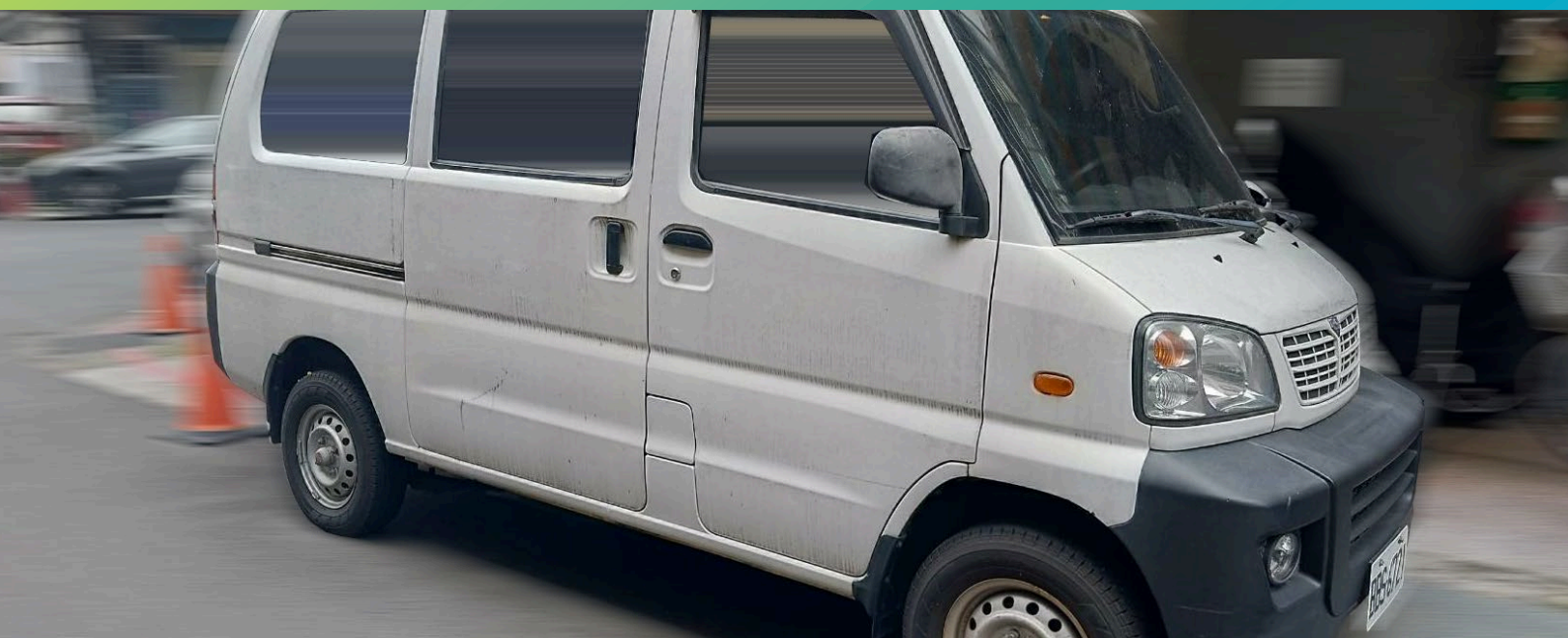**HEXAGON**

Pass noise source estimation and response verification

China Motor Corporation uses Actran to reduce simulation times and extend to higher frequencies

China Motor Corporation has established a simulation process for pass-by noise evaluation of their small truck that allowed them to reduce calculations from 100 hours to just 2 hours and extend the study frequency range to 5000 Hz.

**Based on a presentation by Kuo ZhengXiang**

Background and challenges

Taiwan's Environmental Protection Agency issued the sixth version of pass-by noise regulations in 2018, which reduced the regulatory limits for the acceleration noise of small trucks. It can be seen from the trend of numerical value changes in the first to sixth versions of the regulations that the administration's requirements for the acceleration noise of small trucks have become more and more stringent. This also puts forward higher requirements on the noise index of China Motor Corporation's small trucks. The Automotive NVH team is faced with the challenges of demanding goals, high costs, heavy workload, and impact on profitability.

Phase 6 of noise regulations

In-situ	Acceleration	ASEP
	Constant Speed	

Pass-by noise
ECE regulation No. 51-03

Acceleration to 50 km/h

In the future, the acceleration noise regulations of small trucks will be more stringent as a significant decrease from 71 to 69 dB is envisioned to be applied in 2025.

Regulation phases for pass-by noise in Taiwan

The response of the China Motor Corporation NVH team

China Motor Corporation uses a combination of testing and simulation to deal with the pass-by noise problem.

1. Combination of far/near field acoustic measurement methods to achieve 3D sound source localisation

2. Numerical simulation to analyse the external sound field of pass-by noise
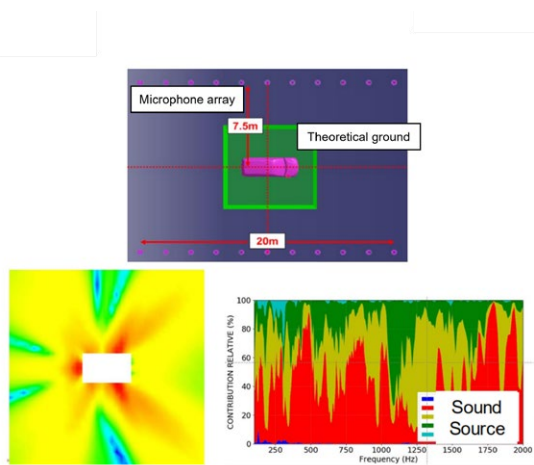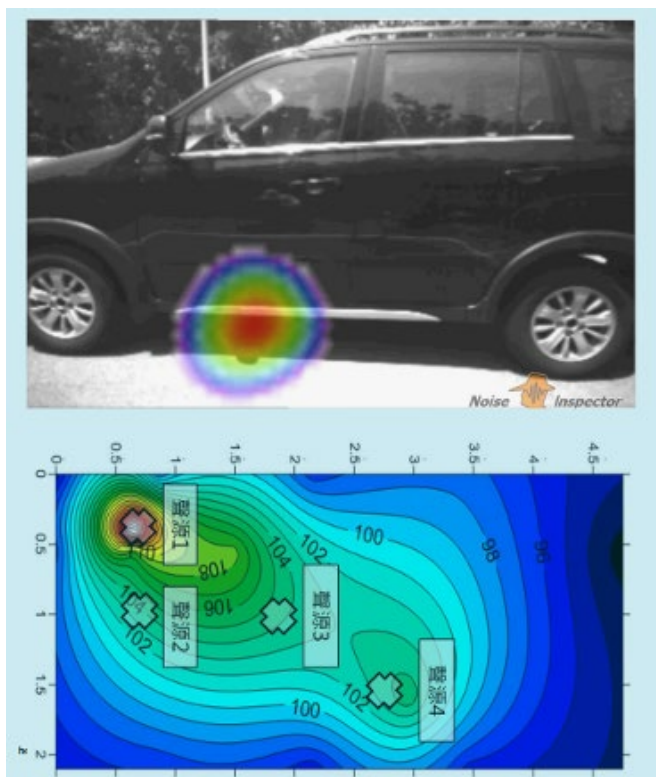
Numerical simulation of the external sound field

Beginning in 2018, China Motor Corporation used the boundary element BEM method to simulate pass-by noise and published an article at the 24th SAE Conference in 2019. The main contribution interval of the actual noise measurement is between 100 and 4000 Hz, but the BEM simulation method cannot reach the highest frequency due to computational efficiency. Even in the frequency range of 100~2000Hz, the solution will take more than 100 hours, and there is an error of up to 9dB from the actual measurement. Therefore, three requirements are proposed for numerical simulation to reduce the solution time, increase the solution bandwidth, and strengthen the accuracy of the solution. In response to demand, China Motor Corporation proposed three methods: 1) finite element FEM technology; 2) high-performance computing (HPC); 3) adaptive grid. Actran perfectly meets these requirements. China Motor Corporation started using Actran for pass-by noise simulation in early 2020. After a short period of time, significant results have been achieved.

		Sequence	Max memory	Time	Single-core equivalent
100-2000-Hz	1 core	Adaptive Mesh Generation	19940 MB	28m 56s	1
		Calculation		5h 59m 0	1
	4 cores multithreaded	Adaptive Mesh Generation	200038 MB	26m 38s	1.086
		Calculation		2h 48m 50s	2.127
	4 cores parallel processing	Adaptive Mesh Generation	76692 MB	12m 31s	2.312
		Calculation		1h 54m 25s	3.139
2000-5000 Hz	1 core	Adaptive Mesh Generation	208155 MB	1h 56m 37s	1
		Calculation		12h 52m 14s	1
	4 cores multithreaded	Adaptive Mesh Generation	213663 MB	1hr 42m 31s	1.138
		Calculation		5h 13m 33s	2.463

First, the solution time is greatly reduced. In the frequency range of 100 to 2000 Hz, it only takes 2 hours to solve the problem, which is significantly more efficient than the original more than 100 hours. The frequency band from 2000Hz to 5000Hz only needs 7 hours of calculation time.

The indirect sound source estimation method is used to calculate the sound source (Source) using the simulated noise transfer function (NTF) and the measured noise (Response) of the near-field microphone.

The NTF is a ninth-order square matrix, and the direct calculation process is very complicated, so a simplification is considered. It is assumed that the sound sources will not interfere with each other, so the coupling term is zero. In this way, the problem can be simplified into 9 one-element equations, and the sound source can be obtained directly.

Comparing the actual measurement results with the Actran simulation result, it can be found that there is only 0.2 dB error, and the accuracy is greatly improved.

Source

NTF calculation with CAE

Measure the SPL

On a microphone in the near field
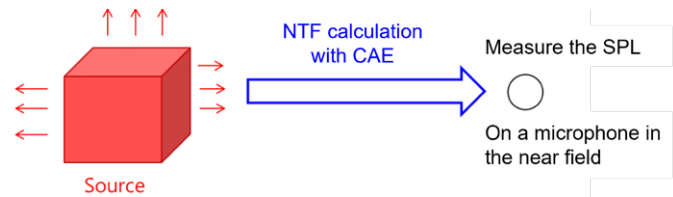
$$NTF \times Source = Response$$

$$\Rightarrow Source = NTF^{-1} \times Response$$

$$NTF \times Source = Response$$

$$\Rightarrow \begin{bmatrix} N_{11} & N_{21} & \cdots & N_{91} \\ N_{12} & N_{22} & & N_{92} \\ \vdots & & \ddots & \vdots \\ N_{19} & N_{29} & \cdots & N_{99} \end{bmatrix}_{9\times9} \times \begin{bmatrix} S_1 \\ S_2 \\ \vdots \\ S_9 \end{bmatrix}_{9\times1} = \begin{bmatrix} R_1 \\ R_2 \\ \vdots \\ R_9 \end{bmatrix}_{9\times1}$$
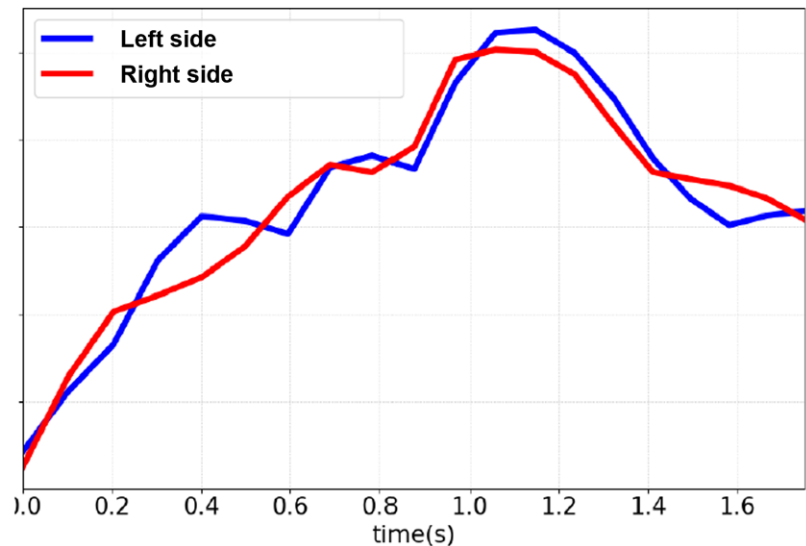
$$\Rightarrow \begin{bmatrix} N_{11} & 0 & \cdots & 0 \\ 0 & N_{22} & & 0 \\ \vdots & & \ddots & \vdots \\ 0 & 0 & \cdots & N_{99} \end{bmatrix}_{9\times9} \times \begin{bmatrix} S_1 \\ S_2 \\ \vdots \\ S_9 \end{bmatrix}_{9\times1} = \begin{bmatrix} R_1 \\ R_2 \\ \vdots \\ R_9 \end{bmatrix}_{9\times1}$$

Verification

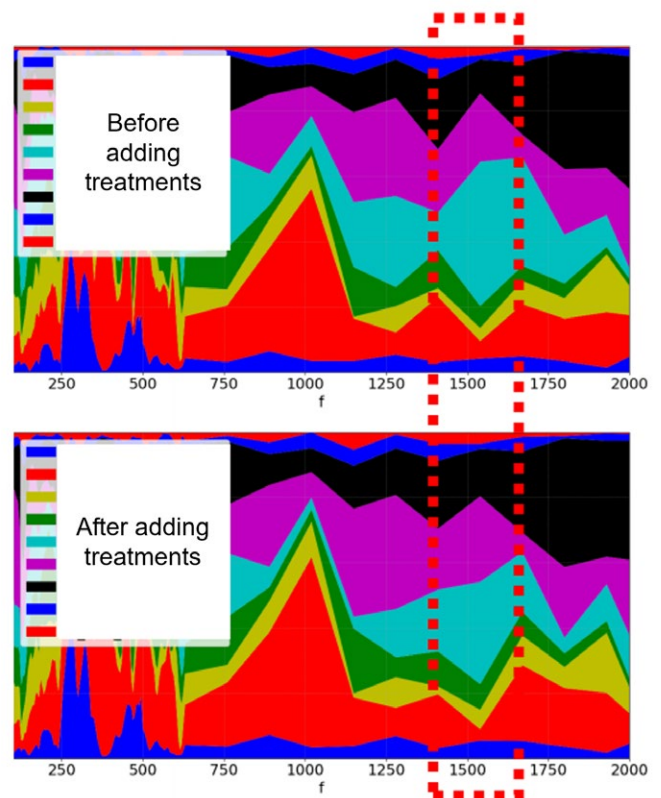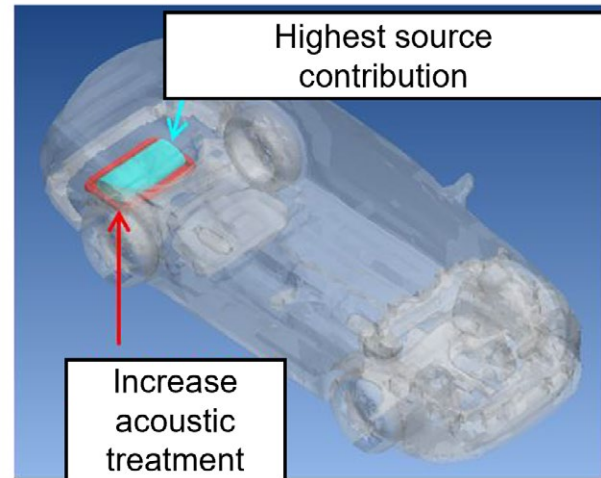## At 7.5 m

Comparing Actran with ARTC measured values

Only 0.2 dB error
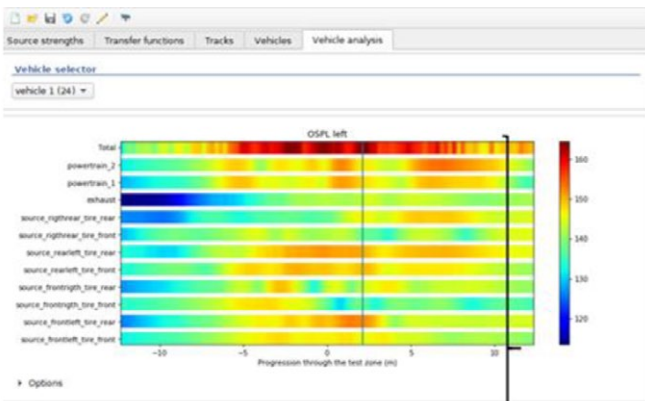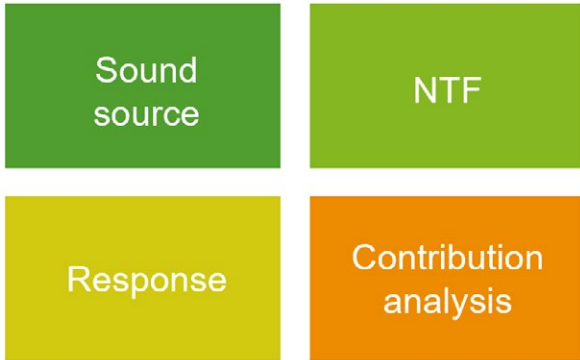

Left side
Right side

time(s)

Dedicated post-processing techniques for treatment analysis

Actran has a dedicated module for processing the results of pass-by noise, which is convenient for users to formulate countermeasures to suppress pass-by noise according to the following process: the first step is to find the highest moment of noise on the left and right sides; the second step is to find the highest moment of noise location; the third step is to find the frequency response at the highest point position and find the frequency with the highest magnitude; the fourth step is to list the contribution of each sound source and find the sound source with the highest contribution of the highest frequency. Sound insulation materials can be added to this part to reduce noise.

In 2020, China Motor Corporation proposed to combine the simulation of pass-by noise and the different steps of the process (sound source analysis, NTF calculation, response superposition, and contribution analysis) into one tool. Actran's development team responded to the demand and launched the pass-by noise vertical of the Workflow Manager in 2021, which directly makes the pre- and post-processing required to pass the noise into an interface to facilitate user operation and analysis.

Highest source contribution

Increase acoustic treatment

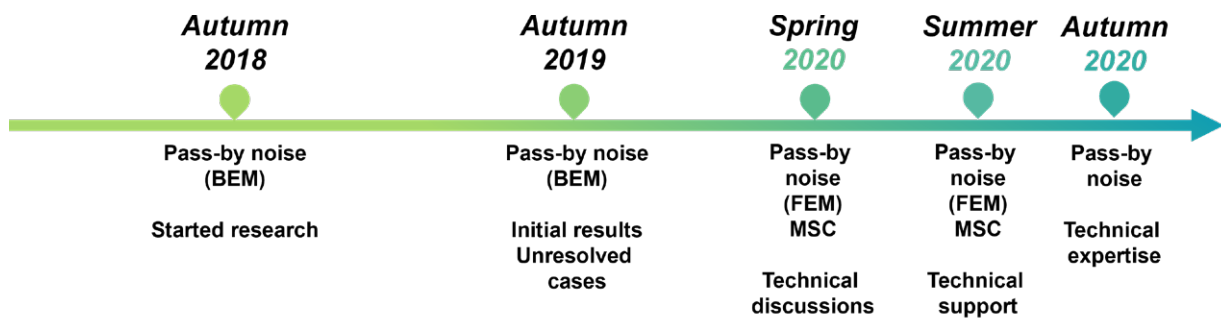Before adding treatments

After adding treatments

Results

Pass-by Noise regulations were promulgated in the sixth phase, which put forward more stringent indicators for acceleration noise, and higher requirements for the noise indicators of China Motor Corporation's small trucks.

Actran met China Motor Corporation's various needs for noise simulation, including the development of the pass-by noise vertical of the Workflow Manager, within one year, helping China Motor Corporation solve current challenges. The pass-by noise process is fully established and already applied to vehicles, with the help of Hexagon's technical staff in Taiwan and China.

Autumn 2018	*Autumn* 2019	*Spring* 2020	*Summer* 2020	*Autumn* 2020
Pass-by noise (BEM)	Pass-by noise (BEM)	Pass-by noise (FEM) MSC	Pass-by noise (FEM) MSC	Pass-by noise
Started research	Initial results Unresolved cases	Technical discussions	Technical support	Technical expertise

Timeline of pass-by noise simulation evaluation in China Motor Corporation

HEXAGON

Hexagon is a global leader in digital reality solutions, combining sensor, software and autonomous technologies. We are putting data to work to boost efficiency, productivity, quality and safety across industrial, manufacturing, infrastructure, public sector, and mobility applications.

Our technologies are shaping production and people-related ecosystems to become increasingly connected and autonomous – ensuring a scalable, sustainable future.

Hexagon's Manufacturing Intelligence division provides solutions that use data from design and engineering, production and metrology to make manufacturing smarter. For more information, visit hexagonmi.com.

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