

Performance of a Monopropellant Thruster Prototype Using Advanced Hydrogen Peroxide Catalytic Beds

L. Torre,* A. Pasini,† L. Romeo,‡ and A. Cervone§

ALTA SpA, 56121 Pisa, Italy

and

L. d'Agostino¶

University of Pisa, 56126 Pisa, Italy

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The present paper illustrates different firing tests carried out on advanced catalytic beds for hydrogen peroxide decomposition in a new monopropellant thruster prototype designed for easier adjustment and control of the main operational and propulsive parameters. The tests refer to the comparison between a Pt/ α -Al₂O₃ catalyst (named FC-LR-87) and a similar commercially available space propulsion catalyst. Up to 2 kg of 87.5% hydrogen peroxide have been decomposed by a single sample of the FC-LR-87 catalyst. Both steady-state and pulsed firings have been carried out in the same reactor configuration. A fresh sample of the FC-LR-87 catalyst has also been tested at a different bed load. Both the FC-LR-87 and the commercial catalysts showed equivalent propulsive performances, with a slight advantage in favor of the FC-LR-87 catalyst in terms of the c^* and temperature efficiencies (up to 94 and 93%, respectively).

Nomenclature

| | | |
|--------------|---|--|
| A | = | cross-sectional area, m ² |
| A_t | = | throat area, m ² |
| C_F | = | thrust coefficient, |
| c^* | = | characteristic velocity, m/s |
| D | = | catalytic-bed diameter, m |
| D_t | = | throat diameter, m |
| F | = | thrust, N |
| G | = | bed load, kg/m ² s |
| g_o | = | sea level gravity acceleration, m/s ² |
| I_{sp} | = | specific impulse, s |
| L | = | catalytic-bed length, m |
| \dot{m} | = | propellant mass flow rate, kg/s |
| p_a | = | ambient pressure, Pa |
| p_c | = | chamber pressure, Pa |
| R | = | gas constant of the exhaust gases, J/mol K |
| T_{ad} | = | adiabatic decomposition temperature, K |
| T_{amb} | = | ambient temperature, K |
| T_c | = | combustion chamber temperature, K |
| T_{exp} | = | decomposition temperature (experimentally measured), K |
| α | = | conical nozzle half-angle, rad |
| γ | = | specific heat ratio of the exhaust gases, |
| η_{c^*} | = | characteristic velocity efficiency, |

| | | |
|-------------------|---|-------------------------|
| $\eta_{\Delta T}$ | = | temperature efficiency, |
| τ | = | dwelt time, s |

I. Introduction

MONOPROPELLANT propulsion systems are attractive for orbit maintenance and attitude control due to their simplicity, which translates into cost reductions and partially counterbalances their lower specific impulse compared with bipropellant systems. The use of hydrogen peroxide (HP), a nontoxic (or green) monopropellant, offers increased safety and cost-effectiveness in the operation of space propulsion systems, owing to the drastic simplification of the health and safety protection procedures.

High-concentration (or rocket-grade) HP has a long heritage in aerospace propulsion. A wide variety of applications on both manned and unmanned systems can be cited from the 1930s to the present time (Ventura and Garboden [1]). Up to the 1960s a significant amount of work has been carried out by NASA laboratories on HP decomposition and its application to monopropellant rockets (Runckel et al. [2] and Willis [3]). The development of the Shell 405 catalyst and higher-purity hydrazine led to a decreased use of HP due to the superior performance and long-term stability characteristics of hydrazine (Wucherer et al. [4]). In the last decade HP has been receiving a renewed interest for application to cost- and safety-driven systems (Wernimont and Ventura [5] and Scharlemann et al. [6]). Effective operation of HP monopropellant thrusters and gas generators is closely related to the availability of long-lived and reliable catalytic beds, able to provide repetitive performances both in continuous and intermittent operations. The attainment of high decomposition efficiency with reduced bed volumes is a crucial design requirement for HP catalytic reactors in space applications.

A number of different catalyst substrates for HP (including compressed gauzes, pellets, and high-porosity foams [7]) have been employed in the past to achieve these targets. In previous applications, mainly grids, pellets, or beads coated with the catalytic substances have been used, because they maximize the active surface-to-volume ratio. Different metals and metallic oxides deposited on granules or pellets of transition aluminas have been investigated in search for the best catalyst for HP decomposition (Rusek [8], Romeo et al. [9], and Russo Sorge et al. [10]). Furthermore, the influence of stabilizers (such as stannate and pyrophosphate, typically contained in commercial H₂O₂ solutions) on the activity of pellet catalysts has been widely studied (Pirault-Roy et al.

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*Project Manager, Via Gherardesca 5, Ospedaletto; l.torre@alta-space.com. Member AIAA.

†Project Engineer, Via Gherardesca 5, Ospedaletto; Ph.D. Student, Aerospace Engineering Department, University of Pisa; a.pasini@alta-space.com. Member AIAA.

‡Project Engineer, Via Gherardesca 5, Ospedaletto; Ph.D. Student, Aerospace Engineering Department, University of Pisa; l.romeo@alta-space.com. Member AIAA.

§Project Manager; a.cervone@alta-space.com. Member AIAA.

¶Professor, Aerospace Engineering Department; luca.dagostino@ing.unipi.it. Member AIAA.