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THE CHALLENGE TO IDENTIFY EXTERNAL VEHICLE NOISE

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INTRODUCTION

The internal combustion engine has always been a source of noise. In the early days of the automobile, at the end of the last century, the engine was often exposed and therefore free to radiate noise. The degree of annoyance has varied over many years as the designs changed and the engine was enclosed with more effort being put into shielding the engine compartment.

To some extent the reduction in noise emanating from the power train was incidental to the better designs. More efficient engines and gears has meant less noise.

The increase in ownership and use of the private motor car has spread the acoustic pollution so that more people are effected. The social pressure has lead to the steady reduction in the external noise from automobiles through politically generated legislation.

With the more stringent requirements coming into force in the near future a greater understanding and identification of the various sources making up the external noise are required.

Two aspects of the vehicle development strategy will be considered. That is the drive-by noise in measurements according to ISO R362 (BS 3425) and the source location and modelling on a rolling road.

DRIVE-BY MEASUREMENTS

The forthcoming reductions in the levels as measured according to ISO R362, to meet the EEC Directive, has made the better understanding of the noise profile a major concern. The EEC Directive lays down a dBA level, not be exceeded, during the full acceleration test.

The facts and measurement requirements such as the entry speed, the test length and the location of the microphone are well known.

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When measuring, with an aim to gathering a full noise profile using some vehicle location equipment, the basic test specification in ISO R362 must not be lost sight of. That is for the Maximum A-weighted level to be a true dBA level as measured with a Precision Sound Level Meter. Therefore the analysis equipment must comply with the relevant standard such IEC 651 (BS 5969).

The challenge to identifying the various external noises is to take a full 1/3 Octave spectrum for both sides of the vehicle simultaneously as the vehicle is driven through the prescribed test routine.

A Doppler shifted radar signal is used to detect and measure the speed of the moving object. It is assumed the whole vehicle moves as one unit. From the doppler signal the incremental movement of the vehicle is used to instruct the Dual Channel 1/3 octave analyser to take a series of spectra. The analysis starts at a known vehicle position.

Each of the multi-spectra also contains the true A-weighted sound level as well as the 1/3 octave spectrum.

Further parameters are telemetered from the vehicle, such as engine or wheel rpm, accelerator position and engine temperatures for incorporation in the positional data.

It must be remembered that the sound takes a finite time to reach the measuring microphone. The sound captured in the results table will typically be from a position 0.6 metres earlier than shown at the end of the run. The vehicle speed and engine rpm will be correct. With positional increments of 1/4 metre the telemetered and received sounds will always be more than one sample out.

In the further analysis for the spectral content there are the two frequency areas of interest. There is the higher frequency broad band noise and the engine related noise which is largely tonal in character.

With the real-time speed of analysis available using digital constant percentage filters the engine order noise can be investigated. Both sides of the vehicle can be measured with bandwidths of 1/12 octave up to 2.8 kHz. Specific orders can then be plotted against vehicle position.

To complete the investigations a wide selection of display and comparisons between files have to be incorporated.

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The drive-by testing on an approved test track not only provides performance testing for Homologation but also narrow band analysis under such testing procedures.

The next, or preferably earlier, investigation to reducing vehicle external noise is to determine the noise sources.

NOISE SOURCE LOCATION

The technique of Acoustic Holography as part of the Spatial Transformation of a Sound Field (STSF) gives the automobile designer details of the main sources of noise and the pattern of sound radiation.

The requirement is to measure the amplitude and phase of the signal at a grid of closely spaced points on a plane near the side of a vehicle.

Dependant on the upper frequency of interest the total number of measurement points can run to several thousand. The maximum spacing between each point must be less than half a wavelength of the highest frequency being analysed.

In a practical system a vertical array of microphones is traversed along the vehicle or engine under investigation.

As each measurement takes place with a changed signal a series of reference inputs is used. The cross spectrum from each of the microphones in the array to each of the reference inputs is measured. Therefore at the end of the complete measurement the cross spectra between each of the points on the grid covering the side of the vehicle can be calculated.

The signal coherent with just one of the reference inputs can be used to map the radiating sound field if necessary. So by locating the individual references close to known sources a detailed investigation can be made specific to a particular location. The reference signals can be from a vibration as well as an acoustic transducer.

Having a complete picture of the sound field at a plane close to the vehicle the STSF Program can calculate the sound field at any other plane.

Normally the goal is to map the sound field as it radiates from the side of a vehicle and understand the location of the various sources. As the complete information exists from the measured data of the radiation pattern the far field sound pressure can be calculated at a point. By taking a series of points along a line 7.5 metres from the vehicle centre line a simulated drive-by can be displayed.

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From the transformed sound field modifications to the levels over specific areas can be made. The effect of these changes to the far field pressure can then be measured to show the resultant effective drive-by dBA level.

To ensure that the whole measured grid will provide a complete representation of the sound radiating from the vehicle a process of validation is required.

The measured cross-spectra signals from the references to each point on the grid are used for calculating the sound field. The autospectra at the grid points are stored as part of the measurement phase.

Using the calculated sound field the sound pressures at each of the points is also calculated and compared with the original sound pressures from the autospectra. This will validate the measurement and calculation.

The source locations can be displayed as contour, vector and 3D plots showing the active and reactive intensity. Also the particle velocity and the sound pressure can be plotted. The graphs can be for single frequencies or for a band of frequencies.

CONCLUSIONS

No other existing technique has the same capabilities as the Spatial Transformation of Sound Field System for measuring non-coherent broad-band sound sources without the need for simultaneous measurements.

The facility for the simulation of source attenuation gives the engineer the chance to try various remedies before modifying the vehicle.

The step from the STSF to calculating the sound pressure at a specified point in space leads onto vehicle drive-by testing.