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A 3D CFD COMPARATIVE STUDY OF AERODYNAMIC PERFORMANCE OF PASSENGER TRAIN FRONTAL DESIGNS

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Summary: This study evaluates the aerodynamic performance of two passenger train models by conducting 3D Computational Fluid Dynamics (CFD) simulations of their frontal designs. The goal is to perform a comparative analysis to determine the superior frontal model, which will serve as the basis for future design improvements to meet aerodynamic and operational standards. The simulations were carried out using ANSYS FLUENT, employing the K-Omega turbulence model and appropriate boundary conditions, with both trains simulated at their operational speed of 61.11 m/s (220 km/h).The primary focus of the CFD simulations was to analyze the aerodynamics of the 3D axis-symmetrical front section of the both trains. Several key parameters were evaluated, including the frontal inclination angle, frontal surface area, frontal block height, blockage rate in a typical tunnel, drag coefficients, and airflow patterns. Concept 4, featuring a more pronounced frontal inclination angle, demonstrated significant advantages, especially when considering train operations within tunnels. The front surface of Concept 4 has an inclination angle of 117.06°, which is 2.6% larger than Concept 3, leading to a reduction in aerodynamic drag and improved airflow. Additionally, Concept 4 outperforms Concept 3 in terms of surface area, facilitating better airflow dynamics and lower drag. The study also assessed the frontal block height and blockage rate. Concept 4’s vertical height at the symmetrical mid-section is 5% higher than Concept 3, and its blockage rate, when considering 85% of the typical cross-sectional area of an oval-shaped tunnel (8m x 9m), is 13% higher. Despite this higher blockage, Concept 4’s design is more efficient, resulting in smoother airflow and lower drag. Subsequent modifications to Concept 4 were followed by a 3D CFD analysis of the first train carriage, which assessed the aerodynamic performance of additional components, such as the wheels and tracks. The analysis showed minimal pressure variation around Concept 4, with re-circulation zones observed at the upper front and smooth airflow around the lower rail guard. Concept 4’s drag coefficient confirmed its favorable aerodynamic profile. In conclusion, Concept 4 demonstrated superior aerodynamic efficiency compared to Concept 3, and the design improvements will enhance overall train performance while adhering to established design standards.

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