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UNIVERSITY OF SOUTHAMPTON

ABSTRACT

FACULTY OF ENGINEERING AND APPLIED SCIENCES

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Doctor of Philosophy

THE AERODYNAMICS OF A DIFFUSER EQUIPPED BLUFF BODY IN GROUND EFFECT

by Andrea Elizabeth Senior

An investigation of the flow physics of a diffuser equipped bluff body in ground effect has been undertaken. Situated at the rear of a racing car undertray, the diffuser is an important component and the least understood part of the vehicle. Diffuser performance can change dramatically with vehicle ride height. This includes a significant loss in performance at low ride heights which can also be a serious vehicle safety issue. An increased understanding of the diffuser behaviour in ground effect is required to assist design improvements. An accurate experimental database of the flow field is necessary both to aid this understanding and also to provide information against which the continuing development of computational simulations may be assessed.

The present research is two-fold; experimental and computational. Model tests were conducted on a generic 3D bluff body equipped with a fixed angle diffuser representative of current racing car diffusers. Extensive experimental tests in wind tunnels equipped with moving belts included mean forces, surface pressures, oilflow visualisation, laser doppler anemometry and particle image velocimetry. The 3D diffuser flow field has been measured for the first time and the results are used to analyse the behaviour of the diffuser in ground effect. Complementary RANS simulations provide valuable insight into the modelling requirements.

It is known that the diffuser generates down-force by accelerating air underneath the model through the channel formed by the model underside and the ground. The diffuser flow is characterised by a counter rotating vortex pair. The present research presents a new understanding of the diffuser flow field and the mechanisms causing its behaviour in ground effect. It has been found that the behaviour of the vortices alters according to the model ride height and the pressure gradient inside the diffuser. Additional down-force is generated due to the low pressure zones associated with these vortices. At relatively large ground clearances, the vortices are coherent and strong with a high axial speed core. At these heights the down-force experienced by the model increases with reducing model ride height. This behaviour is terminated at lower ground clearances by the advent of a plateau in the down-force curve and the occurrence of breakdown in the vortices inside the diffuser. The vortex breakdown results in large, diffusive and weak vortices. Maximum down-force on the model occurs at the lowest ride height of this type of flow at the end of the plateau. A sharp reduction in the down-force occurs thereafter, due to the complete breakdown of one of the vortices. The resulting asymmetric flow consists of a single coherent vortex to one side of the flow and significant flow reversal at the other side. At very low ride heights the vortices are asymmetric and weak

Down-force reduction is believed to occur as a result of the steep pressure gradient inside the diffuser which advances the vortex breakdown inside the diffuser upstream as the model ride height is reduced. At the point of down-force reduction one of the vortices breaks down completely. At very low ride heights the boundary layers at the model underside and at the moving ground are believed to merge to restrict flow through the diffuser inlet.

The experimental database is comprehensive and provides the necessary tool for validation of computational modelling. A computational simulation of the flow at a high ride height successfully predicts force and surface pressure coefficients and the main flow features.