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VEHICLE AERODYNAMIC EFFECTS OF REALISTIC TRANSIENT WIND CONDITIONS

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Realistic turbulent flow conditions, typical for highway driving, can have a significant effect on vehicle aerodynamic performance. This is an important topic for the vehicle aerodynamics community, and is attracting increasing attention. For example, most wind tunnels used for aerodynamic optimization have upstream turbulence intensity levels of around 0.3% or less. On the other hand, the typical atmospheric turbulence in regions where vehicles will be traveling is much higher, even on a relatively non-windy day. Natural wind turbulence intensity levels of 1-5% are common [1]. The effects of wind and environmental turbulence on the vehicle aerodynamics were provided in several studies [2], [3], [4], and [5].

On-road wind velocity measurements show that in the presence of ambient wind or upstream vehicles, turbulence is seen with amplitudes often up to 10% of the vehicle driving speed, measured using the standard deviation of velocity component fluctuations. The turbulent flow structures have a dominant length scale near the size of the vehicle, *e.g.*, 1-10 m, measured using the integral turbulence length scale. These turbulent flow structures cause a significantly non-uniform flow environment for the vehicle and disrupt many of the most important flow features around the vehicle, such as wakes, attached vortices, under body separations and impingements, and backlight separation. These features are intentionally affected by design changes made by aerodynamicists during the vehicle development process in order to optimize aerodynamic performance.

In this paper, a Jaguar XJ sedan is tested using transient aerodynamics simulations with realistic onset flow conditions. The impact of upstream turbulence on the aerodynamic performance is evaluated, and analysis of the key separated flow structures on the vehicle shows the regions of influence of the realistic turbulent conditions. The application of transient simulations using non-uniform flow conditions presented in this study provides a method for evaluating vehicle development decisions against a broader range of operating conditions than can be used in traditional wind-tunnel testing.

A way to compare the unsteadiness of the flow-field for both baseline case and the case with higher upstream turbulence is to calculate the isosurfaces of velocity standard deviations as well as turbulence intensity. Figure 1 shows these isosurfaces for a value of 15%, about twice that of the upstream turbulence values. It is clear that adding upstream turbulence increases the unsteadiness of the whole wake. On the baseline case it can be seen the voids in the isosurface, which correspond to the stable trailing vortices. In general, it can be stated that the upstream turbulence's main effect is not a linear increase of the overall flow-field turbulence energy, but more of a filling in of the baseline regions of low intensity. Basically, upstream turbulence increases the low turbulence areas more than it increases the high turbulence areas, and in doing this changes some of the wake dynamics and proves disruptive enough to diminish the strength of the trailing vortices and generate a more isotropic wake.

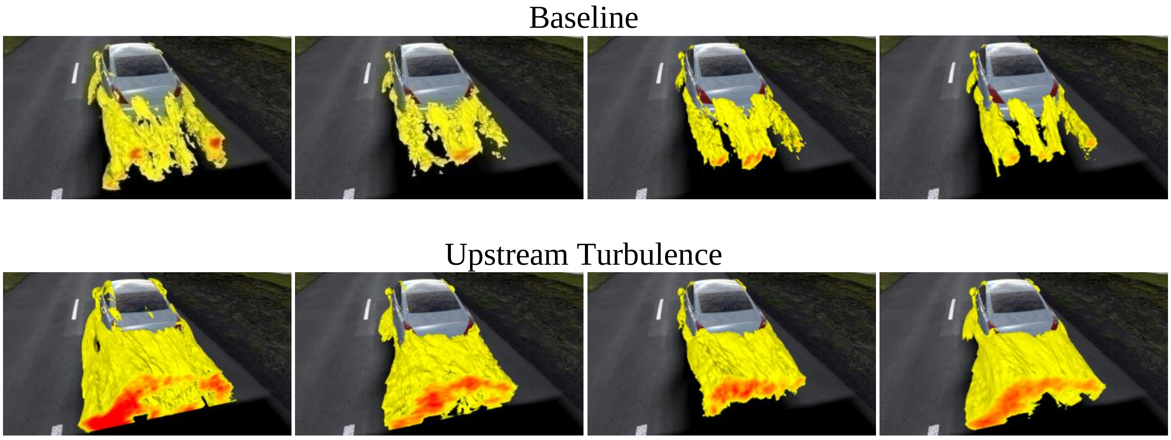

Figure 1. Velocity fluctuations in the region around the vehicle are shown using isosurfaces of turbulence intensity. From left-to-right the images show X-velocity fluctuations (*Ix*), Y-velocity fluctuations (*Iy*), Z-velocity fluctuations (*Iz*), and total turbulence intensity (*I*), each with value 15%. The lack of symmetry in the wake is due to low-frequency fluctuations coming from the upstream turbulence.

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