Vehicle Cabin Noise from Turbulence Induced by Side-View Mirrors

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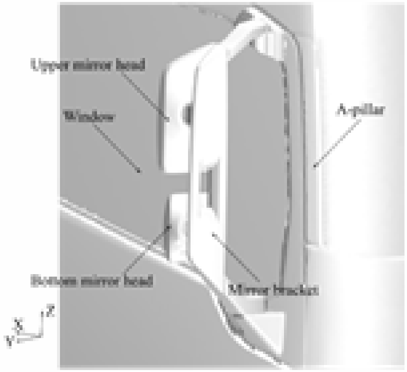
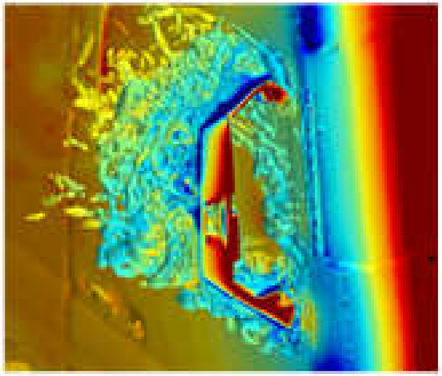
An Important Cabin Noise Source – Turbulence

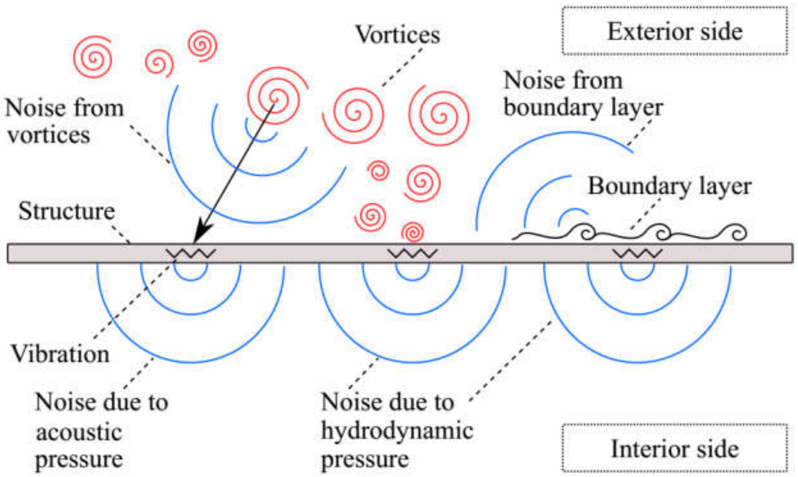
- As the development of quiet powertrains and tires, turbulent flows become a significant contributor to the cabin noise, especially for electrical vehicles.
- A quiet environment in the cabs is required for the health of drivers and passengers.





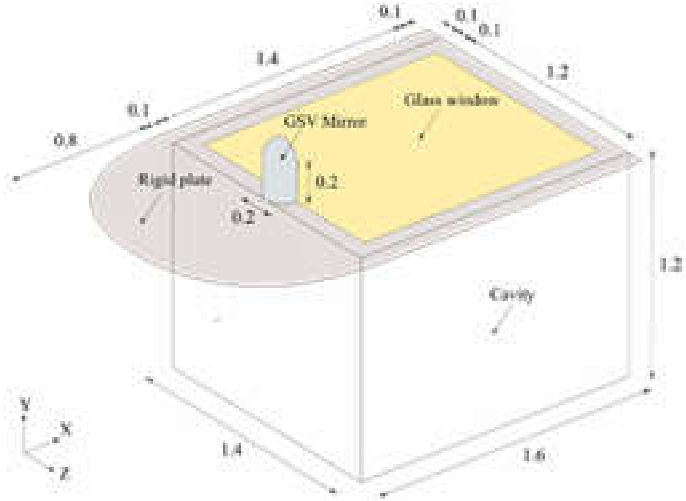
How Do Flows Contribute Cabin Noise?

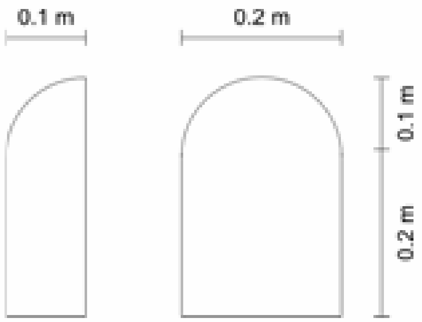
- An important source of the interior noise in the cabs is the window vibration excited by:
  the exterior flow (indirect noise generation);
  the exterior flow-induced noise (direct noise transfer).



A generic side-view (GSV) mirror

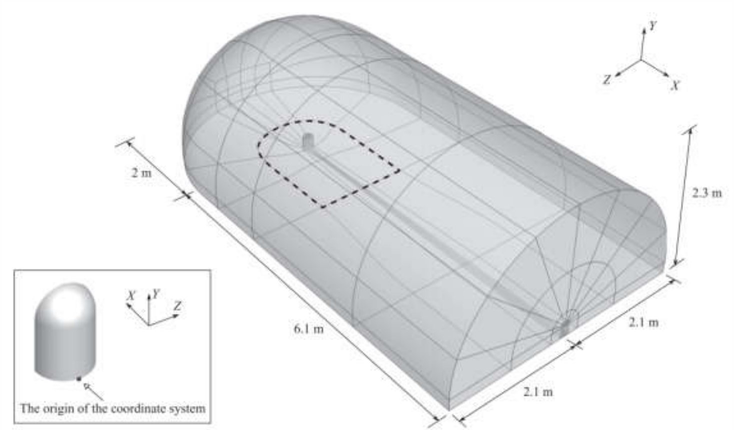
- The GSV mirror has been widely studied for its aerodynamics characteristics.
- The geometry is simple, while it possesses similar characteristics as a real mirror.
- The geometry is used to explore the principle mechanisms of aero-vibro acoustics.

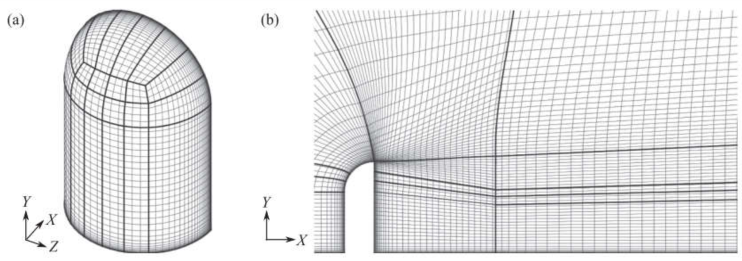




Investigation of basic mechanisms

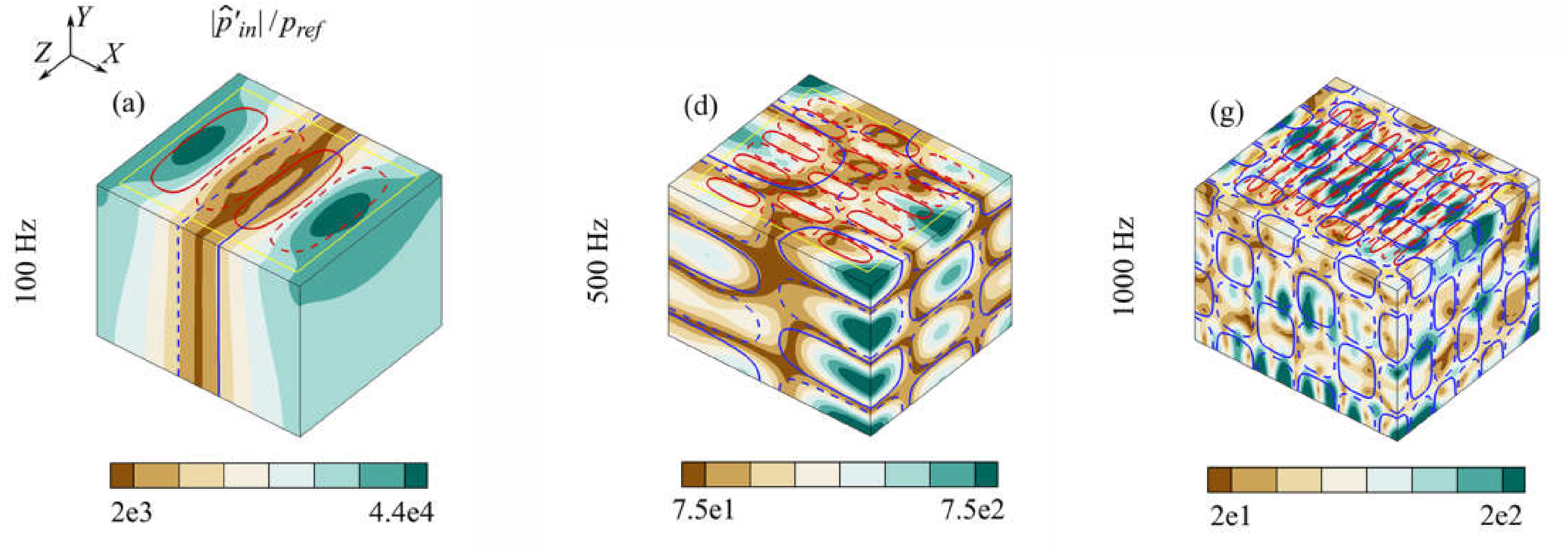
- Turbulent flows past a generic side-view mirror. A rectangular glass window is placed downstream of the mirror. The window vibration is excited by the surface pressure fluctuations and emits the interior noise in a cuboid cavity.
- Compressible LES is coupled with a finite element method.





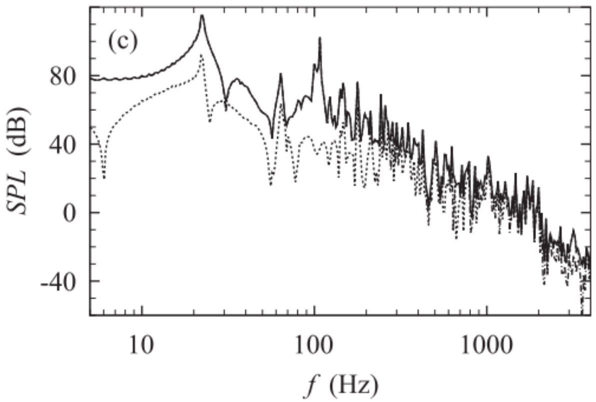
Effect of mode shapes

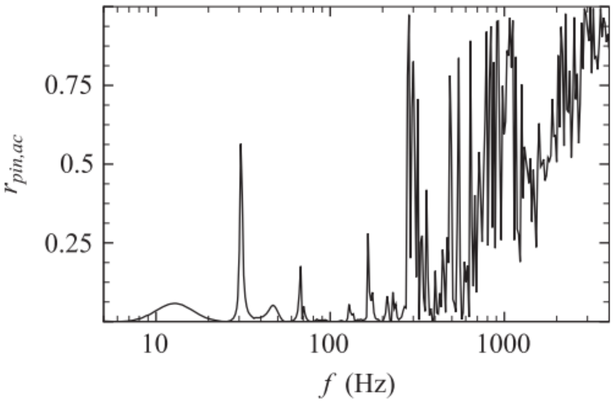
- The combination of the mode shapes of the window and cavity greatly affects the magnitude distribution of the interior noise.



Interior noise

- The acoustic component is more efficient in the generation of the interior noise than the hydrodynamic component, while the hydrodynamic component is still dominant below approximately 250 Hz.
- The structural modes of the window determine the low-frequency interior tonal noise.





Conclusions

- The wavenumber-frequency spectra of the surface pressure fluctuations are identified with some new features that cannot be explained by the Chase model for turbulent boundary layers.
- The spectra contain a minor hydrodynamic domain in addition to the hydrodynamic domain caused by the main convection of the turbulent boundary layer.
- The minor domain results from the local convection of the recirculating flow. These domains are formed in bent elliptic shapes. The spanwise expansion of the wake is found causing the bending.

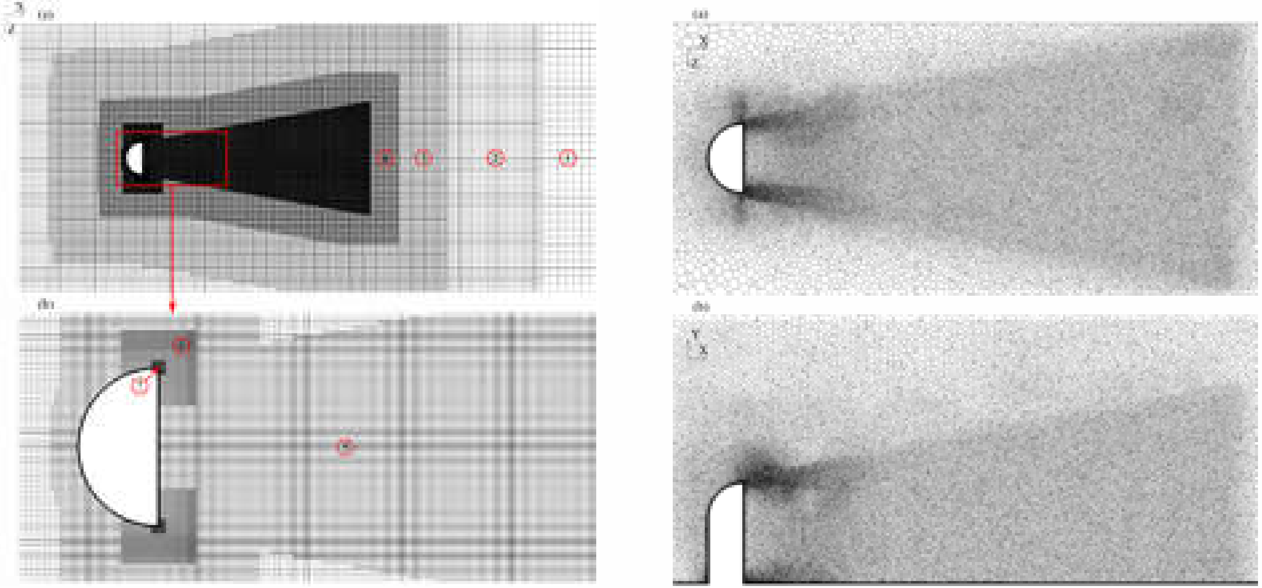
Study of Numerical Methodologies

CFD and CAA methodologies

- Compressible LES (C-LES).
- Compressible DES (C-DES).
- Incompressible DES (IC-LES), where both polyhedral and trimmed mesh generation approaches are studied.
- Incompressible DES integrated with acoustic wave model (AWE)

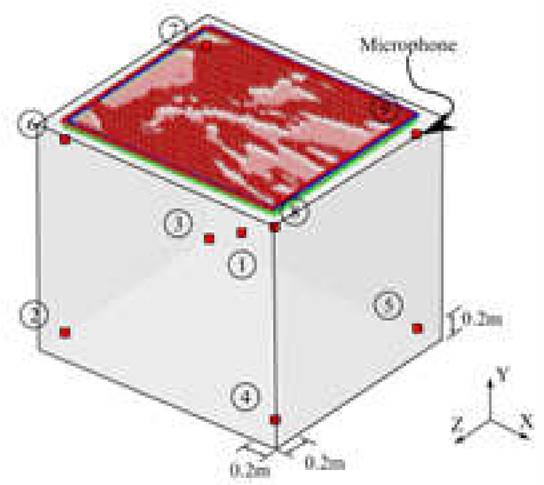
Computational meshes

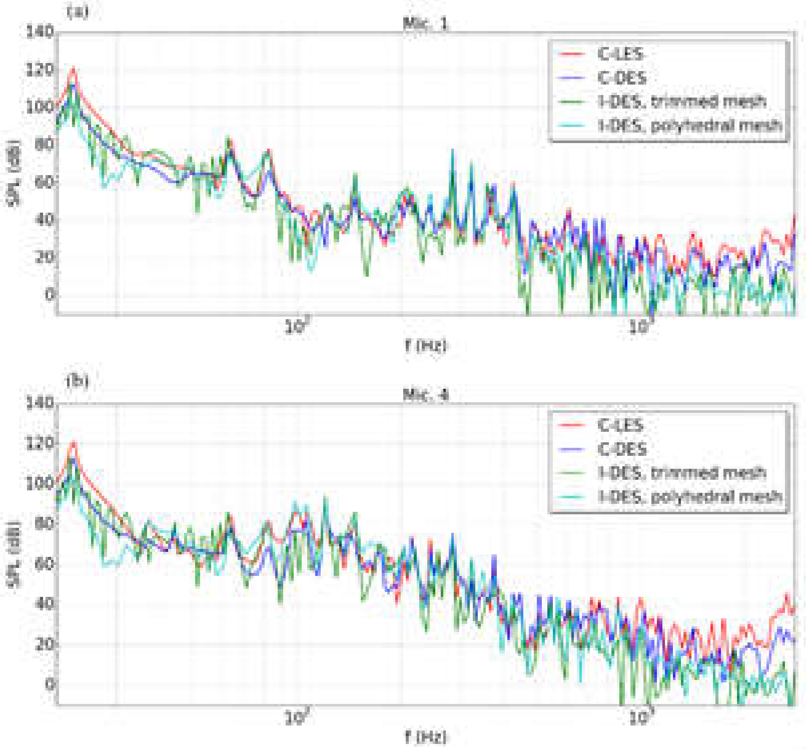
- A mesh of polyhedral cells and a mesh of trimmed cells are generated in terms of the same cell size settings.



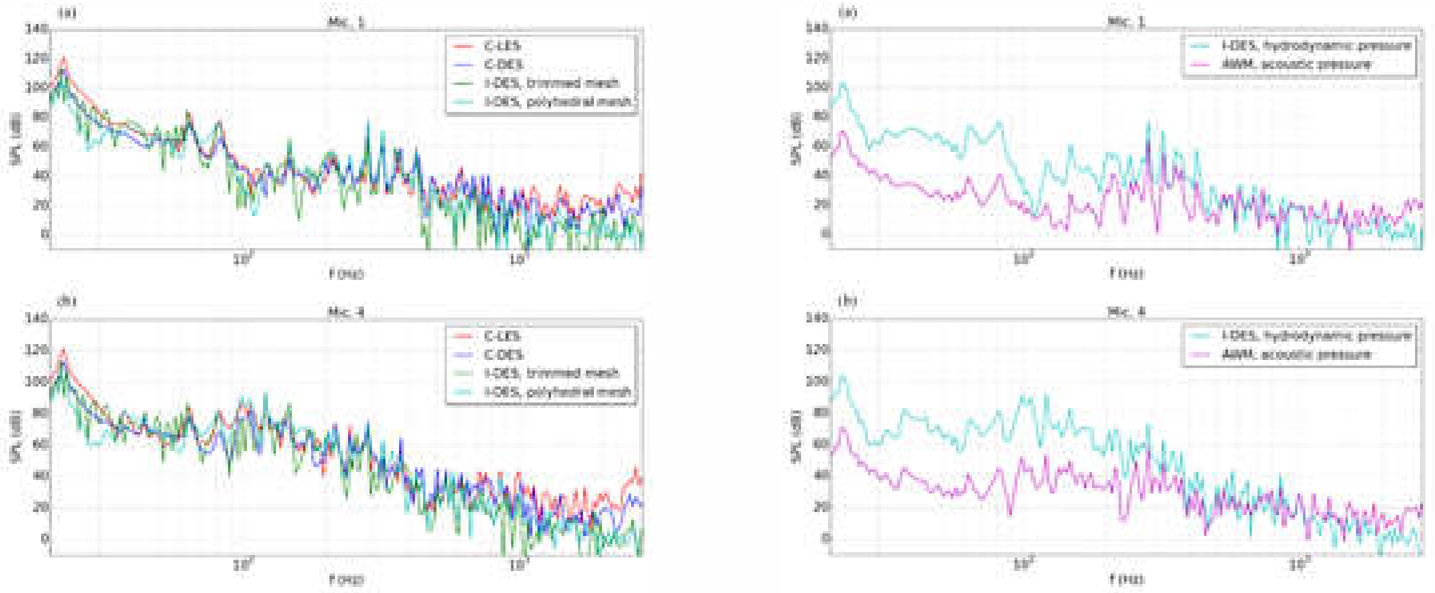
Interior noise

- LES provides the largest noise levels.
- I-DES provides the lowest noise levels.



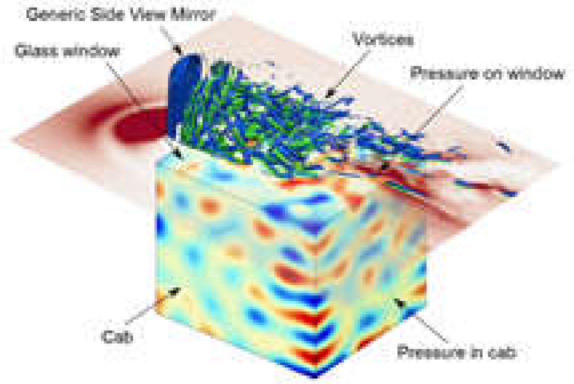


- The exterior acoustic pressure component (the exterior noise) plays a dominant role in the interior noise generation above approximately 1000 Hz.
- The exterior hydrodynamic pressure component is dominant below 500 Hz.



Conclusions

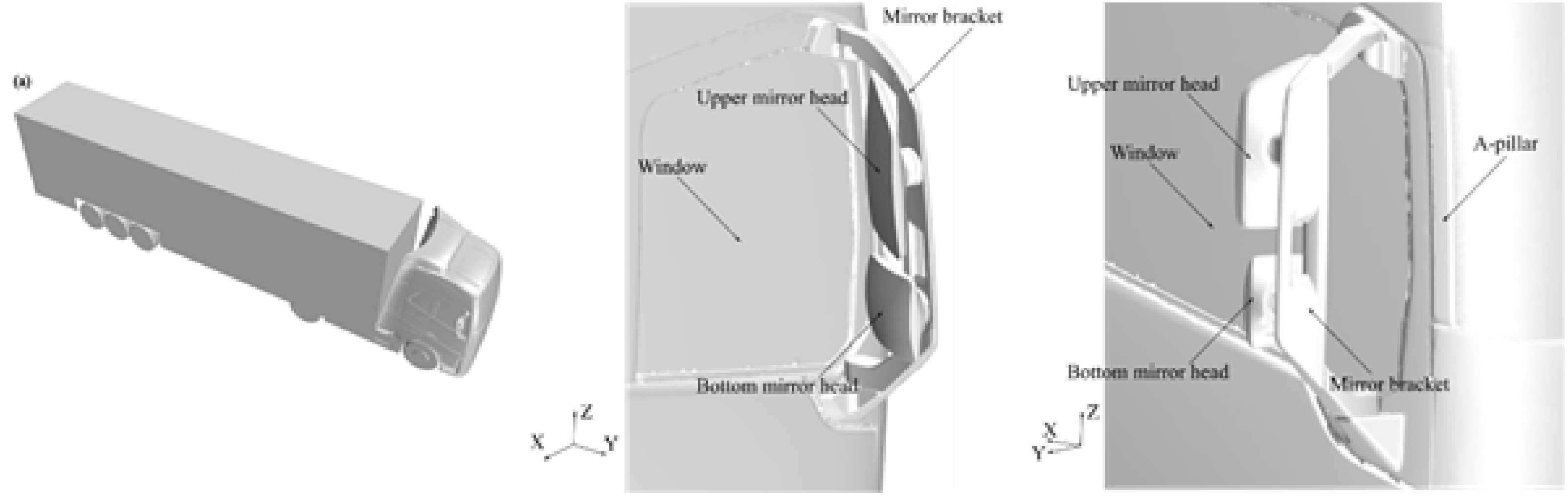
- LES predicts the largest noise levels since it gives the most intensive fluctuations.
- LES is fastest since it solves the lest equations.
- The improvement of the solutions introduced by the polyhedral mesh is not obvious, as compared with the trimmed mesh, given the mesh quality is refined enough.



Industrial applications

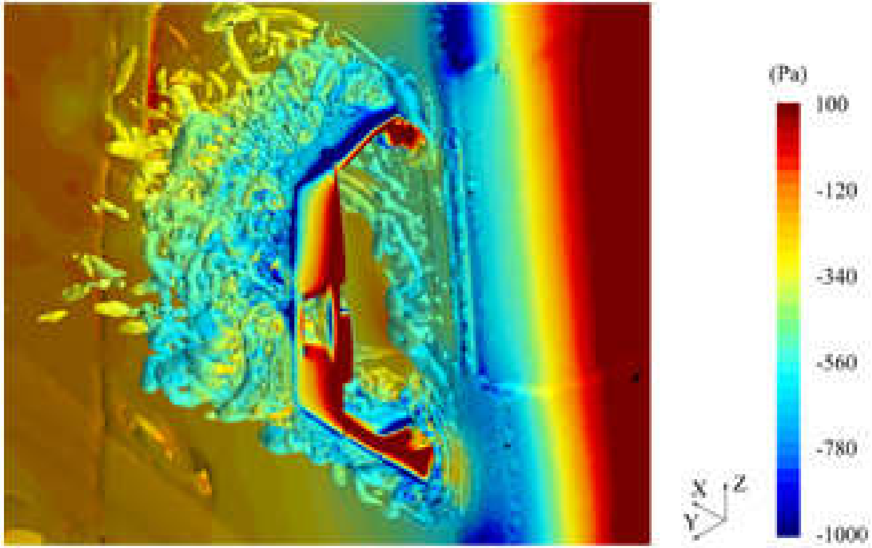
Full-scale truck simulation

- A simplified geometry is used to reduce computational costs.
- The flow near the A-pillar, mirror and window is concerned.



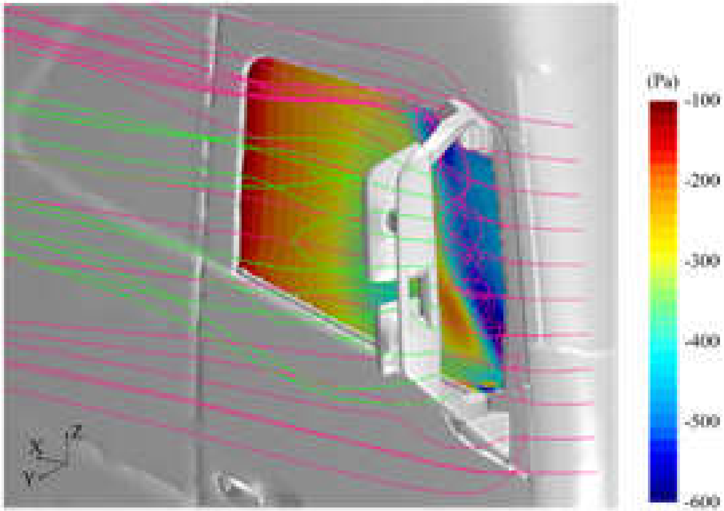
Flows near window

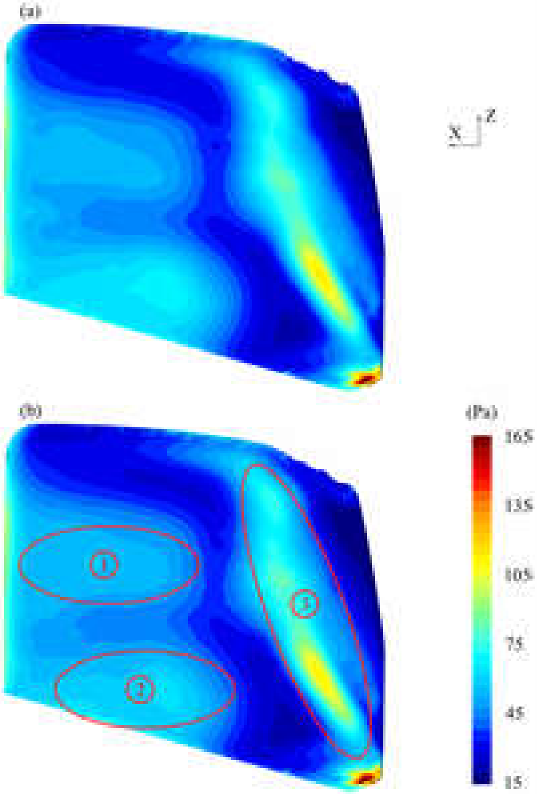
- Turbulent flow structures are introduced by the A-pillar and mirror.



Hydrodynamic impingement

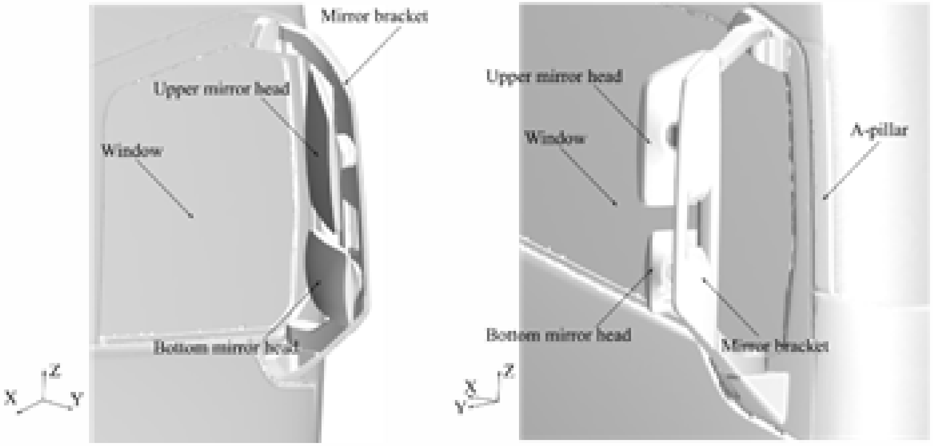
- The A-pillar induces more effective impingement on the window than the mirror.

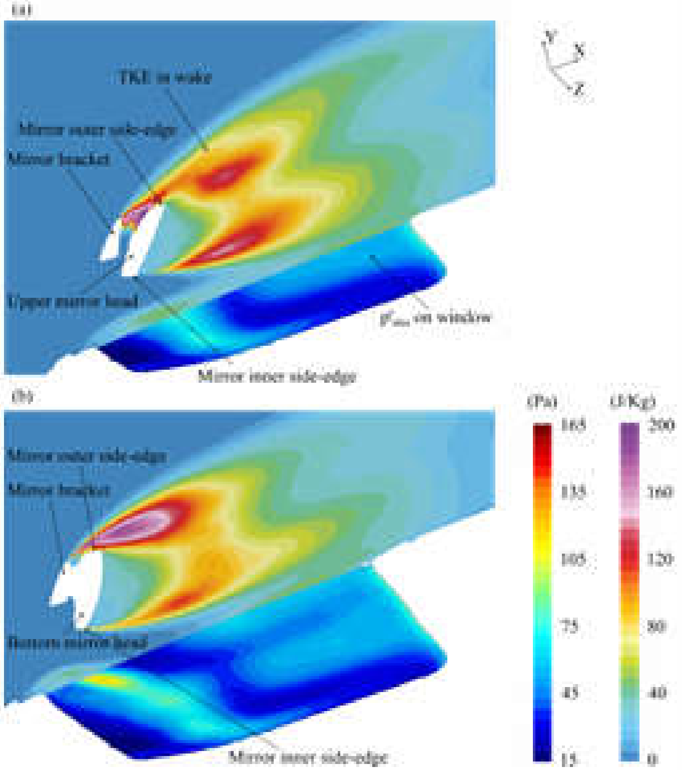




Vortex shedding

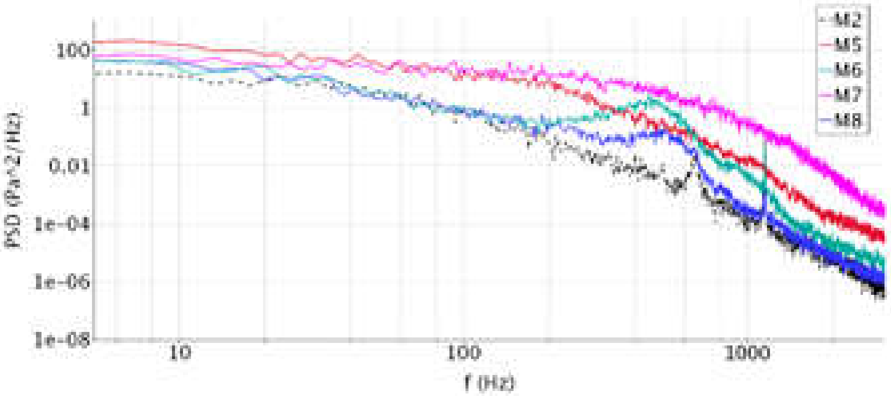
- The vortex shedding that develops from the mirror bracket impinges on the outer side edges of the mirror heads.





Development of shedding

- Peaks of pressures fluctuations are only observed near the mirror inner edges.
- The development of the shedding from the outer mirror edges are disturbed by the upstream shedding and become highly turbulent.



Conclusions

- The simplified geometry and computational strategy significantly reduce many computational costs.
- The simplified geometry gives comparable results for the flows near the mirror mounted on the original geometry.
- The mirror bracket triggers the shedding from the mirror outer edges to be turbulent. The tonal noise might therefore be suppressed.
- The geometric optimization of the mirror inner edges is needed to suppress the shedding, which could introduce the tonal noise. An alternative is to adapt/add structures upstream of the inner edges to control the flows.

Thank you

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