Green Propulsion: Catalysts for FP7 Project GRASP

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The GRASP Project

The FP7 funded project GRASP (GReen Advanced Space Propulsion) investigated the issue of Green Propulsion and the possibility of replacing presently used toxic hydrazine propellant by Green Propellants. Within the GRASP project, eleven entities from seven European countries were cooperating for three years. Several propellant candidates have been proposed associated with new catalysts and catalyst supports based mainly on cellular ceramics.

New tools were designed and developed allowing the evaluation of the couple propellant-catalyst in real working conditions. Significant progresses in catalyst development and propulsion system have been achieved. Monolithic catalysts have demonstrated high activity for decomposition of different propellants.

Catalytic ignition of propellants

The catalytic ignition of propellant represents a very simple and robust subsystem with numerous restart possibilities. Figure 1 presents the scheme of a monopropellant engine using a remote controlled valve, an injector and a catalyst bed.

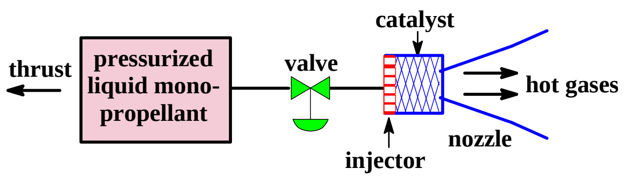

Figure 1. Scheme of a monopropellant engine.

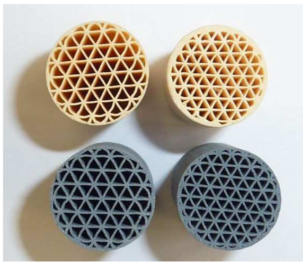

Figure 2. Honeycomb supports with triangular channels; cordierite (top), SiC (bottom); 400 cpsi (left), 600 cpsi (right).

The catalyst must be thermally and mechanically stable in very harsh operating conditions (thermal and pressure shocks), able to trigger the decomposition reaction at low temperature (room temperature) and suffer long term use (more than 15 years). The current challenge is to find and develop an adequate catalyst for a given propellant and we propose to substitute the classical alumina pellets used as supports for hydrazine decomposition by cellular ceramic like honeycombs or foams; the advantages of cellular ceramics are numerous: low pressure drop, good mechanical properties and thermal stability, resistance to thermal shocks, low thermal expansion coefficient and the large heritage from cleaning of car exhaust gas.

The propellants under investigation were (i) concentrated hydrogen peroxide (87.5 wt.-%) or (ii) different blends based on energetic ionic liquids like HAN (hydroxylammonium nitrate $[NH_3OH]^+[NO_3]^-$), ADN (ammonium dinitramide $[NH_4]^+[N(NO_2)_2]^-$) or AN (ammonium nitrate) [2].

Preparation of catalysts

More than 300 catalysts have been prepared and sorted in about 40 sets for the decomposition of the different propellants. The parameters taken into account for the support manufacturing and the catalyst preparation are:

- comparison of pellets, honeycomb monoliths and foams;

- comparison of square channels and triangular channels for monoliths;
- comparison of two channel densities: 400 and 600 cpsi (channel per square inch);
- comparison of support nature: γ-alumina, cordierite ($2MgO•2Al_2O_3•5SiO_2$) and SiC;
- comparison of different washcoat procedures;
- comparison of different active phases: Pt, MnO_x, Pt-Cu, Pt-Zn;

The cellular ceramics have been manufactured and delivered by company CTI (Céramiques Techniques Industrielles, Technical and Industrial Ceramics, Salindres, France) [3]. Typical examples of monolith supports with triangular channels are presented in Figure 2.

Catalyst characterization and evaluation

The catalysts have been characterized using X-ray diffraction, scanning electron microscopy, transmission electron microscopy, thermal analysis, nitrogen physisorption for textural properties. In the case of monoliths, dedicated tools have been developed to perform the analysis. The different samples have been evaluated at the lab level in batch constant volume reactor and in dynamic reactor coupled with online mass spectroscopy analysis. They have also been tested in real working conditions in EBB (elegant breadboard) and in demonstrator in order to proof the possibility to replace hydrazine by green propellants and to use new cellular ceramic as catalyst supports. Different examples of green propellants and associated catalysts will be presented and discussed.

Conclusions

FP7 project GRASP has established a large data base with regard to green propellants including material properties, toxicity assessment, and potential applications. Significant progresses in many areas such as simulations, catalyst development and propulsion system developments have been achieved. Monolithic catalysts have demonstrated high activity for decomposition of different propellants. GRASP has build up a knowledge base with which industry can make informed decisions how to embarge on a transition towards non-toxic propellants.

References

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