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Experimental and Computational Investigation into Race Car Aerodynamics

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Forti Corse SLR Formula One Team - 1995 Monaco Grand Prix

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Synopsis[a]

Title:	Experimental and Computational Investigation into Race Car Aerodynamics
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In this study, experimental tests and Computational Fluid Dynamics are used to investigate the aerodynamic performance of two types of track-based racing cars. After the literature study, where automotive aerodynamics is discussed in very general terms, the air flow beneath a Formula One Grand Prix Racing Car is investigated. This is achieved by fitting the under-tray of a 30% scale model of the Parmalat Forti Ford FG01-95 with surface-static pressure ports and testing the model in a rolling-road wind tunnel. By varying a number of model parameters, it is found that the wheels significantly alter the pressure distribution under the floor of the racing car at positions away from the centre-line. It is shown that the front or rear wheel sets are independently sufficient to induce the flow changes. The addition of the other set then only produces milder and more local changes.

The numerical part of the floor investigation is aimed at reproducing the centre-line flow pattern by solving the full Reynolds-Average Navier-Stokes equations over a two-dimensional curvilinear grid of the isolated floor. Two algorithms, Roe's flux-difference splitting method and the commercial package, STAR-CD which employs the SIMPLE algorithm and a two-equation turbulence model, are used to solve the governing equations. It is found that although the correct trends are observed when two different ride heights are simulated, absolute correlation is inadequate despite the use of experimentally-controlled boundary conditions. The simulations are however used to demonstrate the saturation in downforce with increasing vehicle speed.

In order to improve numerical accuracy, a second study was launched where the effect of including the centre-line profile of the complete vehicle is investigated. To reduce the amount of detail a 1/12th scale model of a generic BMW Touring Car is used. Experimental data in the form of centre-line surface-static pressure coefficients are used for numerical correlation. The data is obtained by testing the three-dimensional model in a wind tunnel fitted with a stationary-road raised-platform floor. To establish continuity, the experimental data is used to show the similarities between the pressure distribution on the centre line of the open-wheel and the closed-wheel racing car. The effect of a rear-mounted aerodynamic device on the downforce is also discussed.

The numerical investigation using the SIMPLE algorithm of STAR-CD and three high Reynolds-Number turbulence models, is based on the centre-line profile of the experimental model. It is seen that although qualitative correlation exists in areas around the car, quantitative agreement is less positive. Discrepancies are found to be most significant under the floor. It is shown that the influence of the three dimensional flow field on the experimental results are unlikely to cause satisfactory correlation. It is suggested that, in order to improve correlation, a new investigation is launched aimed at refining the numerical model. An outline for the new study is presented and includes simulations indicating the dependence of the computational solution on the density of the grid and on the user-definable turbulence parameters.

Key Words:
Aerodynamics, Automotive, Racing Car, Road Vehicle, Formula One, Touring Car, Wind Tunnel, STAR-CD, Navier Stokes, Computational Fluid Dynamics

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[a] To fulfil the requirements as laid down by the University of Pretoria, the synopsis is repeated in Afrikaans on the next page.

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Opsomming

Titel:	Experimental and Computational Investigation into Race Car Aerodynamics
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In hierdie studie word eksperimentele toetse en Berekeningvloeidinamika gebruik om die aërodinamiese werkverrigting van twee tipe baangebonde renmotors te ondersoek. Na die literatuurstudie, waar voertuig aerodinamika in breë terme bespreek word, word die lugvloei onder die vloer van 'n Formule Een Grand Prix renmotor ondersoek. Hier word die vloer van die 30% skaalmodel van die Parmalat Forti Ford FG01-95 met oppervlak statiese druktappunte ge-instrumenteer en dan in 'n rolvloer windtonnel getoets. Deur 'n aantal model-parameters te varieer is daar gevind dat die wiele die drukverdeling onder die vloer beduidend verander by posisies weg van die voertuig middellyn. Dit word getoon dat die voorste of agterste wiele die karakteristieke vloei veranderinge op hulle eie induseer. Die ander stel wiele veroorsaak dan slegs kleiner en meer lokale veranderinge.

Die doel van die numeriese gedeelte van die vloerondersoek is om die middellyn-vloeipatroon weer te gee deur die volle Reynolds-Getal Navier-Stokes vergelykings oor 'n twee dimensionele kromlynige rooster van die geïsoleerde vloer op te los. Twee algoritmes, Roe se "Flux difference splitting" metode en die komersiële pakket STAR-CD wat die SIMPLE algoritme en 'n twee vergelyking turbulensie model word toegepas, om die vloei op te los. Daar word vasgestel dat alhoewel die korrekte drukpatrone waargeneem word wanneer twee verskillende rithoogtes gesimuleer word, die absolute korrelasie onbevredigind is ten spyte van eksperimenteele beheerde grenstoestande. Die simulasies word egter wel gebruik om die versadiging in afwaartse krag met toenemende voertuigspoed te demonstreer.

Om die numeriese akuraatheid te verbeter is 'n tweede studie geloods waar die effek van die totale middellyn op die simulasies ondersoek word. 'n 1/12^de^ skaalmodel van 'n generiese BMW "Touring Car" word vir die doel aangewend. Die numeriese simulasies word gekorreleer deur middel van ekprimenteel bepaalde middellyn oppervlak-statiese-drukkoëffisiëntte. Die data word verkry deur die drie-dimensionele model in 'n windtonnel, toegerus met 'n verhewe-platform statiese vloer, te toets. Die eksperimentele data word eerstens gebruik om kontinuïteit met die eerste studie te bevestig deur korrelasie tussen die middelyn drukprofiele van die geslote-wiel en die oop-wiel renmotors aan te toon. Laastens word die effek van 'n agter-gemonteerde aerodinamiese installasie op die agter afwaartse krag bepreek.

Die numeriese ondersoek gebruik die SIMPLE algoritme van STAR-CD en drie hoë Reynolds-getal turbulensie modelle om die middellyn van die eksperimentele profiel te simuleer. Dit word getoon dat alhoewel kwalitatiewe korrelasie in sekere areas bestaan, die kwantitatiewe korrelasie nie so goed is nie. Die mees beduidende verskille word onder die vloer aangetref. Dit blyk onwaarskynlik dat die effek wat die drie-dimensionele vloeiveld op die ekpsrimentele reslutate het, die oorsaak hiervan is. Dit word voorgestel dat 'n nuwe studie geloods word met die doel om die numeriese model te verbeter. 'n Raamwerk vir die nuwe ondersoek word voorgelê, waar verdere simulasies die afhanklikheid van die oplossings aan die digtheid van die rooster asook die gebruikers-definieerbare turbulensie parameters aan toon.

Sleutelterme:
Aërodinamika, Voertuig, Renmotor, Padvoertuig, Formule Een, Touring Car, Windtonnel, Navier Stokes, STAR-CD, Berekeningsvloeidinamika,

TABLE OF CONTENTS