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Effect of geometry simplification and boundary condition specification on flow field and aerodynamic noise in the train head and bogie region of high-speed trains

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CFD model

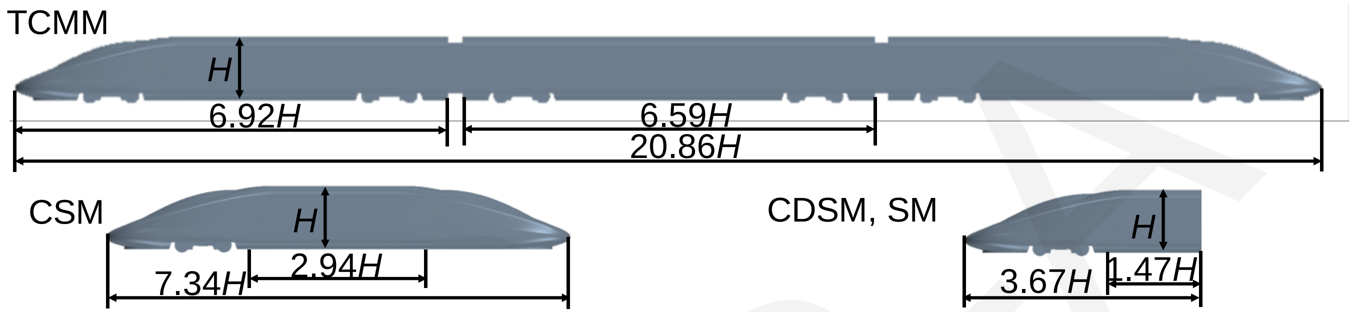


Fig. 1 Schematic diagram of train geometry and size
(TCMM: three-car marshalling model, CSM: carbody shortening model, CDSM: computational domain shortening model, SM: sub-domain model)

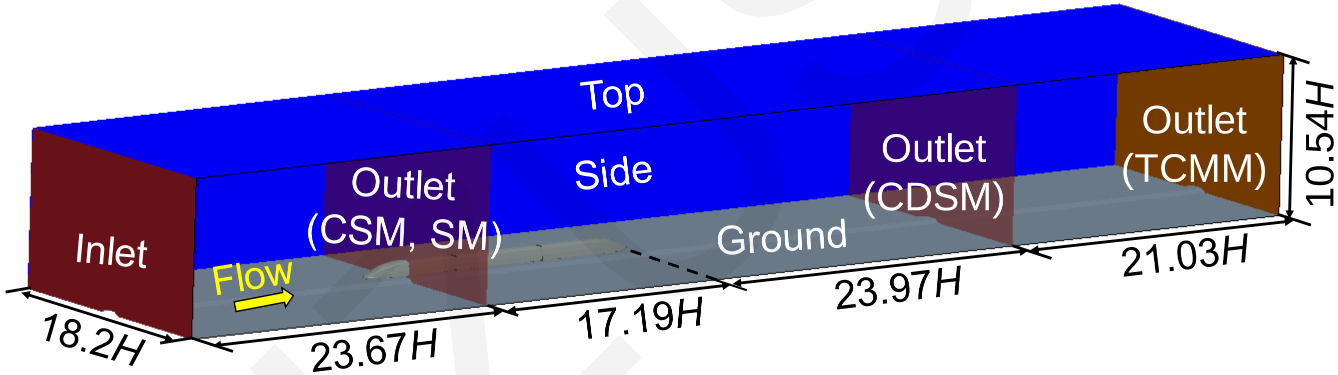


Fig. 2 Computational domain of the four models

- **For the TCMM, CDSM and CSM, the gauge pressure at the outlet is set as 0. For the SM, the pressure and turbulence parameters at the outlet are obtained by a steady RANS simulation based on the TCMM.**

Time-averaged pressure

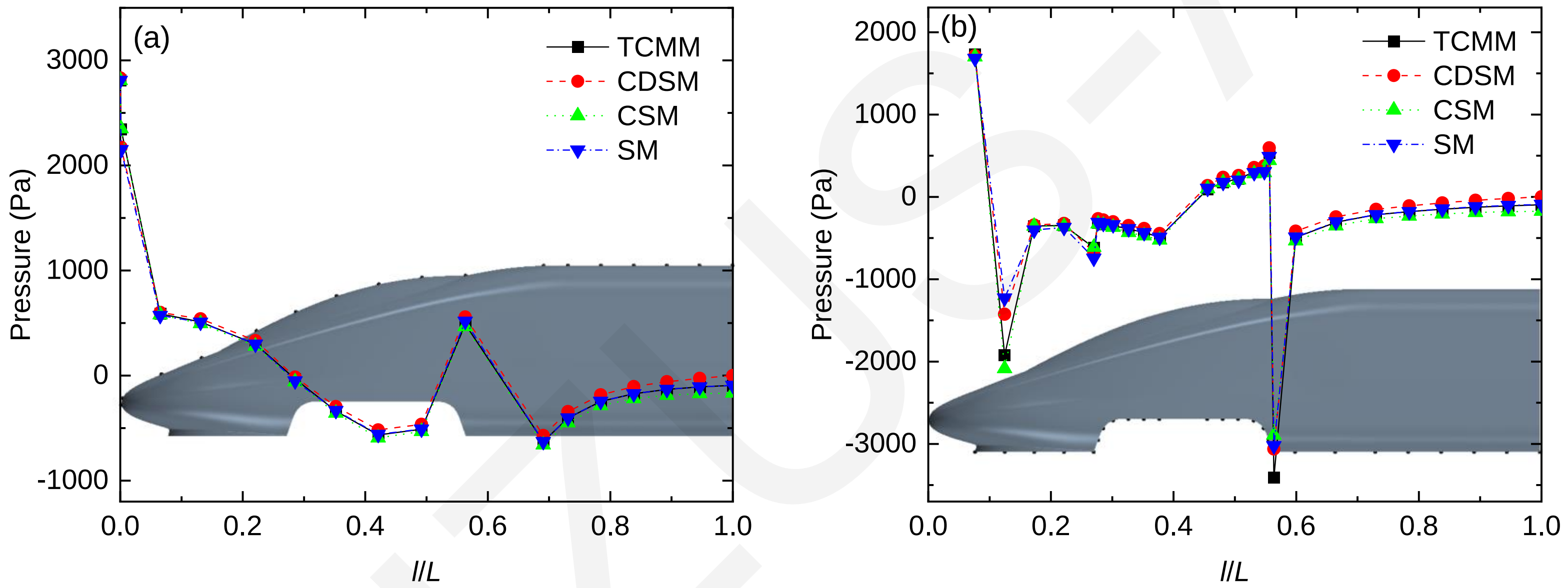


Fig. 3 Time-averaged pressure distribution on the central line of the train head: (a) central line of upper part of train head; (b) central line of lower part of train head

Time-averaged velocity

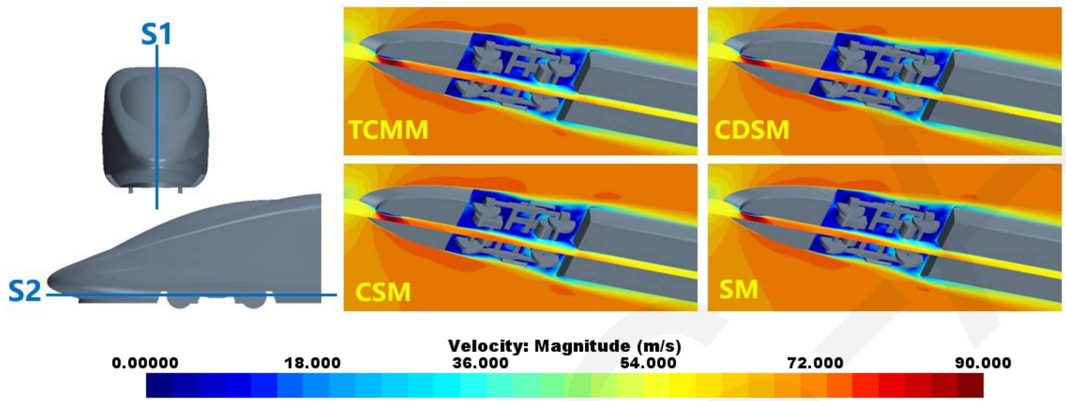


Fig. 4 Time-averaged velocity distribution

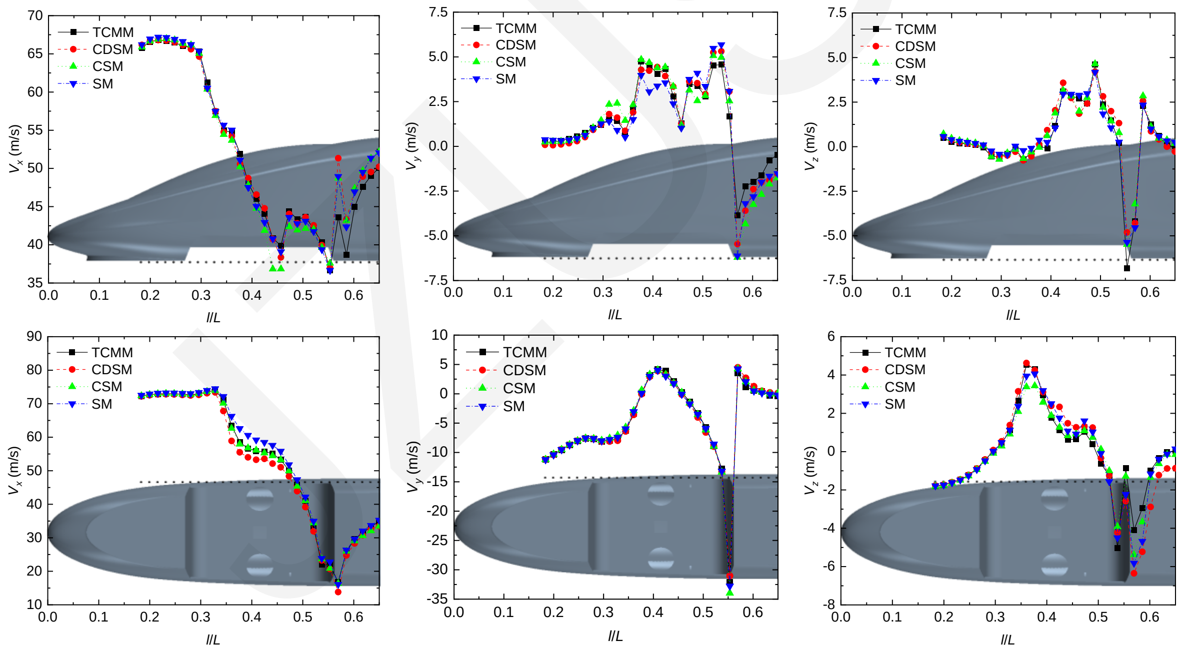


Fig. 5 Time-averaged velocity distribution (Top: line probe beneath the bogie cavity; Bottom: line probe at the side of the bogie cavity)

Fluctuating pressure

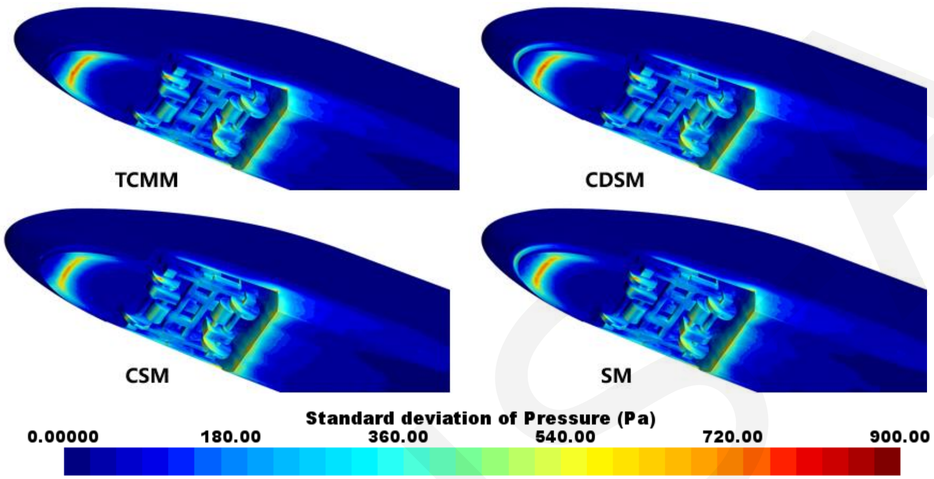
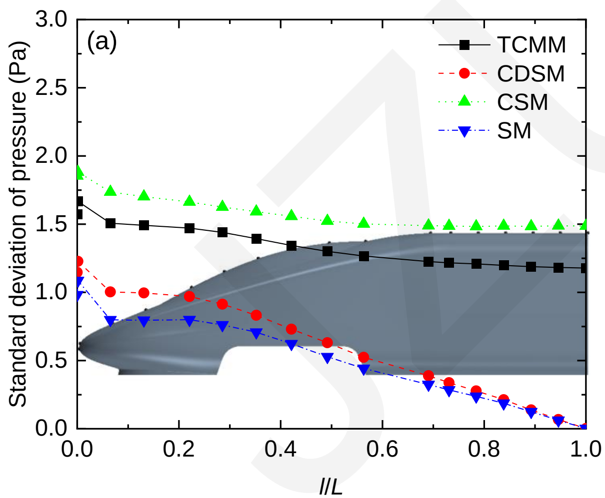


Fig. 6 Fluctuating pressure distribution in the train head and bogie region



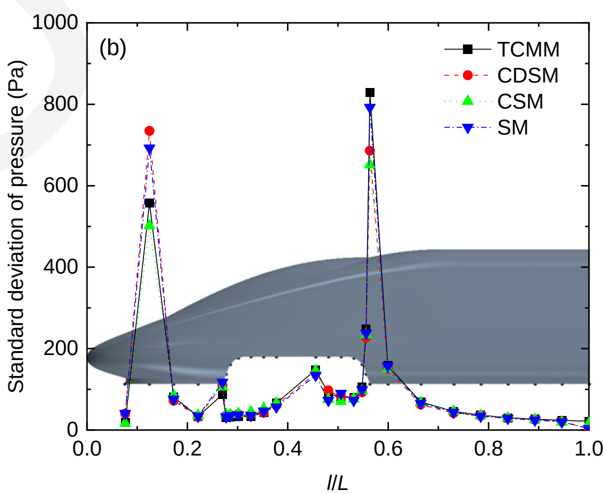


Fig. 7 Fluctuating pressure distribution on the central line of the train head: (a) central line of upper part of train head; (b) central line of lower part of train head

Fluctuating velocity

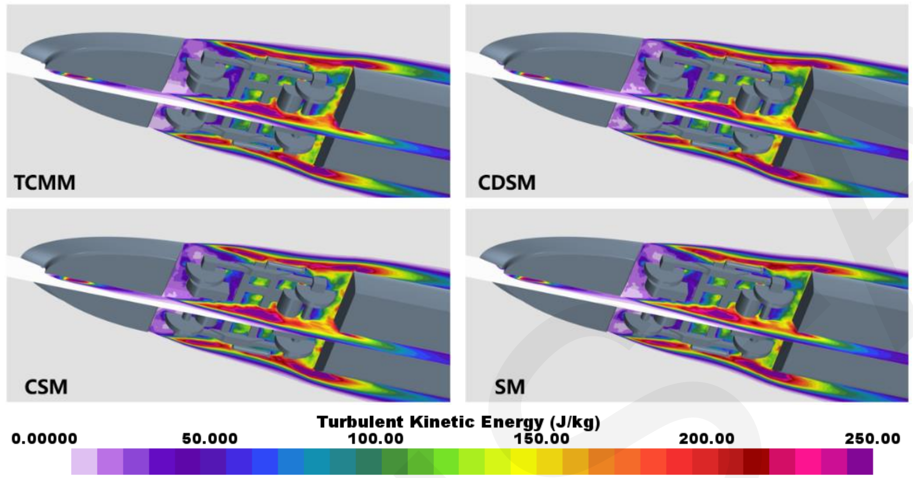


Fig. 8 Time-averaged turbulent kinetic energy distribution

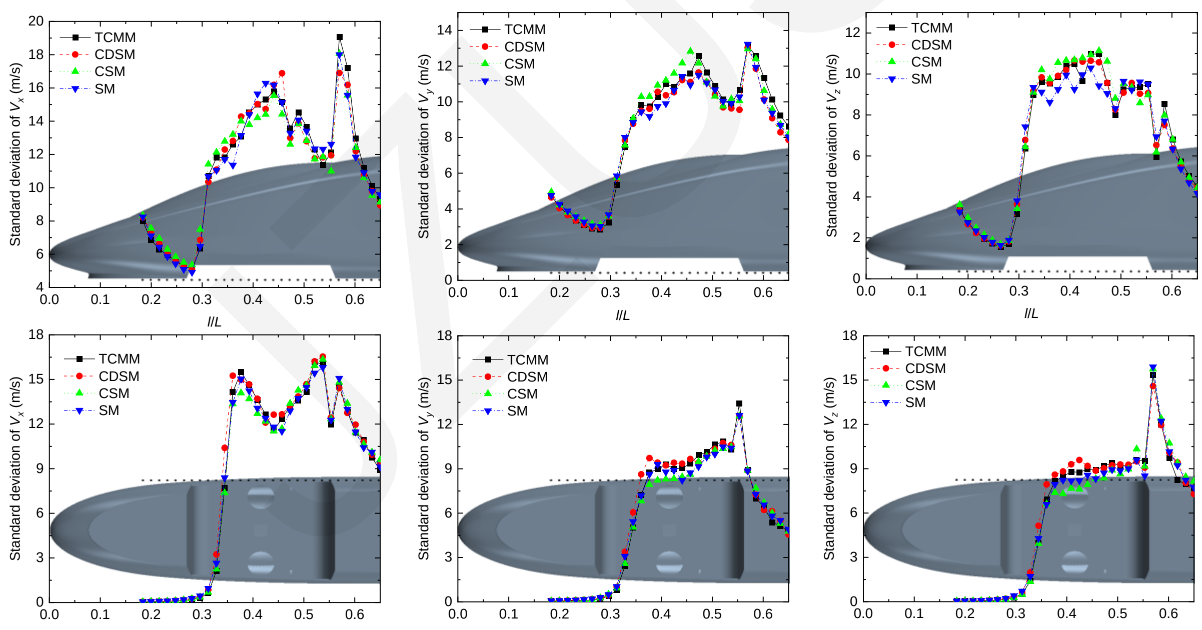


Fig. 9 Fluctuating velocity distribution (Top: line probe beneath the bogie cavity; Bottom: line probe at the side of the bogie cavity)

Far-field noise

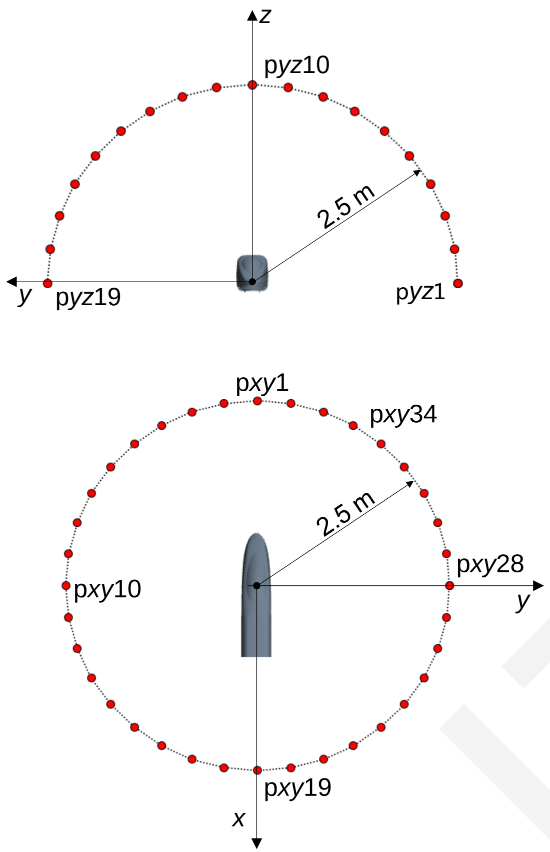


Fig. 10 Far-field noise receivers

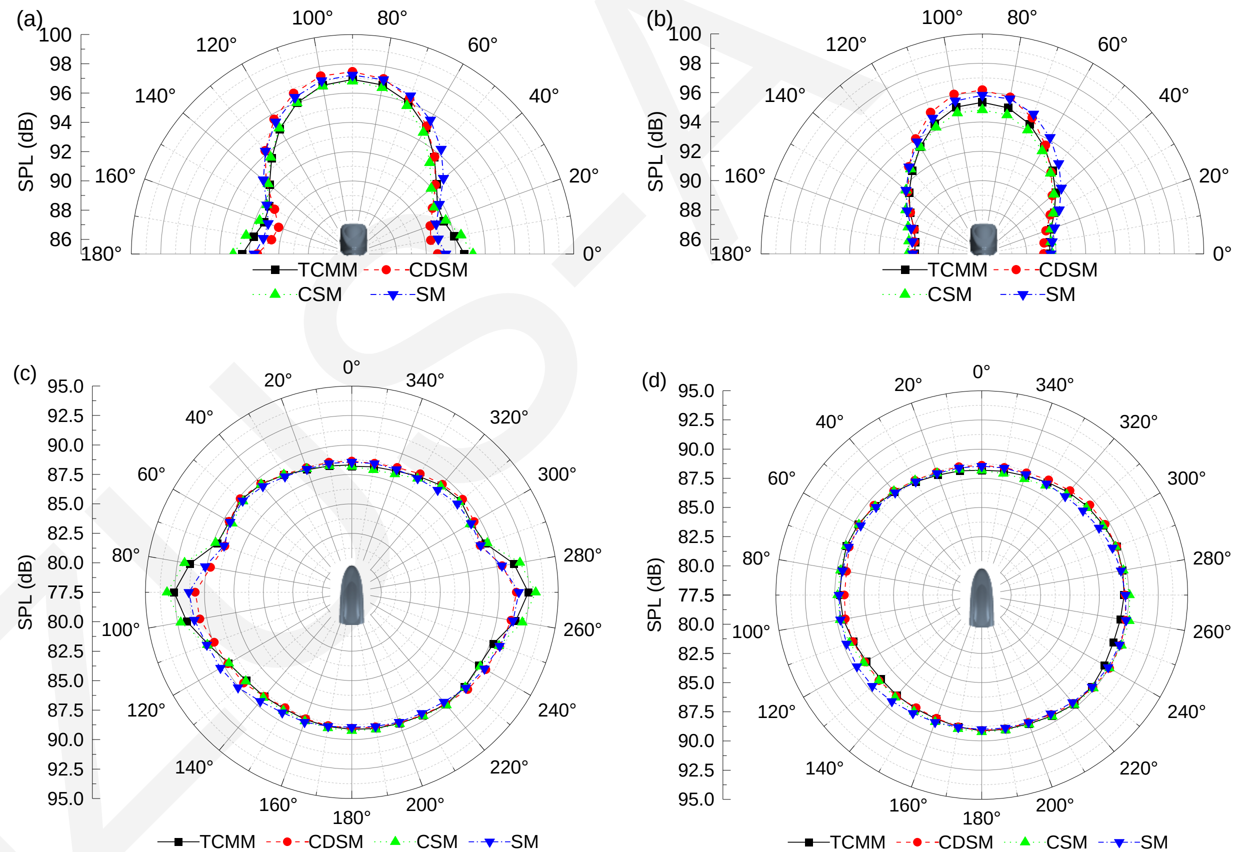


Fig. 11 OASPL results in the XOY and YOZ planes: (a) train head_YOZ plane; (b) bogie region_YOZ plane; (c) train head_XOY plane; (d) bogie region_XOY plane

Far-field noise

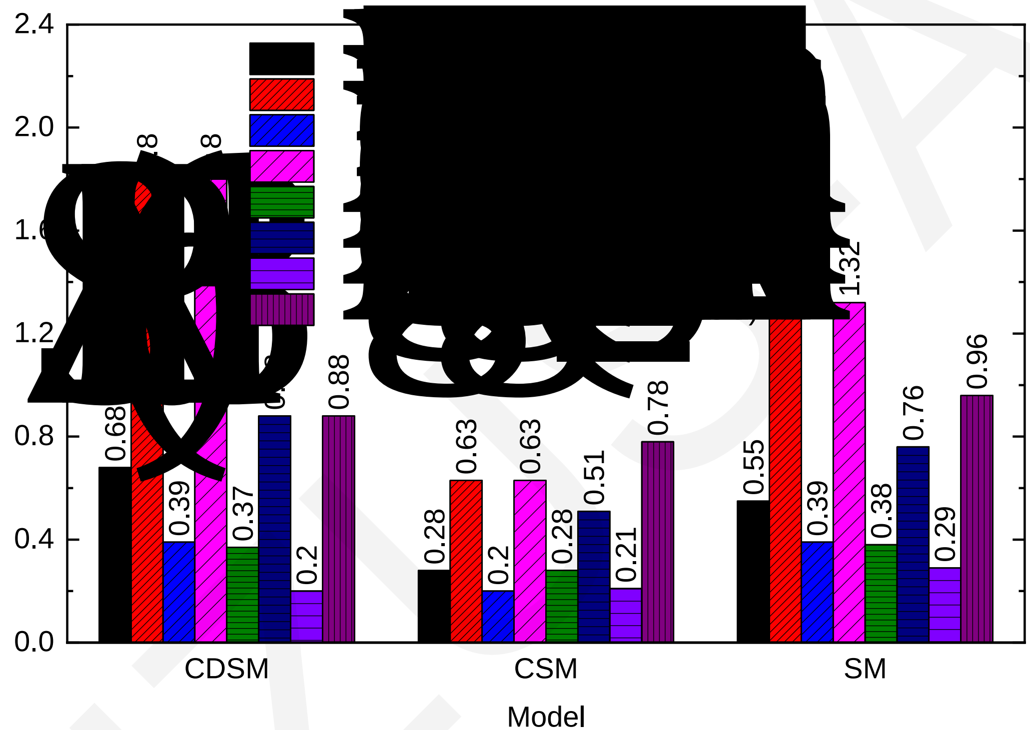


Fig. 12 Statistics of the difference between the OASPL results of the three simplified models and TCMM

- **The CSM seems to be a good choice for aeroacoustics optimization of the bogie region. It can significantly improve the efficiency of CFD simulation while ensuring consistency with the results of the TCMM.**

Conclusions

- The time-averaged pressure distributions on the train surface predicted by the three simplified models are in good agreement with the results of the TCMM. The time-averaged velocity fields in the bogie region predicted by the three simplified models are also consistent with the results of the TCMM.
- The pressure fluctuation at the lower part of the train is much more intense than that at the upper part of the train. The usage of the non-time-varying outlet boundary conditions in the CDSM and SM is likely to weaken the pressure fluctuation on the head streamlined surface and the carbody surface upstream the outlet boundary.
- The fluctuating velocity results of all four models are also in good agreement. Since the strength of the velocity fluctuation can reflect the stability of the shear layer, it can be considered that the dynamic process of the formation, development and destabilization of the shear layers in the four models also appears to be consistent.
- When only the bogie region is used as the noise source, the far-field noise results of the three simplified models are very consistent with those of the TCMM, with difference of OASPL within 1dB. When the whole train head is used as the source surface, due to the underestimation of dipole source intensity on head streamlined surface in the CDSM and SM, the OASPL results of them and of the TCMM can differ by up to 1.3 dB and 1.8 dB in certain specific directions, while the difference between the OASPL results of the CSM and TCMM is still less than 1 dB.