Development and Testing of Catalytic Beds for Hydrogen Peroxide Decomposition

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In the last years several efforts have been done in order to reduce the environmental impact, the toxicity and the cost of space propulsion systems. The hydrogen peroxide is one of the most interesting Green Propellants mainly because of its low toxicity and high versatility [1]. High concentrated solutions of hydrogen peroxide, so-called HTP (High Test Peroxide, denoting H_2O_2 concentration higher than 85% wt.), can be used both as monopropellant in propulsion systems for satellite attitude control, station keeping, de-orbiting (typically requiring low thrust levels, in the range 1÷20N), and as oxidizer in bipropellant systems for orbit insertion manoeuvres, attitude control of more massive systems, as cargo carrier vehicles (typically requiring thrust level up to 500N).

HTP versatility mostly derives from its capability to release energy by thermal and catalytic decomposition. The aim of the present work is to develop and test catalytic beds able to decompose HTP solutions with high efficiency, high activity and stability on a wide range of operational conditions, high resistance to thermal and mechanical shocks (associated to ignition/shut down cycles), short response time, and low weight and pressure drops.

In order to satisfy the above requirements two configurations, e.g. structured (honeycomb modules) and unstructured (pellets) have been designed, prepared and tested with both vapour and liquid phase HTP solutions. The catalysts consist in a ceramic support (in Yttria-stabilized zirconia) and a catalitically active phase (MnO_x) deposited on it, according to in-house developed preparation procedures. Mn-based catalysts have been widely studied showing promising results [2, 3, 4, 5]. Precipitation and impregnation procedures were developed, both properly modified to obtain high dispersion of the active phase and better reproducibility of the materials. The catalysts were characterized by XRD, N2 adsorption, H2 TPR and SEM/EDS techniques.

H_2O_2 decomposition tests were carried out for the first time in the vapour phase in a flow apparatus. The reactor was properly designed to allow the vaporization and preheating of the feed mixture. Experimental conditions were: T = 200°C, space velocities GHSV = 2.00 and 2.67 s^{-1}, volumetric feed composition: 11% H2O2, 22% H2O, 67% He. The effluent from the reactor was analyzed for O_2 content by a thermal conductivity detector (TCD). From the concentration of O_2, the H_2O_2 conversion was calculated.

The results of H_2O_2 decomposition tests in the vapour phase indicated that the conversion increased with the Mn-content and depended on the shape of the support and on the preparation methods. A strong increase of H_2O_2 conversion with decreasing space velocity was observed on all catalysts and attributed to an autocatalytic effect. A radical mechanism was hypothesized: it was assumed that a reaction between O_2 and Mn species produces radicals that promote the overall reaction.

The isothermal reactor above described allows a preliminary estimation of kinetic data that can be used as base for the design of a propulsive system [6]. Tests on the catalytic beds with non-diluted liquid HTP solutions have been then carried out in order to evaluate the operating life of the catalyst beds, their activity and stability. The test bench, showed in Figure 1 includes the catalyst chamber (i.e. the catalytic bed, the case, and the case support), the injector module, the feeding system and the data acquisition system. The catalyst chamber has several lateral holes for the thermocouples. All the test-bench components are in AISI316 stainless steel. The thermocouples measure the stream temperature in the catalytic bed, allowing an estimation of the catalytic efficiency: the higher is the temperature, the higher is the H_2O_2 dissociation. A parametric analysis has been conducted in order to quantify the influence of the geometry of the catalytic beds (structured and unstructured) on the decomposition efficiency, the start-up characteristics and the operating life.

The results has also been compared with those obtained in the past on structured reactors prepared and used in the frame of GRASP program [7].

Figure 1. Test bench details for catalyst testing

References

[1] Scharlemann C., 2010. GRASP- A European Effort to Investigate Green Propellants for Space Application. *Space Propulsion 2010*

[2] Bonifacio S., 2006. Analysis and Design of a Multi-Phase Catalytic Reactor for the Decomposition of Hydrogen Peroxide in Space Propulsive Systems. PhD Thesis. Università degli Studi di Napoli Federico II, Facoltà di Ingegneria

[3] Bonifacio S. and Russo Sorge A., 2006. Modelling Hydrogen Peroxide Decomposition in Monolithic Beds. In: *European Space Agency Special Publication ESA-SP-635*

[4] Turco M., Bagnasco G., Russo Sorge A., 2005. Manganese oxide on pure and stabilized zirconia catalysts for decomposition of hydrogen peroxide for propulsive application. *Chemical Engineering Transactions* 39-44

[5] J.Knozinger, G.Ertl, J.Weitkamp, Preparation of Solid Catalysts.Editor: Wiley-VCH Verlag GmbH

[6] S. Bonifacio, G. Festa and A. Russo Sorge, Experimental Assessment of Hydrogen Peroxide Decomposition in a Monopropellant Thruster, International Journal of Energetic Materials and Chemical Propulsion, 10 (6): 497-522 (2011)

[7] https://www.grasp-fp7.eu/grasp/.