Overview on Gel Propulsion Activities at DLR Institute of Space Propulsion

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Abstract

A growing interest in gelled fuels, propellants or propellant combinations for rocket and ramjet propulsion applications can be observed worldwide in the last two decades because of their safety and performance benefits. Gelled propellants can be throttled like liquid propellants but can be handled simply and safely like solid propellants so that they combine major advantages of the liquid and the solid propulsion systems.

Since the year 2000 detailed research and pre-development work on gel propulsion for rockets and ramjets has been conducted at the DLR Institute for Space Propulsion at Lampoldshausen test site. The here proposed publication will give a detailed overview about the work conducted.

The three main test facilities, used respectively to conduct spray tests and combustion tests under ramjet- and rocket-like conditions will be described, as well as the instrumentation used for the rheological characterization of the gels.

In this abstract only a short view of the themes and the obtained results can be given due to limited space.

One of the main results obtained in the characterization of the physical and rheological properties of gels is the formulation of a new constitutive equation, the Herschel-Bulkley-Extended (HBE) law, that describe the dependency of shear viscosity on the shear rate. Based on this law a Generalized Reynolds number has been defined. The influences of the HBE parameters on the velocity profile and on the transition laminar-turbulent have been studied in detail.

Also the atomization of gel propellants has been investigated. The results have been summarized in a Regime diagram, showing the influence of various non-dimensional numbers of the spray structure. The influence of injection velocity, injector geometry and kind of gel on the diameter of the droplets has been characterized. Another significant result obtained is the determination of the influence of viscoelasticity on the formation of thread-like structures during the injection instead of droplets.

The combustion of gel fuels and propellants has also been studied. In particular the study under ramjet relevant conditions has been focused on the influence of metal particles on the combustion process. The combustion behaviors of gels containing micro- and nano-sized

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particles have been compared. The combustion tests conducted under rocket conditions have been focused on the determination of the range of operating condition allowing a stable condition. This research has been conducted varying various parameters as combustion chamber length, injector type and propellant mass flow rate.

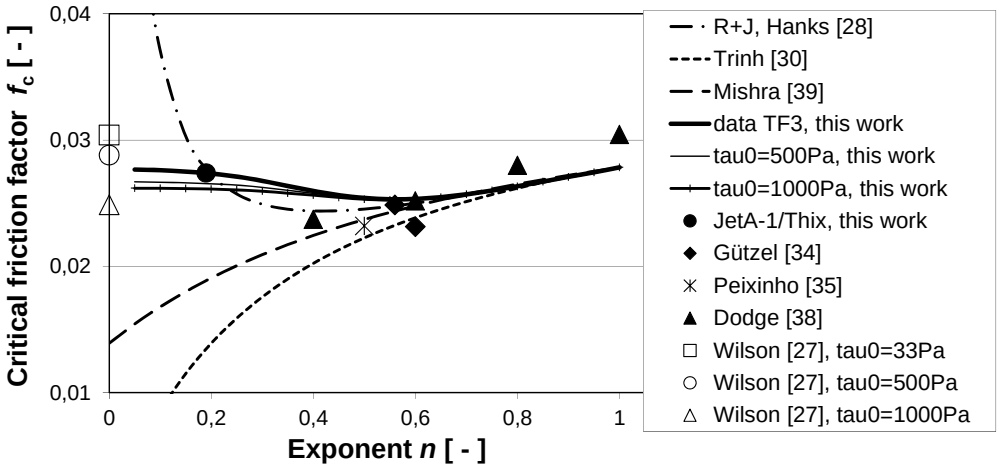

Fig. 1: Critical Darcy friction factor in dependence upon the HBE exponent *n*. Comparison of theoretical approaches and experimental results.

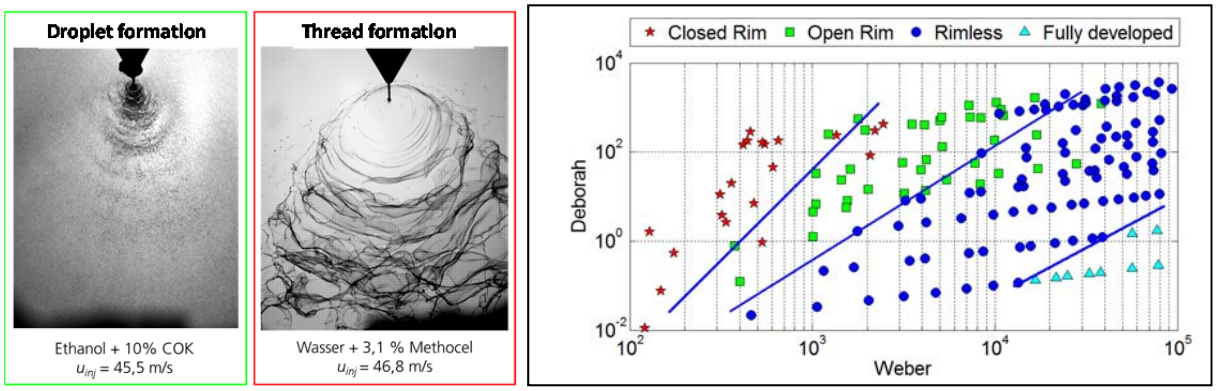

Fig. 2: Left: shadowgraph images of two gels with different breakup behavior, with formatin of threads or droplets, Right: We-De-diagram of Boger fluids.

Fig. 3: Test run of a gel model rocket combustor at M11 test complex at DLR at Lampoldshausen test site