World Academy of Science, Engineering and Technology
International Journal of Sport and Health Sciences
Vol:18, No:02, 2024

Computational Fluid Dynamics Analysis of Sit-Ski Aerodynamics in Crosswind Conditions

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Abstract : Sit-skis enable individuals with limited lower limb or core movement to ski unassisted confidently. The rise in popularity of the Winter Paralympics has seen an influx of engineering innovation, especially for the Downhill and Super-Giant Slalom events, where the athletes achieve speeds as high as 160km/h. The growth in the sport has inspired recent research into sit-ski aerodynamics. Crosswinds are expected in mountain climates and, therefore, can greatly impact a skier's maneuverability and aerodynamics. This research investigates the impact of crosswinds on the drag force of a Paralympic sit-ski using Computational Fluid Dynamics (CFD). A Paralympic sit-ski with a model of a skier, a leg cover, a bucket seat, and a simplified suspension system was used for CFD analysis in ANSYS Fluent. The hybrid initialisation tool and the SST k–ω turbulence model were used with two tetrahedral mesh bodies of influence. The crosswinds (10, 30, and 50 km/h) acting perpendicular to the sit-ski's direction of travel were simulated, corresponding to the straight-line skiing speeds of 60, 80, and 100km/h. Following the initialisation, 150 iterations for both first and second order steady-state solvers were used, before switching to a transient solver with a computational time of 1.5s and a time step of 0.02s, to allow the solution to converge. CFD results were validated against wind tunnel data. The results suggested that for all crosswind and sit-ski speeds, on average, 64% of the total drag on the ski was due to the athlete's torso. The suspension was associated with the second largest overall sit-ski drag force contribution, averaging at 27%, followed by the leg cover at 10%. While the seat contributed a negligible 0.5% of the total drag force, averaging at 1.2N across the conditions studied. The effect of the crosswind increased the total drag force across all skiing speed studies, with the drag on the athlete's torso and suspension being the most sensitive to the changes in the crosswind magnitude. The effect of the crosswind on the ski drag reduced as the simulated skiing speed increased: for skiing at 60km/h, the drag force on the torso increased by 154% with the increase of the crosswind from 10km/h to 50km/h; whereas, at 100km/h the corresponding drag force increase was halved (75%). The analysis of the flow and pressure field characteristics for a sit-ski in crosswind conditions indicated the flow separation localisation and wake size correlated with the magnitude and directionality of the crosswind relative to straight-line skiing. The findings can inform aerodynamic improvements in sit-ski design and increase skiers' medalling chances.

Keywords : sit-ski, aerodynamics, CFD, crosswind effects
Conference Title : ICASEST 2024 : International Conference on Advances in Sports Engineering and Sports Technology
Conference Location : London, United Kingdom
Conference Dates : February 12-13, 2024