Exhaust System P5.2: Optimizations of Acoustical Attenuation Conditions

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Abstract

The German Aerospace Center’s Institute of Space Propulsion (DLR) in Lampoldshausen organizes tests of liquid rocket propulsion engines, research work and the development and operation of test benches. In the context of the Ariane 6 program DLR is contracted to design and to build the new test facility P5.2 in order to test the A6 upper liquid propulsion module.

This article will deal

1) with the description of the purpose of the P5.2 exhaust system,
2) with its rocket noise reduction technology using water injection,
3) with the acoustical simulation methods used for the prediction of the impact of the sound pressure levels on the upper stage and with the results and consequences of these simulations.

1) The exhaust system is part of the test bench P5.2 and has three main functions: safe and directed deflection of the jet off the engine, cooling-down the jet of hot gases and noise damping both for the surrounding and mainly for the reduction of the sound pressure impact on the upper stage itself. The design of the exhaust system was performed by the DLR engineering. The design process was supported by CFD simulations taking into account the post-combustion of H2 in the test bench and regarding the water spray analysis using the Euler-Lagrange particle model. All these aspects will be presented.

2) The noise reduction mechanism of the guiding tube system is based on water injection into the flow of the Vinci engine of the A6 ULPM. The water injection causes an exchange of mass, heat and momentum between the water droplets and the hot gas jet. Both the kinetic and the thermal energy are lowered. Additional the jet is limited in space by the guiding tube which leads to more reflections of the stream and therefore to a repeatedly treatment of the emitted jet by water. DLR gained knowledge and experience about the noise reduction by water injection with several guiding tubes used at different test benches in the DLR test site and will describe an overview of the various results.

3) The prediction of the impact of the sound pressure levels on the upper stage itself needs the simulations of the sound propagation over the whole frequency range within the P5.2 test facility. This acoustical study was performed by Müller-BBM GmbH applying for frequencies higher than 100 Hz a hybrid method using source image models and ray tracing and for frequencies lower than 100 Hz the finite-element method based on the wave equation. The goal of the simulations was the determination of the sound pressure levels at several measurement points around the surface of the upper liquid propulsion module and the comparison with the acoustical requirements for the upper stage. In order to meet all the requirements over the whole frequency range additional structural measures like noise shielding elements need to be integrated in the test bench P5.2. The methods, execution, results and consequences of the acoustical study will be presented within this paper.