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Title

The Impact of Guide Tubes on Flow Separation in Rocket Nozzles

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Abstract

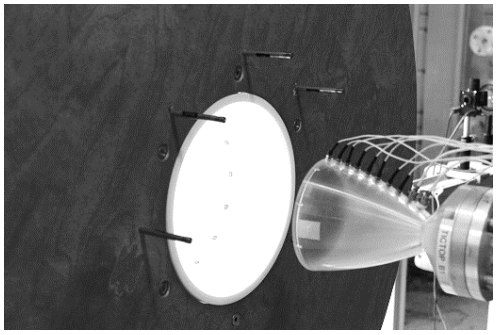
Figure 1, Setup at test facility P6.2.

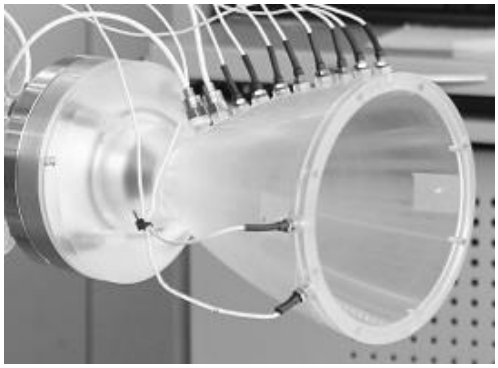
Figure 2, equipped TICTOP B1 nozzle.

The flow within a convergent-divergent rocket nozzle can be over-expanded only to a certain point. Under strongly overexpansion the boundary layer lifts off the nozzle wall and ambient air is sucked into the remaining separated backflow section of the nozzle. For a given nozzle geometry, the position of the flow separation is a function of the gas properties, the total and the ambient pressure. The flow separation leads to undesired side loads stressing the nozzle itself, the rocket engine, the rocket structure and the payload. The knowledge of the separation position is crucial for rocket engine design and determines the maximum possible nozzle length, a deciding factor for the engine performance.
Test facilities and launch pads are typically equipped with a guide tube. Its purpose is the controlled and safe routing of the hot rocket nozzle exhaust gases. Currently its capability to reduce the exhaust jet's noise emission, by injecting a sufficient amount of water, comes more and more into focus. Experimental studies revealed geometrical dependencies as main influence parameters, in particular the ratio of the nozzle exit diameter vs. guide tube inlet diameter and the distance of nozzle exit and guide tube inlet.
In addition, the guide tube induces a throughput that effects the nozzle flow, namely the flow separation during transient start-up and shutdown of the engine. Hence, cold flow subscale tests, where a rocket nozzle in combination with a set of guide tubes (varying in diameter and length) was studied experimentally, were evaluated concerning the flow separation impact.
The evaluation reveals that for nozzle exit to guide tube inlet distances beyond half of the nozzle exit diameter the suction effect has nearly no impact on the flow separation. The suggested conference contribution introduces to the topic (including literature), presents the experimental setup, evaluates the derived data and concludes practical recommendations.