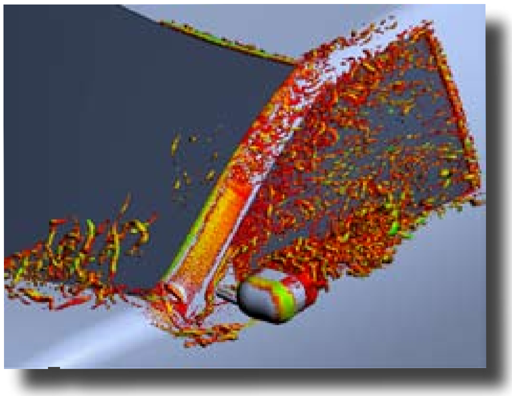
Wind Noise

ADDRESSING THE PROBLEMS OF WIND NOISE

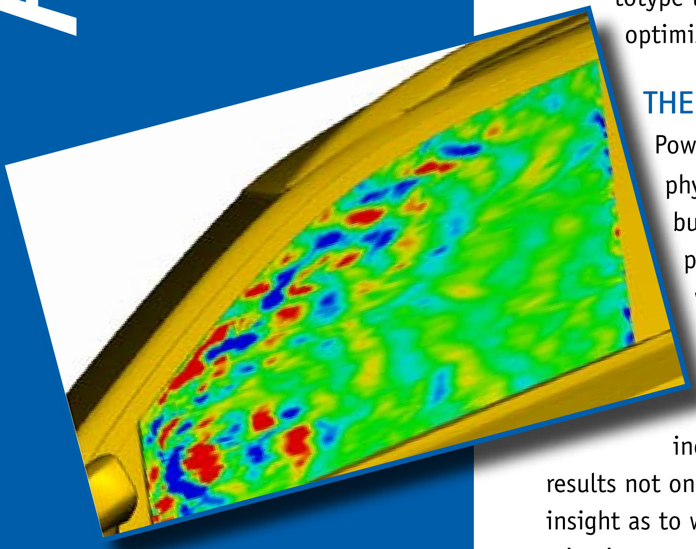
A vehicle's interior noise level is a significant component of passenger comfort. As manufacturers continue to reduce the level of noise generated by engine, transmission and tires propagating to the passenger cabin, the importance of wind noise continues to rise. Noise is consistently ranked among the top complaints in customer satisfaction surveys, and a quieter interior is perceived as an attribute of superior quality. Typically noise targets are achieved using thicker glass and soundproofing of the cabin, thereby adding cost and weight. However, noise reduction can also be achieved via small changes to the exterior geometry which affect the airflow and therefore the sources of wind noise.



Physical testing for wind noise optimization is expensive. A high quality model is required, time and budgetary constraints restrict the number of prototypes and geometry changes that can be tested, and very limited information (if any) can be obtained about the sources and mechanisms of noise generation. Moreover, by the time prototype testing can be done, it is too late to consider many of the shape design optimization options that would have been possible earlier.

THE POWERFLOW SOLUTION

PowerFLOW provides a fast, efficient and cost effective complement to physical testing, especially in the early stages of the design cycle prior to building a prototype. With its near-linear scalability on distributed compute nodes and its ability to handle extremely complex detailed geometry with minimal user intervention, the Lattice Boltzmann based PowerFLOW software is a unique tool that solves the transient compressible Navier-Stokes equations with extremely low numerical dissipation. Consequently, PowerFLOW provides a highly accurate direct computation of flow-induced pressure fluctuations that act as wind noise sources. PowerFLOW results not only enable rank ordering of various designs, but also provide tremendous insight as to why one design is superior to another, thereby guiding the design optimization process. Use of Exa's PowerCLAY software to enable rapid changes to the CAD geometry yields a complete solution process for fast turnaround of wind noise design optimization studies.



Snapshot of transient surface pressure fluctuations on a front sideglass, using band-filtered pressure for 2000 Hz; Above right: Snapshot of λ_2 isosurfaces (vortex core visualization using λ_2 criterion).

Exa

CASE STUDY

Transmission of greenhouse noise sources through the panels to the vehicle interior can be reduced by various means, such as using thicker glass, laminated glass, or more complex seals. However, the need for such expensive measures can be reduced using early stage wind noise design optimization made possible by PowerFLOW.

Design Iteration

The PowerFLOW wind noise design optimization process is illustrated as follows. The predicted sideglass wall pressure fluctuations (WPF) on a production vehicle was reduced by making a minor geometry modification to the side mirror. Though a production car offers much less opportunity for improvement relative to an early prototype, this geometry change was able to provide a significant improvement.

The mirror modification, shown in Figure 5, was designed to widen the channel between the mirror and the sail. The use of PowerCLAY to rapidly morph the tessellated geometry and directly import modified parts, with no need to touch the remainder of the surface mesh, along with the scalability of PowerFLOW on a large cluster, allows for fast turnaround time between design iterations.

Figure 6 shows a “dB map” of the sideglass surface, indicating the fluctuating pressure level at every point on a very fine surface mesh, for the baseline and modified geometries. The dB map can be band-filtered for any desired frequency band, and here the 2000 Hz octave band is chosen to be the frequency range of interest. Figure 7 shows fluid volume isosurfaces of fluctuating pressure, again filtered to the 2000 Hz octave band, superimposed over the dB maps. Fig 8 shows isosurfaces of time-averaged total pressure, which clearly shows the change in the mean flow mirror wake structure.

The visualization comparison reveals that the mirror modification was able to divert the mirror wake away from the sideglass, which reduced its impingement on the surface. Although the dominant frequencies of the mirror wake are low, the resulting flow structures break down to smaller scales in a turbulent cascade that transfers energy to higher frequencies. Hence the differences seen at high frequency can be attributed to the changes in the mirror wake. This design modification reduced the surface averaged fluctuating pressure on the sideglass by ~0.5 dB for the 2000Hz octave band.

Empowering the Engineer

Using PowerFLOW, extensive design optimization studies can be carried out, where the feature changes are guided by analysis of the flow structures relative to the geometry. Modifications to the pedestal and sail also typically can contribute to reduced sideglass noise. In this example the mirror modification achieved the desired change in flow behavior and yielded favorable results. In general, while not every attempted feature change will work, the key to successful and efficient design improvement is to understand what the flow is doing and how it can be modified. In this regard the PowerFLOW tool suite provides a unique and powerful capability for wind noise design optimization.

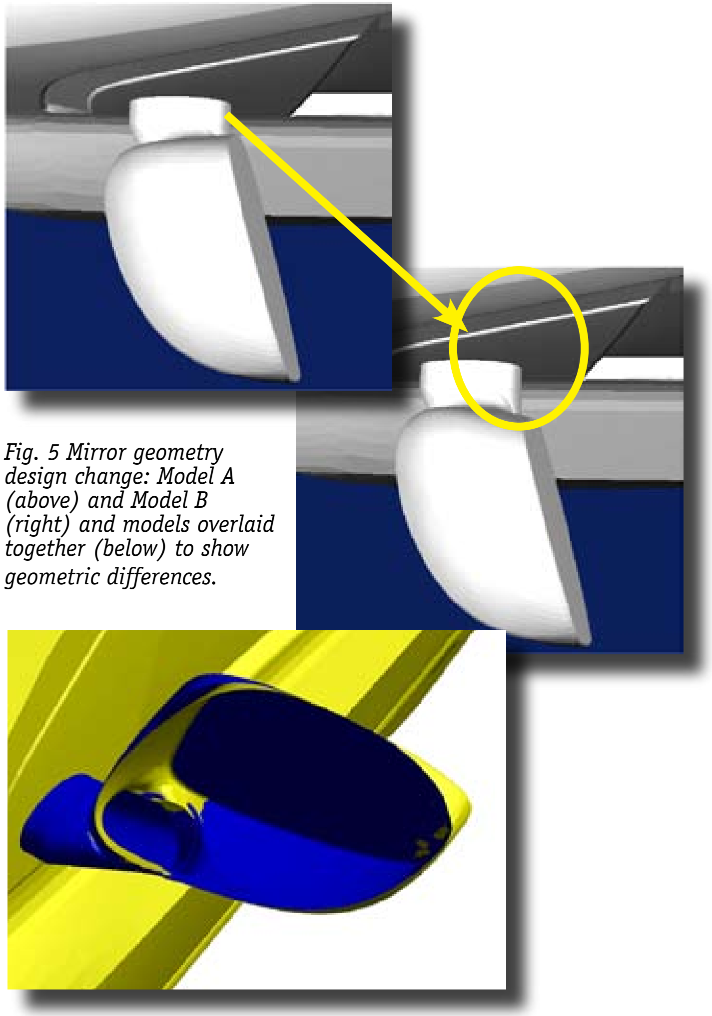


Fig. 5 Mirror geometry design change: Model A (above) and Model B (right) and models overlaid together (below) to show geometric differences.

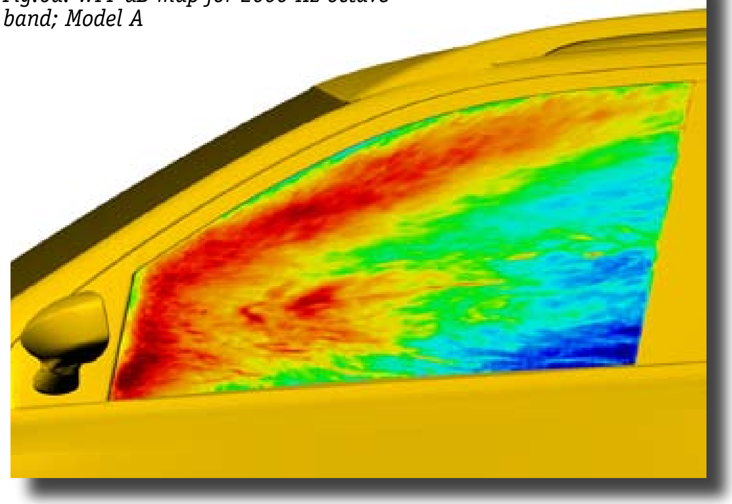


Fig.6a: WPF dB map for 2000 Hz octave band; Model A

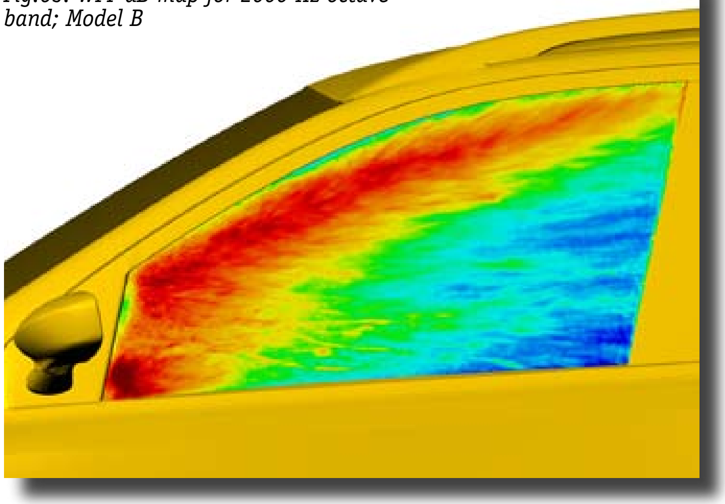


Fig.6b: WPF dB map for 2000 Hz octave band; Model B

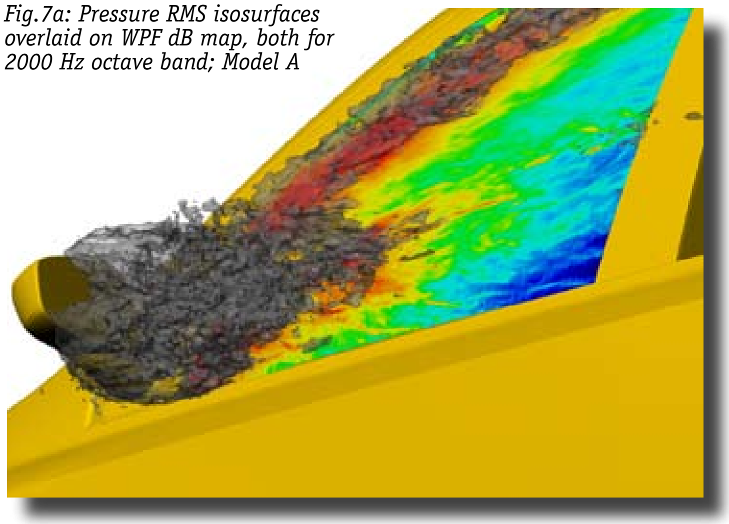


Fig.7a: Pressure RMS isosurfaces overlaid on WPF dB map, both for 2000 Hz octave band; Model A

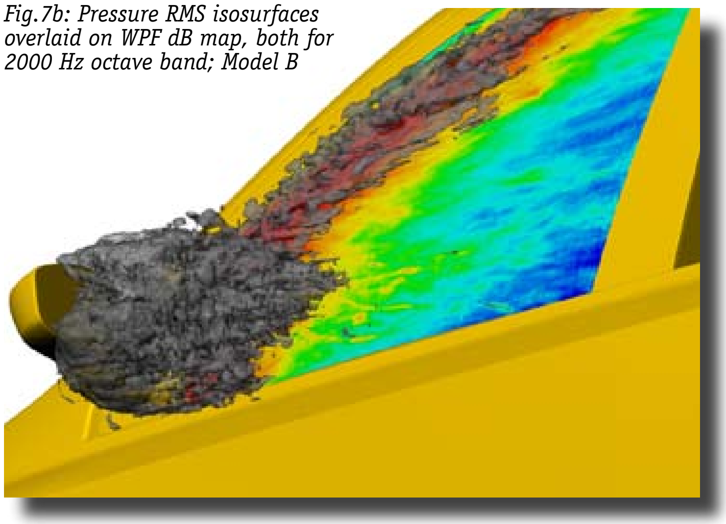


Fig.7b: Pressure RMS isosurfaces overlaid on WPF dB map, both for 2000 Hz octave band; Model B

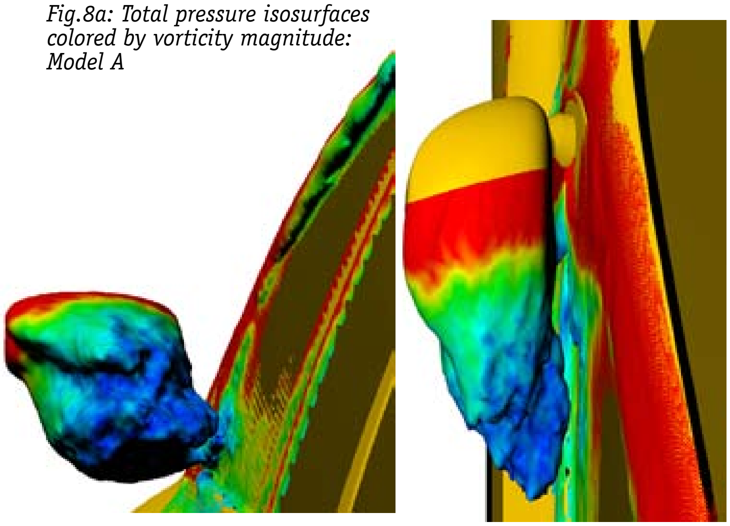


Fig.8a: Total pressure isosurfaces colored by vorticity magnitude: Model A

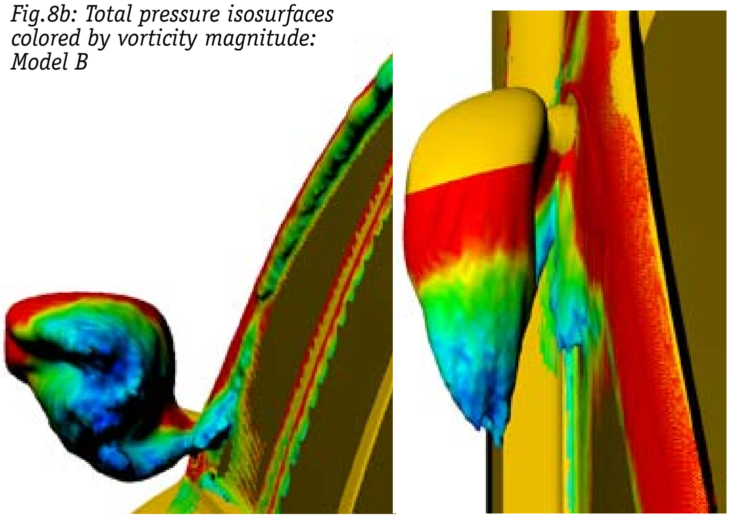


Fig.8b: Total pressure isosurfaces colored by vorticity magnitude: Model B