

SUZUKI WIND TUNNEL USED FOR FULL-VEHICLE NOISE SOURCE IDENTIFICATION

The Suzuki name can be seen on a full range of motorcycles, automobiles, outboard motors, and related products and is recognised throughout the world for quality products offering both reliability and originality. And Suzuki is always creating advanced 'value-packed products' for their customers. So, in 2006, as one of their investments, Suzuki's R&D division built a new "full-scale aero-acoustic wind tunnel" for the study of aerodynamics and reduction of wind noise for their motorcycles and automobiles.

To locate the sources of wind noise on cars, Suzuki needed a noise source identification measurement system that could operate in a wind tunnel where the wind speeds would reach 190 km/h. The system also had to be fast, enhancing productivity, measure the top and side of the vehicle simultaneously, and work at low and high frequencies. So when Brüel&Kjær was approached to make a proposal that would meet Suzuki's requirements for noise source identification, they came up with a solution that combined two measurement methods – Spatial Transformation of Sound Fields (STSF) and Beamforming.

Acoustic Holography – STSF

STSF is a way of measuring a sound field and then predicting how it radiates into space. It uses cross-spectra made between the individual measurement points and one or more reference microphones to produce a sound field map of the noise in the measurement plane coherent to the reference microphones. This measured data is then transformed using near-field acoustic holography algorithms to provide a 3D model of the sound field. This enables a detailed investigation to be made in planes closer to, or further from, the test object than the original measurement plane. Suzuki uses the STSF method for calculating the sound field close to a surface and for frequencies up to 1000 Hz.

Acoustic Imaging – Beamforming

Beamforming is a method of mapping noise sources by differentiating sound levels based upon the direction from which they originate. It can be used for noise mapping from a distance and is particularly suitable for mapping large



The aerodynamic properties of a Suzuki SPLASH are clearly demonstrated in the wind tunnel

Brüel & Kjær has supplied two acoustic arrays to Suzuki for use in their wind tunnel - the half-wheel array shown on the right provides noise source identification data in the vertical plane while the full-wheel array measures noise sources in the horizontal plane over the vehicle



objects – in fact, objects larger than the array itself can be mapped with relatively few channels. The method is quick and a full map can be calculated from a single-shot measurement. It also works at high frequencies. The Brüel & Kjær beamforming solution consists of a numerically optimised array with a powerful PULSE™-based analysis and display package. This combination provides high-quality results, free of the spurious results (ghost images) that commonly affect beamforming measurements. Suzuki uses the beamforming method for identifying noise sources from a distance and at frequencies above 1000 Hz.

The Suzuki Solution

Brüel & Kjær's 282-channel PULSE-based combined STSF and beamforming system for Suzuki includes a 114-channel, full-wheel array for beamforming measurements on the top of the vehicle, a 108-channel, half-wheel array for beamforming measurements on the side, and a 60-channel robot for STSF measurements on

both top and side. The arrays are equipped with Type 4951 microphones and the robot with Type 4944-A microphones.

The full-wheel array is designed for mounting on a supporting frame fixed in the ceiling, including an elevation tool for raising/lowering the array for service and calibration. The half-wheel array is designed so that it can be easily separated into two sections and stored elsewhere. The robot is specially designed for use in the wind tunnel with wind speeds of up to 200 km/h at yaw angles of up to $\pm 10^\circ$. The robot can also be easily dismantled for storage elsewhere.

The Traverse Robot with STSF Microphone Arrays

STSF is used to analyse mid and low frequencies. To make measurements, the car is positioned in the wind tunnel at an angle of 0, 5, and 10 degrees compared to the wind direction, and exposed to wind at speeds up to 190 km/h. The STSF measurement is done using two line arrays of 24 microphones each and 12 reference microphones. One array is placed above the car and one array vertically beside the car. Both arrays are placed on an aerodynamically optimised traverse that can move them along the side of the car to reduce background noise. But still, measuring in strong wind induces heavy independent noise

directly into each array microphone. However, these independent noises are cancelled out by correlation to the reference microphones in the subsequent STSF calculation.

The Beamforming Arrays

Beamforming is used to analyse mid and high frequencies. For the beamforming measurement, the noise is measured using irregular circular microphone arrays placed some distance away from the car – a full-wheel array of 114 microphones is positioned on top of the car and a half-wheel, side-array of 108 microphones is positioned at the side. Both are out of the main wind flow in an area where the wind speed does not exceed 8 m/s (28.8 km/h). The side-array is mounted on wheels allowing it to be moved easily. The top-side array is mounted on a levelling system so that the array can be lowered to the ground for calibration. However, when positioned for measurement it is fixed to the roof to avoid it moving with the wind.

When the measurements have been stored, the maps for the low (200 Hz – 1 kHz) and high (1 kHz – 10 kHz) frequencies are calculated using "off-the-shelf" as well as customised Brüel & Kjær software to combine and analyse the measurements.