseous oxidizer for the hybrid rocket combustion studies.

The present paper details the design of the test facility and the arrangement for the distillation of rocket grade H_2O_2. The results of the engine tests under simulated conditions are also presented.

2. FACILITIES

2.1 Engine Test Facility

The design of the 100N engine is detailed in Ref. 5. The sketch of the engine and the facility are given in Figs. 1 and 2. The specifications of the engine are given in Table 1.

2.2 Hydrogen Peroxide Distillation Unit

Possibly the main impediment in starting the H_2O_2 based rocket research is the difficulty in getting the rocket grade H_2O_2, say 90 percent or more of concentration. To solve this problem, a distillation unit has been realized and this is shown in Fig. 3.

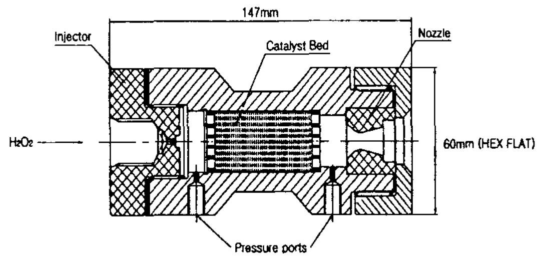

Fig. 1 Hydrogen peroxide engine of 100N thrust.

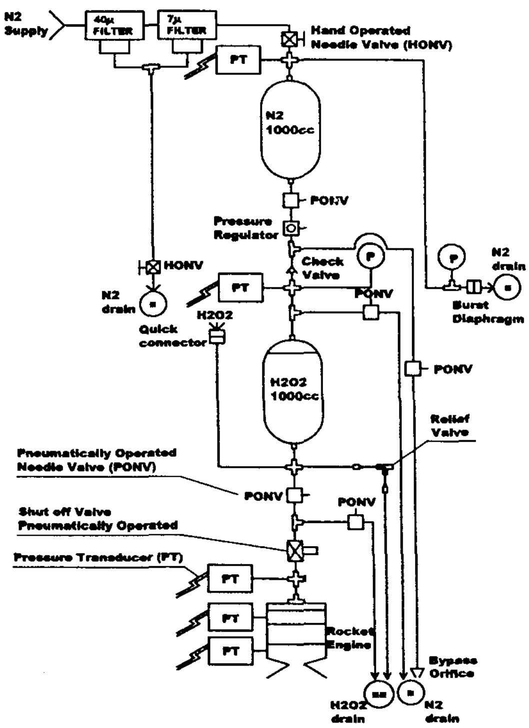

Fig. 2 Hydrogen peroxide rocket engine facility.

Table 1. Specifications of the H_2O_2 engine and its facility.

Engine thrust	100 N
Estimated specific impulse	1110 N-s/kg
Regulated H_2O_2 tank pressure	3.75 MPa
Injector pressure drop	0.70 MPa
Injector orifice diameter	1.8 mm
Nozzle entry stagnation pressure	2.0 MPa
Propellant flow rate	0.090 kg/s
Catalyst (20 mesh pure silver screen) bed-length	55 mm
Approximate thrusting time	12 s
Nozzle throat diameter	7 mm
Nozzle exit diameter	12 mm

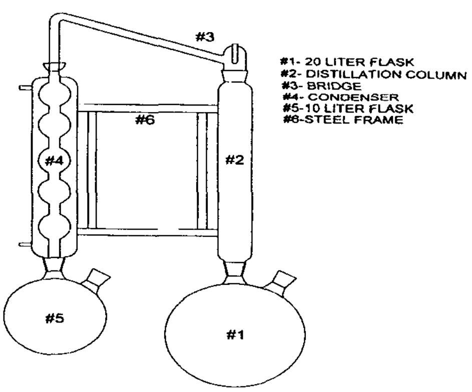

Fig. 3 Hydrogen peroxide distillation unit.

In the 20 liter flask, Fig. 3, low concentration H_2O_2 solution is stored. The distillation unit is evacuated to a pressure of about 100mm of mercury. The 20 liter flask is heated to a temperature around 70 degrees Celsius. The H_2O_2 solution in the 20 liter flask will start boiling and the water contained in it will evaporate to get condensed in the 10 liter flask. Thus the concentration of the sample in the 20 liter flask keeps increasing with time. Cold water is circulated in the condenser for the easy condensation of the water vapor. At any time, the concentration of the H_2O_2 in the 20 liter flask can be found from the known initial concentration of H_2O_2 solution and its initial volume, and the volume of the water condensed in the 10 liter flask. Once the required concentration is reached in the 20 liter flask, the heating is stopped. After the unit gets cooled to ambient temperature, the vacuum is released. The concentrated H_2O_2-solution from the 20 liter flask is collected. The exact concentration of H_2O_2 in the solution is evaluated. If found at the desired level, the solution is stored for the use in the rocket.

The industrial grade H_2O_2 of 50 percent concentration and the laboratory reagent grade, a variety purer than the former, of 30 percent concentration are freely available. For the present studies, it is decided to concentrate the laboratory reagent grade to 90 percent concentration.

3. SIMULATED TESTS

3.1 Engine Test

Sufficient safety features have been incorporated by introducing burst diaphragm and relief valve in the test facility, Fig. 2. All the control valves are pneumatically operated. As the pressure regulator of low flow capacity required for the 100N engine was prohibitively expensive, a pressure regulator of high flow capacity (c_v = 0.06) had to be selected and this was made suitable for the 100N engine by adding a bypass orifice.[5] Pressure transducers are fitted at five stations: pressurization tank, propellant tank, upstream of the injector, chamber pressure upstream of the catalyst bed, and downstream of the catalyst bed.

Propellant is filled into the 1000cc H_2O_2-tank through quick connectors. Pressure regulator is set to the required propellant tank pressure. Recording and display of the pressure transducer-readings are initiated. Nitrogen supply is opened and it enters the gas pressurization tank of 1000cc volume after passing through 40- and 7-micron filters. Once the propellant tank pressure is stabilized, shut-off valve is opened to initiate the engine operation. It is planned to run the engine until the propellant is consumed (~12s). Once the propellant is consumed nitrogen-purging automatically follows to cool the engine.

At the present time, the facility has been tested under simulated condition using water or nitrogen. While using nitrogen, the injector orifice and nozzle throat diameters were altered to simulate the engine operation. A typical recording of the simulated test using nitrogen is given in Fig. 4.

3.2 Distillation

Under water-simulated condition, the distillation unit has been operated a few times. Evidently, the initial volume of water taken in the 20 liter flask should be equal to the volume of water collected in the 10 liter flask plus the volume of water remaining in the 20 liter flask. This volume conservation is found to be satisfied with an error below 5 percent. This small error is possibly due to the loss of water-vapor through the vacuum pump.

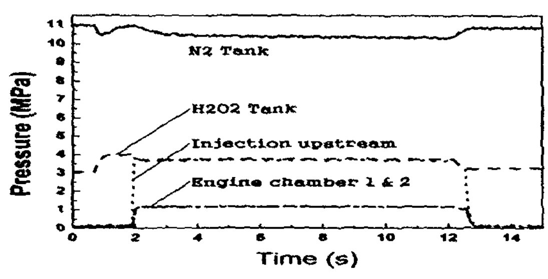

Fig. 4 Engine pressure-recordings of a simulated test using nitrogen.

4. CONCLUDING REMARKS

A H_2O_2 rocket engine facility and a distillation unit to produce concentrated H_2O_2 solution have been realized. Initial "cold" engine-tests and water simulated distillation-runs have been successfully completed. These have given required confidence and experience. "Hot" tests are being planned.

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