Lehrstuhl für
Aerodynamik und
Strömungsmechanik

Term paper/master's thesis
Wall roughness modeling under transcritical conditions
(theoretical/simulative)

Liquid Rocket Engines (LRE) face extreme thermal conditions during the operation time. High combustion temperatures up to 3600 K combined with a high combustion chamber pressure up to 20 MPa imply an effective cooling system. A regenerative cooling system uses the cryogenic propellant for structural cooling by routing the the coolant through small cooling channels within the combustion chamber wall (fig. 1). After that, the propellant together with the cryogenic oxidizer is injected into the combustion chamber.
The prediction of heat transfer at the combustion chamber wall is a crucial for performance as well as for safety reasons and is affected by many factors, as for example the cooling channel roughness.

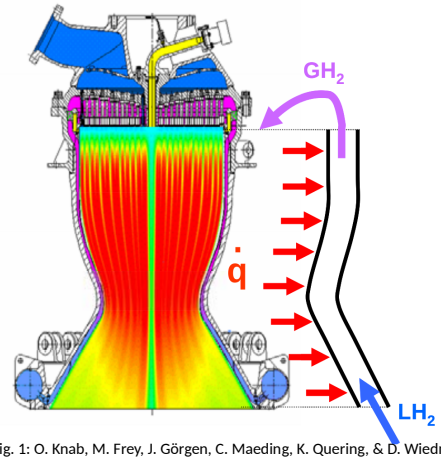

Fig. 1: O. Knab, M. Frey, J. Görgen, C. Maeding, K. Quering, & D. Wiedmann. "Progress in Combustion and Heat Transfer Modelling in Rocket Thrust Chamber Applied Engineering". In: 45th AIAA/ASME/SAE/ASEE Joint Propulsion Conference & Exhibit. American Institute of Aeronautics & Astronautics, 2009.

In order to study the effects of roughness on the heat transfer and the flow dynamics CFD simulations are a powerful tool. Figure 2 shows a mean velocity shift compared to a smooth wall due to a momentum deficit which depends on the roughness height. These results are obtained using our in-house code CATUM, which solves the compressible Navier-Stokes equations using a LES approach. Three different roughness models are already implemented in a wall model that is applied in the near wall area. All three models are in good agreement with ideal gas experimental data but they are failing in flows with strong property variations (real gas effects).

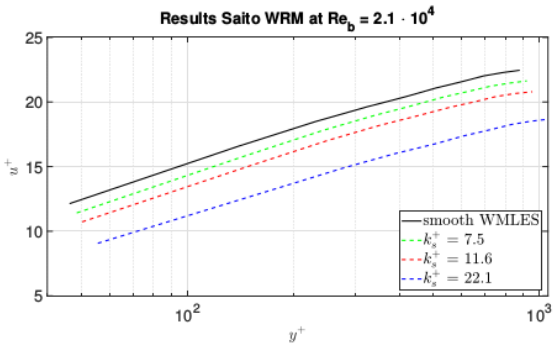

Fig. 2: Mean velocity profile comparison between a smooth wall and the roughness model of Saito for different sand grain roughnesses.

The work comprises the following steps:

- Familiarization with in-house code CATUM
- Performance analysis of the already implemented roughness methods
- Improvement or development of a new roughness models, considering real gas effects.
- Running 2D and 3D simulations with the developed methods.
- Postprocessing and validation.

The final report should be written in English.

Start: from now on (announcement: 05.04.2019)

Requirements:

- Ability to work independently
- Basic knowledge of numerical flow simulation
- Good knowledge of thermodynamics and gasdynamics
- Basic knowledge of Fortran
- Knowledge of linux advantageous

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