Isolated jet noise cross-comparison in various EU small and mid-size test facilities and geometric far-field

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Benefits of conventional large R/Dj jet noise tests

Any complex yet finite noise source appears like a point source if the observer is positioned very far away. This guideline has been the fundament for acoustic testing of small jet nozzles Dj at large microphone distances R in large test facilities. A ratio of R/Dj =100 has been experimentally determined to fulfil the far-field conditions especially for jet noise - a complex distributed noise source along the engine axis between engine exit and ~10 Dj. The far-field microphone distance comes with the benefit of producing a negligible error when picking just any source reference point in the vicinity of the engine exit in order to apply wind tunnel corrections.

Challenges to master small R/Dj jet noise tests

The wind tunnel tests in the EU project DJINN however were conducted in small and mid-size wind tunnels only. With the far-field benefits being gone, a working solution for microphone placement and correction in small R/Dj tests had to be found.

Having this assignment in mind, individual microphones which are not placed in the geometric far-field are cross-compared against their expected far-field signal. This simple comparison was done knowing full well that there are more sophisticated far-field extrapolation methods using beamforming algorithms.

The following test facilities have contributed their isolated jet noise data for a jet Mach number of Mj=0.6 and a jet diameter of Ø50mm:
CNRS Bruit & Vent, DLR JExTRA, SOTON Doak Lab, VKI JAFAAR. The far field reference data is generated from the SJET model which is based on tests at NASA GLENN, SHJAR.

Data evaluation and analysis

This data can be used to (1) show that it is possible to reproduce very similar jet noise data in different small-scale facilities, if the microphones are positioned exactly at the same position. It does also show (2) that the scaling wrt. the engine exit does not collapse as nicely as it is expected for microphones in the geometric far-field. However, the lower frequencies of the spectrum agree well when (3) the source reference point is shifted to a position 5...8 jet diameters downstream the engine axis.

Hence, for each facility's test, this new source reference point has been determined. Microphone distances were normalized wrt the new source reference point and polar angles recalculated. With these small adjustments, a successful cross-comparison for certain polar angles has been conducted: the low-frequency data collapses very well and with good uncertainty in a 1-2dB band (see Fig.1).

High-frequency data (e.g. above 5-8 kHz for ¼" microphones) requires more post-processing in terms of wind tunnel corrections. While forward arc data collapses well, this is not true for the rear arc: The greatest offsets of small R/Dj experiments to far-field reference data have been found for high frequencies in the rearward arc for polar angles below 60 deg (aft-to-front).

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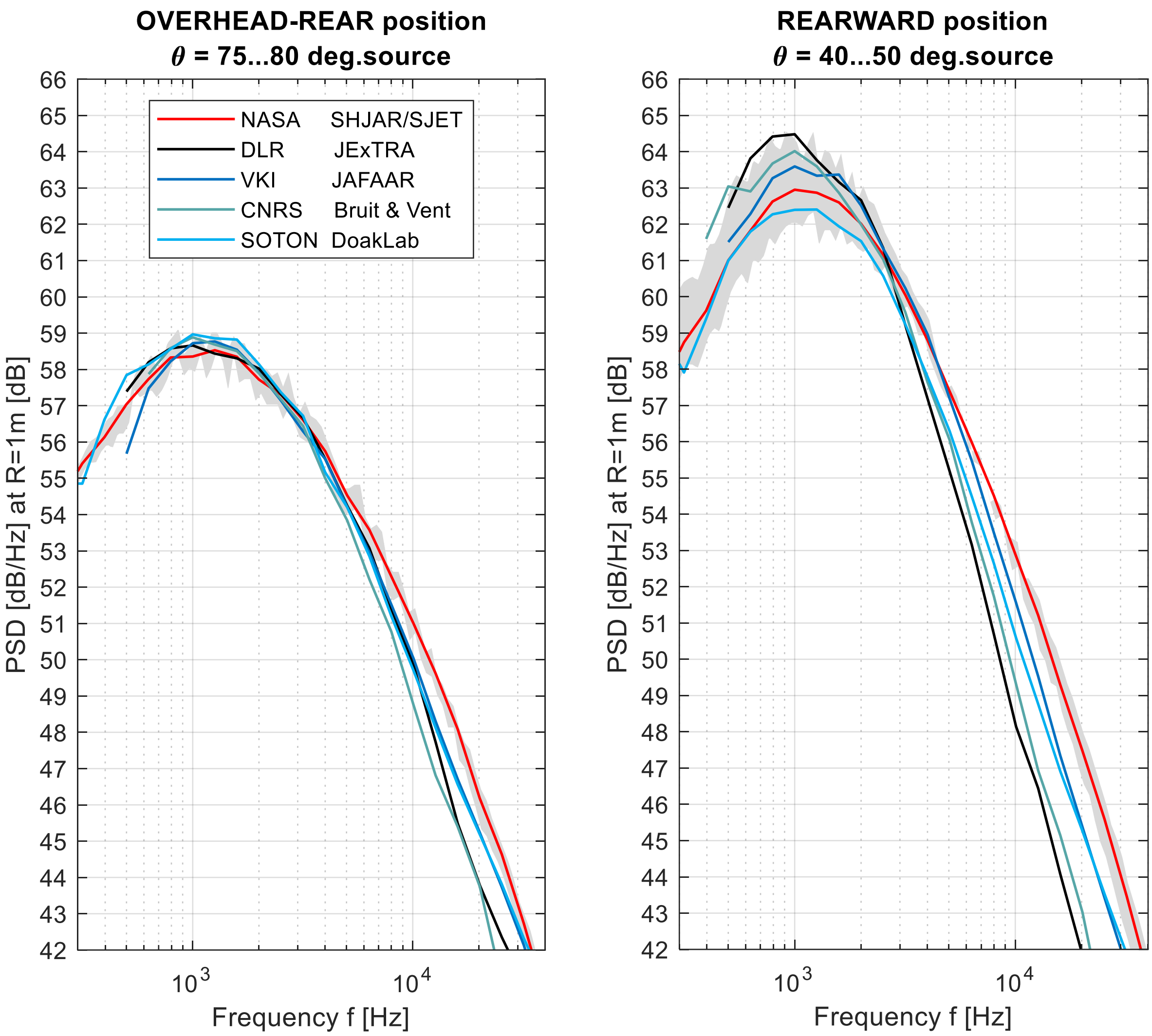

Fig. 1 Jet noise spectra for different facilities at overhead to rear-arc positions.

Conclusion

The main takeaway of this paper is that all facilities deliver good jet noise data. The greatest challenge is how to handle a complex noise source in small R/Dj jet noise tests. The test data is most useful for direct comparison when it is corrected wrt. a few jet diameters downstream the engine axis. Since this position cannot be determined with great certainty, it is wise to keep on stating the conventionally specified coordinates wrt. the engine exit, i.e. a geometrically fix position.

The far-field comparison of individual microphones can be improved by avoiding corrections or improving their precision. Better precision in terms of source position or distribution can be delivered with the help of quick source localization methods. Microphone incidence corrections may be partly avoided by using smaller microphones (0…1dB offset for frequencies up to 7-8kHz for 1/4” microphones or 16-18 kHz for 1/8” microphones) or advanced microphone installation.