Fundamental Fluid Dynamics Relevant to Road Vehicle Aerodynamics (RVAD)

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Figure 1. McLaren F1 driven under wet conditions.

1. Introduction

Road vehicle aerodynamics (RVAD) is one branch of fluid dynamics in which much knowledge has been gained empirically through experiments and quit straightforward theoretical discussions. However, new legislations, increasing fuel prices and customer demands have increased the requirements of more aerodynamically optimized vehicles. Together with new facilities in terms of large wind tunnels and the fast development of both computers and numerical methods it is today possible to take one step further in the vehicle optimization. Figure 1 show a McLaren F1 driven under wet conditions, and the spray formation around the car yields an excellent visualization of the complex flow field created. This flow field may be characterized as un-steady, three-dimensional and to a large extent separated. In order to understand and control these phenomena it is a necessity to link these complex flow patterns to the fundamental governing equations of fluid mechanics and in this process fully understand the constraints necessary and the boundary conditions used. In figure 2, the flow around a cylinder, a wing profile and a flat plate perpendicular to the flow direction are shown. These flow cases are good examples of general and fundamental flow patterns where concepts like incompressibility, boundary layers and separation are of significant importance for the flow development. These flow patterns have also been studied in great detail through the years, and a central issue today is to transfer this fundamental knowledge into RVAD.

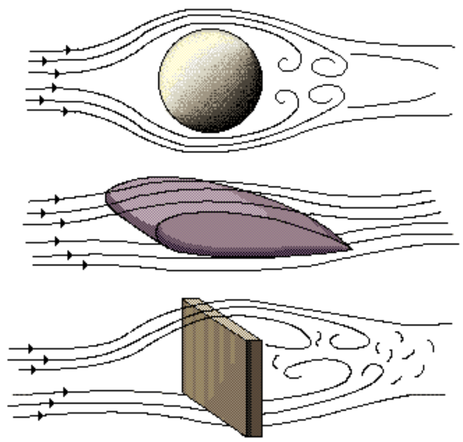

Figure 2 Three fundamental flow cases.

The objective of this lecture is to briefly summarize the governing equations of fluid dynamics and their restrictions, to simplify the equations from a RVAD perspective and to discuss a few fundamental issues of importance in RVAD. However, it is out of the scope to make any detailed derivations of the governing equations, since this has already been done in ordinary textbooks on the subject. Good examples of such are the introductory books by Tritton [1] or Crowe [2], and the more advanced treasuries by Panton [3] or Batchelor [4]. In spite of this, some equations will be needed for the discussions and these equations are accordingly given in their most common form. Coordinates, velocities and constants used are defined following the simple nomenclature of fluid dynamics, i.e. x,y,z are the Cartesian coordinates in the streamwise, normal and spanwise directions, respectively, and u,v,w are the associate velocities. Necessary constants like density (ρ), dynamic viscosity, (μ), and kinematic viscosity, (ν), are introduced when needed. Also included in the lecture is a discussion on the boundary layer approximations, the fundamental criteria for flow separation and some basic definitions used in wing theory. To close the lecture, some of the flow phenomena occurring in the flow a round a rotating wheel are considered in terms of the governing equations and their restrictions.

2. Basic Assumptions

All flows considered in RVAD obey the continuum hypothesis; in short, this means that there is always a value in the flow field of all quantities considered like pressure, temperature or density, and that the behaviour of single molecules should not be considered. In addition, no discontinuities are accepted and it is assumed that it is possible to linearize the change in one quantity like velocity or pressure from one point to another. These assumptions, which are formulated much more strictly in e.g. Panton [3], are cornerstones in the derivation of the