High-Speed Particle Image Velocimetry of the Flow around a Moving Train Model with Boundary Layer Control Elements

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Abstract : Trackside induced airflow velocities, also known as slipstream velocities, are an important criterion for the design of high-speed trains. The maximum permitted values are given by the Technical Specifications for Interoperability (TSI) and have to be checked in the approval process. For train manufactures it is of great interest to know in advance, how new train geometries would perform in TSI tests. The Reynolds number in moving model experiments is lower compared to full-scale. Especially the limited model length leads to a thinner boundary layer at the rear end. The hypothesis is that the boundary layer rolls up to characteristic flow structures in the train wake, in which the maximum flow velocities can be observed. The idea is to enlarge the boundary layer using roughness elements at the train model head so that the ratio between the boundary layer thickness and the car width at the rear end is comparable to a full-scale train. This may lead to similar flow structures in the wake and better prediction accuracy for TSI tests. In this case, the design of the roughness elements is limited by the moving model rig. Small rectangular roughness shapes are used to get a sufficient effect on the boundary layer, while the elements are robust enough to withstand the high accelerating and decelerating forces during the test runs. For this investigation, High-Speed Particle Image Velocimetry (HS-PIV) measurements on an ICE3 train model have been realized in the moving model rig of the DLR in Göttingen, the so called tunnel simulation facility Göttingen (TSG). The flow velocities within the boundary layer are analysed in a plain parallel to the ground. The height of the plane corresponds to a test position in the EN standard (TSI). Three different shapes of roughness elements are tested. The boundary layer thickness and displacement thickness as well as the momentum thickness and the form factor are calculated along the train model. Conditional sampling is used to analyse the size and dynamics of the flow structures at the time of maximum velocity in the train wake behind the train. As expected, larger roughness elements increase the boundary layer thickness and lead to larger flow velocities in the boundary layer and in the wake flow structures. The boundary layer thickness, displacement thickness and momentum thickness are increased by using larger roughness especially when applied in the height close to the measuring plane. The roughness elements also cause high fluctuations in the form factors of the boundary layer. Behind the roughness elements, the form factors rapidly are approaching toward constant values. This indicates that the boundary layer, while growing slowly along the second half of the train model, has reached a state of equilibrium.

Keywords : boundary layer, high-speed PIV, ICE3, moving train model, roughness elements
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