The Three Waves of Commercial CFD

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In recent years, many papers have been published on the history of flow simulation. Many early CFD pioneers like Brian Spalding, David Tatchell, Ferit Boysan and Michael Engelman have talked or written about their memories. This pool of historical facts, technical information and personal impressions give a remarkably consistent description of the way engineering simulation software evolved from academic research codes towards the modern CFD products we know today. Developed and supported on an industrial scale by multinational software companies.

Closely linked to the performance of available computing hardware, this development was, particularly in the early stages, driven primarily by research and development projects for aerospace and defense, but latterly also increasingly by interest from civilian industry. Looking back, three major phases of the development of CFD software for industrial applications can now be recognized:

- The First Wave: The beginnings of commercial CFD software in the 70s and 80s.
- The Second Wave: In the 90s, CFD enters the research and development departments of large industrial enterprises.
- The Third Wave: After the millennium, CFD becomes an indispensable part of the product development process.

The First Wave: The beginnings of commercial CFD software

Since 1958 the codes of the CFD software engineers in the first phase had its roots in the work of the Fluid Dynamics Group T-3 at the Los Alamos National Laboratory (USA), and the research activities under Prof. D. B. Spalding at Imperial College London in the 1960s and 1970s.

In the late 1960s, Concentration, Heat and Momentum (CHAM) Ltd., founded by Spalding, and initially located at Imperial College London, dealt with consulting work. The era of commercial CFD software began in 1974, when CHAM Ltd moved to its own offices in New Malden near London. Initially, the development of customized CFD codes was central to the business activities of CHAM. That became too time-consuming and inefficient, so CHAM decided to develop a general-purpose CFD package for in-house consultancy work, and released this as a commercial product, PHOENICS, in 1981. This may well be regarded as the birth of the CFD software industry (see CHAM Ltd, 2008). Others quickly followed suit. For instance, Fluid Dynamics International (USA) followed in 1982 with FIDAP, a FEM-based CFD package, and in 1983 Creare Inc (USA) released the finite-volume CFD code, Fluent. Computational Dynamics/ADAPCO (UK/USA), co-founded by Prof. David Gosman, another professor at Imperial College London, released StarCD in 1989.

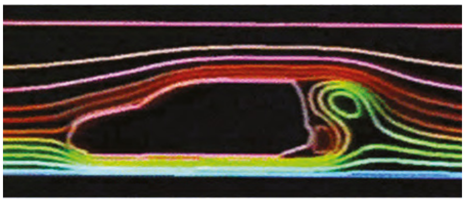

Figure 1. Fluid flow simulation in the 1980s, taken from Hanna & Parry (2011)

The basic technologies behind most of the CFD packages of this era had been created by former employees or guest scientists of the two aforementioned research institutions in London and Los Alamos, or were based on their scientific publications. But there were also other developments of CFD technology: in the 1980s alternative approaches for CFD simulation emerged as part of the military and civilian aviation and space program of the former Soviet Union, largely unnoticed by the Western scientific community due to the political situation. Their technical tasks for CFD simulations were similar to those in the West, but the available computing resource for their solution was much more limited. Conversely, because of the high political priority of these research programs, very extensive experimental data for numerous fluid flow and heat transfer phenomena, especially in the near-wall area, were generated. This situation led to the development of alternative CFD methods, which, building on known methods for

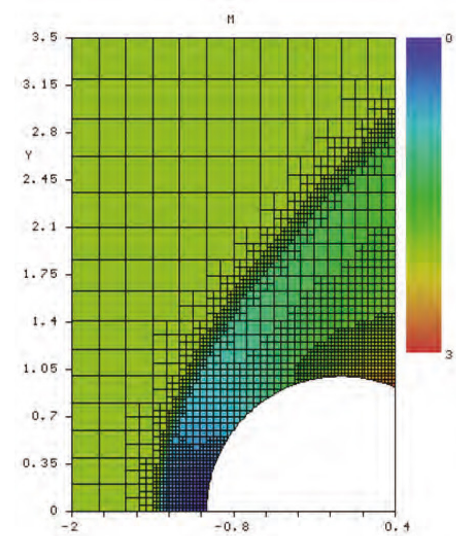

Figure 2. Result plot of Aeroshape-3D (Parry et al., 2012)

Cartesian grids as published in the scientific publications in the West, were based on a combination of numerical, analytical, and empirical data. This innovative approach yielded high-quality simulation results in virtually, arbitrarily complex computational domains while maintaining the low resource requirements and the effectiveness of methods using Cartesian grids. With the gradual economic liberalization in the Soviet Union in the late 1980s, several teams of scientists have commercialized this CFD technology and, since the early 1990s, sold their products and services in Europe and Asia. The best known products of this kind were Aeroshape-3D by Prof. V. N. Gavriliouk and team (Petrowa, 1998 & Alyamovskiy, 2008) and FlowVision by Dr. A. A. Aksenov and team (Aksenov et al., 2003).

From the beginning of the 1990s, the conditions for CFD software and simulations changed quite rapidly. Computer hardware, mathematical methods and physical models all experienced huge performance gains. Numerical methods such as unstructured Finite Volume methods, multi-grid methods, sliding mesh, etc., suitable for complex geometry and optimized for HPC, became commercially available as well as more reliable, more flexible and more broadly applicable physical models. CFD technology became much more feasible, and for the first time, quite realistic model sizes, for real industrial applications were possible. These new capabilities heralded a new phase in the usage of commercial CFD software - entry into the research and development departments of industry across the board.

The Second Wave: CFD enters the Research and Development Departments of the Industry

Using technology typical of the first phase, Flomerics Ltd., founded in 1988 by David Tatchell and Harvey Rosten in Kingston-upon-Thames (UK), played a pioneering role in marketing CFD software developed exclusively for industrial applications with its software package FloTHERM, first released in 1989. Both founders worked for CHAM Ltd in senior positions before leaving to found Flomerics, with the aim of “providing good science to industry” (Tatchell, 2009). FloTHERM was a first paradigm shift in the CFD industry, away from the focus on complex CFD technology, towards the solution of engineering tasks in industry as the central goal. This also meant that from then on engineers working in product development, and not scientists, were the main target users of this type of CFD software. The available CFD technology, computer hardware and operating systems imposed certain limits on such an innovative approach. Therefore Flomerics concentrated initially on only two application areas: electronics cooling (with FloTHERM) and built environment HVAC (with FloVENT). The requirements of engineering-oriented CFD software for these application areas were relatively clearly defined and, more important, also just feasible.

This concept opened up completely new market opportunities, because for the first time engineers in product development without special knowledge of numerical methods and without extensive CFD experience were empowered to employ CFD simulations as a development tool. The solution of a technical engineering task became the center of attention, while the underlying CFD technology was more or less just a means to an end.

Obviously, other CFD providers also recognized the beginning of this paradigm shift and especially the new business opportunities associated with it, responding to this trend with their own product offerings. Overall, huge investments from all CFD software vendors in better user interfaces, robust solvers and reliable physical models could be observed, with the clear objective of entrenching CFD into the research and development departments of large industrial enterprises and thereby attracting a new generation of CFD users.

After establishing CFD as a successful tool for the functional design, verification and optimization of product designs, features, processes and physical effects in large industrial companies in the early 2000s, the reputation of this technology amongst engineers improved significantly. As a result, the demand for CFD simulations showed strong growth, especially in medium-sized and small companies keen to reduce the costs associated with physical prototypes. Another important aspect was the need to integrate CFD simulation into the regular product development process, as these companies usually had as yet no

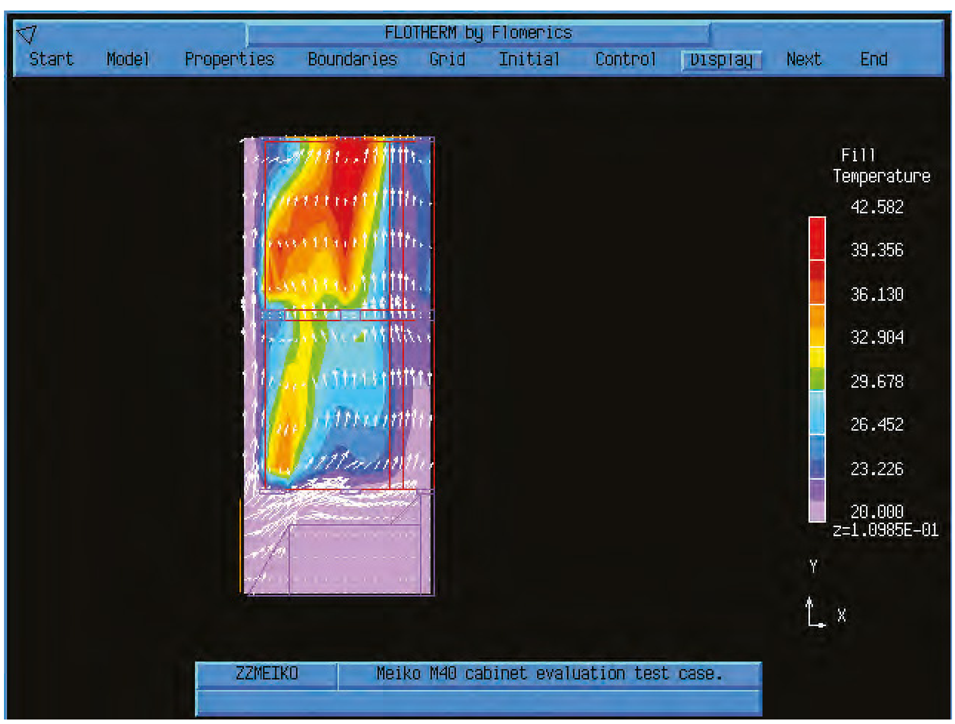

Figure 3. Early version of FloTHERM (Hanna & Parry, 2011)

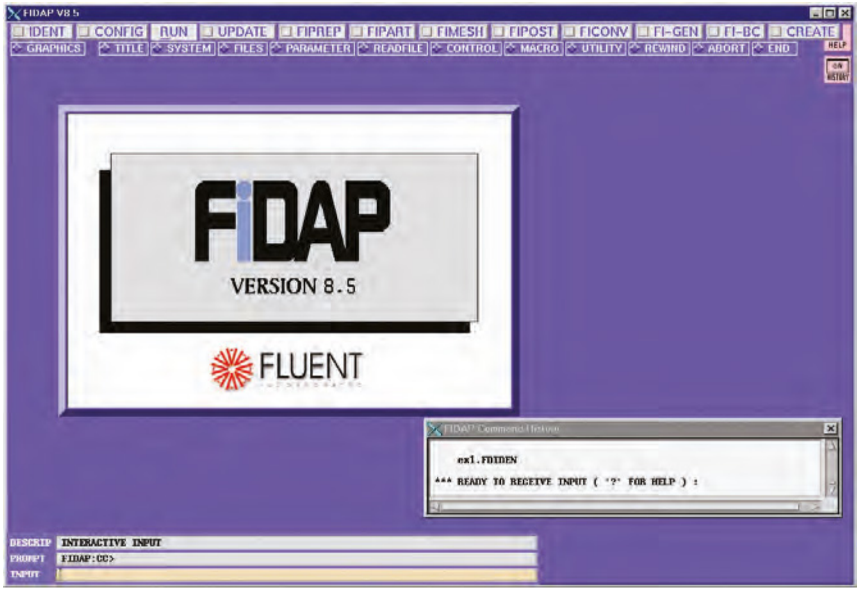

Figure 4. FIDAP User Interface in the late 1990s (University of Delaware, 2007) URL

dedicated simulation departments. This meant that qualified engineers from product development or design groups would perform the simulation themselves. The efficiency with which simulation projects were conducted had to be increased, so CFD results would be available sufficiently in sync with the product design cycles, for the results to help guide proposals for design improvements. In this context the handling of industry-level geometry played a key role. At that time this was already being provided as 3D CAD data which should, of course, be used with as little simplification and modification effort as possible to be useable by the subsequent and preferably fully-automated mesh generation step. The CFD software market responded to these demands with new and improved products – and a third wave of CFD software for industrial product design began and continues to this day.

The Third Wave – CFD Becomes an Essential Element of the Product Design Process

The major CAD and Product Lifecycle Management (PLM) vendors play a key role in this third phase. Since the 1990s, they have been successfully introducing the concept of PLM, which encompasses CAE. As a result, customers have put pressure on commercial CFD software vendors to conform to this concept and to take steps to integrate their products into the major PLM systems. In the 2000s, virtually all CFD software providers upgraded their systems with, at the least, CAD import interfaces. Some have developed bi-directional links with major CAD/PLM systems, and a few have even embedded their CFD technology directly into the 3D CAD systems themselves. New CFD techniques to support these requirements were also developed, partly from scratch, and partly as enhancements of existing technology.

The company NIKA GmbH, founded in 1999 as a German-Russian joint venture, was a typical example of a new commercial CFD software vendor emerging at the start of this third wave. NIKA exclusively developed, based on the above mentioned Aeroshape-3D technology, CAD embedded CFD software, which is now offered as FloEFD for several major 3D CAD systems.

The current third wave has allowed newcomers from other areas the opportunity to enter the CFD market, refreshing it with new technologies. But all have one thing in common: The industrial user, with his or her need for easy-to-use, task-oriented, automated, reliable, efficient and readily-available CFD software as an indispensable tool for digital prototyping is the focus. The result of changing development processes and, as a consequence, the changing role of the simulation engineer. Aspects like process integration, reliability, modeling safety, and reproducibility are becoming the center of attention, and influence purchasing decisions for CFD software. The further development of CFD software based around these requirements will bring exciting new technologies and products to market. A new fourth wave may be expected to follow soon…watch this space.

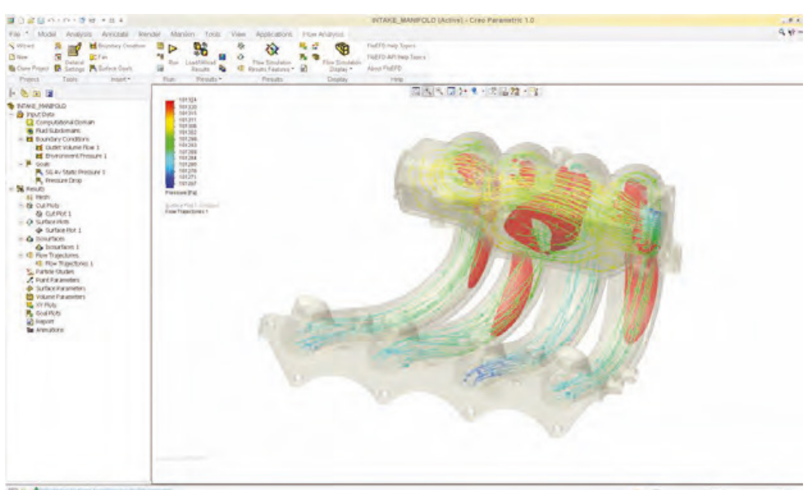

Figure 5. FloEFD for Creo by Mentor Graphics

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