Using Composite Material for Hybrid Propulsion Systems in Ballistic Experimental Rockets

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In order to reach high altitudes and top velocities with ballistic experimental rockets two elements are required: 1) a lightweight launcher structure and 2) an efficient propulsion system.

On the one hand it is a state of art technology to achieving 1) by utilizing fiber-reinforced composite materials to construct optimized launcher chasses. On the other hand 2) up to now is mostly achieved by using rocket engines based on a metallic lightweight design, due to heavy systems requirements and production restraints.

In the course of the project HyCOMET-1, conducted by the University of Applied Sciences Augsburg and described in the following, the use of fiber-reinforced composite material for propulsion systems is investigated. Due to the extensive thermal, pressure and structural load requirements of this subsystem this materials family are a promising solution to achieving a higher lift-off capacity and a better mass balance within the launchers.

Background

HyCOMET-1 is part of the STERN program by the German Aero-Space Agency (DLR). STERN's main goal is the support and improvement of the academic education in the fields of launch vehicle and propulsion systems design. German university projects dealing with the development and design of ballistic sounding rockets are promoted and financially supported with this program.

HyCOMET-1 (Hybrid Composite Experimental Rocket) is funded by the DLR project code 50RL1257 since November 2012.

Based on a long-ranging knowledge heritage of and experience with designing and utilizing fiber-reinforced composite materials at the University of Applied Sciences Augsburg HyCOMET-1 puts its main scientific focus on the development of lightweight rocket propulsion systems with innovative composite material technologies.

The HyCOMET-1 propulsion system is laid out as a hybrid rocket engine with a two-component-propellant, each component being stored at a different physical state. The oxidizer is provided in liquid and the fuel in solid state. As oxidizer liquid N_2O (nitrous oxide) and as fuel a polyethylene compound or HTPB will be used.

Major advantage in using this combination is that both components can be stored and handled at low risk, as they do not react with the environment or themselves at laboratory conditions.

Project Focus

Key components of such an engine design are the pressurized oxidizer tank (a), the piping and valve system (b), the combustion chamber including the solid fuel (c) and the rocket engine nozzle (d) [1].

Using fiber-reinforced composite materials for (a) and (d) is state of art and a well-established technology in industrial applications. Different composite materials are used for (a) and (d) representing the varied mechanical requirements. Due to relatively low thermal loads and high impermeability requirements in case of (a) polymer-based composites are used. In case of (d) due to high thermal loads ceramic-based composites are utilized [2].

For the small experimental rockets as described here these two technological solutions for (a) and (d) have not been utilized due to issues with manufacturing, size, and cost. In HyCOMET-1 new ways of production will be explored to implement these solutions for small experimental rockets.

Implementing the combustion chamber (c) in fiber-reinforced composites HyCOMET-1 is following an innovative approach. By designing the chamber as a multilayer construction of different composite materials the multiple challenges of thermal, structural, and pressure load, as well as impermeability requirements are approached.

Project Design

The development of HyCOMET-1 takes place in two major steps. First an engineering model (EM) of the rocket engine is designed and built. It will run in zero level conditions mounted on a horizontal test bench. Tests with this EM will be used to gather data on process parameters and material behaviors during working conditions of the engine.

Secondly a flight model (FM) will be developed based on the evaluation of the experiments with the

EM. The FM then be tested in laboratory conditions and verified during a flight campaign at ESRANGE in Kiruna in Summer 2015.

REFERENCES

[1] R. Schmucker "Hybridraketentriebwerke: Eine Einführung in theoretische und technische Probleme" *Goldmann Verlag*, 1972

[2] H. Schürmann "Konstruieren mit Faser-Kunststoff-Verbunden" *Springer*, 2005