CHALLANGES AND LIMITATIONS OF CFD IN ROAD VEHICLE AERODYNAMICS

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1. INTRODUCTION

Computational Fluid Dynamics, or CFD, has been used in most automotive industries around the world for about two decades. Although each car company uses the results of CFD to a different extend which suits their specific vehicle program development, it can be said that CFD is considered today, an indispensable tool in the design and optimization process of both the upper and the under body of a vehicle. At Volvo, CFD is an integral part of all car programs, from the early pre-concept phase to the late verification of production status. With management decisions and requirements of short lead-times and reduction of costs, the role and importance of CFD in industry is yet to grow.

We regard specifically to Volvo Car Corporation, CFD contributes to the product development process in the following areas: external aerodynamics, aero-acoustics, soiling or dirt and snow deposition, cooling air flow, thermal management of engine bay components, brake cooling systems, climate systems, and engine combustion. Reasons for using CFD in such large areas of fluid dynamics applications vary from the need of reduction of costs and lead time, to supporting and complementing experimental results with the advantage of visualization of the complete flow field, access to comprehension of flow phenomena in difficult areas such as the interior of an engine and the under body where measurements are practically impossible.

Being such a relatively new tool and with such large area of application, CFD has several challenges and limitations to overcome in order to further establish a strong position of its usage in the vehicle industry. It is the author's opinion and choice, based on personal experiences, to classify these challenges and limitations into two major categories, named: short lead-time and accuracy. In order to save product development costs, more and more management decisions demand shorter lead-time and effectiveness on the pre-concept and concept phases which, in its turn, pressure the use of virtual development tools, such as CFD. At the same time, confidence in the results obtained by any virtual method is strongly depended on its accuracy of prediction of the necessary values or relevant parameters compared to the equivalent results obtained in physical tests, for example, in a wind tunnel. High confidence on numerical results means extensive usage of these results with the purpose of influencing the final product. This meaning that there is no real value on performing numerical simulations and generating results only for the sake of it.

In order to understand the challenges and limitations of CFD that we face today in the area of application Road Vehicle Aerodynamics, RVAD, this paper will be structured in the following manner: Firstly, a brief look at the advances made over the two decades in which CFD has been used in the vehicle industry will presented. Secondly, an analysis of the general limitations and difficulties of performing numerical simulations in industry due to both hardware and software constrains will be examined. Thirdly, the present and future challenges of CFD applied to properties of interest of the vehicle industry will be discussed. And finally, the author will conclude this lecture with some final remarks.

2. BRIEF HISTORY OF CFD APPLIED TO RVDA AT VOLVO CAR CORPORATION

It is the believe of this author that a good representation of the evolution of CFD applied to industrial vehicle aerodynamics can be accomplished by shortly presenting the history of development of CFD at Volvo Car Corporation. Although CFD started at Volvo concern in late 80's, it is not until early 1991 that a CFD Group is officially formed and recognized. The early tasks of the group, initiated by Dr. Mats Ramnefors, were primarily related to the aerodynamic evaluation of existing models and a few new design proposals. Today, almost 15 years later, the group is responsible for several others fluid dynamic applications besides external aerodynamics, such as: aero-acoustics, cooling air flow, engine bay component temperature, soiling (dirt and snow deposition), brake cooling, and climate systems.

2.1 Late 1980's:

Basically, only two-dimensional (symmetry line), steady-state computations of the Navier-Stokes equations were performed. Time was also spent looking at the possibility of using panel methods, similar to what was done in aeronautics.

<u>Computer resources:</u> 1 HP725 with 32 MB.

2.2 1991 to 1993:

In 1991, the first three-dimensional external flow calculation on a Volvo car model was performed. The mesh generation of 100000 to 200000 cells took weeks to be completed and the cost of the run on an IBM computer corresponded to the cost of a workstation. At the time, it was estimated that lead-time for building a mesh, performing an external flow computation and analyzing the results was around 4 months. The model was quite simplified, having no cooling flow, no wheels nor wheelhouses and a flat underbody. A steady-state formulation and a high-Reynolds turbulence model were used. The goal at the time was to compute the drag coefficient with an accuracy of ±0.010 on a basic car model without the wheels or other detailing. No lift coefficients were calculated since the geometry was too simplified. Figure 1 shows an example of an early mesh constructed on a Volvo 850, taken from ref. [1].

With investments in new softwares and hardware in 1993, the time for mesh generation, computation and evaluation of an exterior model decreased to six weeks. Of this time, mesh generation took between one to two weeks; while the rest of the time was spend on computation and analysis. This time reduction made possible for CFD to be used in the early stages of car development process at Volvo Cars.