CFD FOR MECHANICAL DESIGN ENGINEERS
"A PARADIGM SHIFT FOR BETTER DESIGN"

PRODUCED BY CIMDATA, INC., SEPTEMBER 2009

WHITEPAPER

Mentor Graphics®

MECHANICAL ANALYSIS

There is demonstrated, real value in using CFD to analyze products earlier in the product development lifecycle than has been possible under the common scenario of reserving this important analysis regimen for CFD specialists. Mentor Graphics' FloEFD solution allows companies to make this paradigm shift by providing an accessible CFD solution that can be used by engineers and designers who are not specially-trained in complex CFD practices. Embedding CFD analysis within the normal design environment (CAD) further enhances the value of this solution, allowing it to be used throughout the product definition lifecycle to guide decision-making and product validation. This brings value to the company by promoting more innovative, higher-quality product designs accomplished in less time.

1. INTRODUCTION

This paper provides CIMdata's perspective on Computational Fluid Dynamics (CFD) analysis; the motivations for its use, its value and future, and the importance for making CFD available to all engineers earlier in the product design/development lifecycle. It also describes Mentor Graphics' FloEFD CFD analysis solution that is designed to provide product designers and engineers with direct access to CFD techniques directly in their design (CAD) environment. The following sections address:

- *CFD Market Drivers*—a brief review of the challenges that affect, and impacts from the early use of CFD within an overall Product Lifecycle Management (PLM) strategy.
- *Value of Earlier Use of CFD*—a brief discussion of the benefits associated with early use of CFD.
- *Mentor Graphics' Approach and CFD Solution*—how FloEFD enables early use of CFD by designers.
- *Summary and Concluding Comments*—a brief summary of the paper along with concluding remarks.

2. CFD MARKET DRIVERS

Companies are striving to design innovative products while reducing the cost of product development and time to market. The pace of product innovation has also increased dramatically and is a primary contributor to companies' overall profits and market share. Factors companies must address include increasing product complexity, the time and cost to create physical prototypes, and a lack of resources that can perform required analyses and simulations.

In a recent survey of companies producing a wide range of products, mechanical design engineers and their managers cited the following factors as creating the greatest pressures on engineers[1]:

- 29% creating more functional products
- 26% faster time to market
- 25% creating more reliable products
- 18% reducing product costs

Product complexity continues to increase as engineers' abilities to develop more diverse products improve and as consumers demand more capabilities and personalization in what they buy. Complexity comes in many forms, including the embedding of electrical and software components in more products than was possible in the past. Products must also be more ergonomic and environmentally efficient. For example, reducing the cost of using a product (e.g., using less fuel to run an automobile) is requiring designers and engineers to perform more and more sophisticated analyses earlier in the development process.

These factors present major challenges to product designers to create new and more imaginative products more quickly than has been typical, speed to market being critical to profitability. They want tools that enable them to

[1] *EFD customer requirements survey sponsored by Flomerics*

conduct more comprehensive analyses earlier in the development lifecycle. That capability helps them explore more product design options, thus developing the most competitive product while avoiding poorly functioning, faulty, or low-quality products. Product analysis, testing, and validation take on increasingly time-critical roles in assuring that products reach the marketplace without crippling design flaws.

Product validation during the design phase of products has historically been the responsibility of engineering analysis specialists. However, as the need for faster product development grows, the designers and product engineers have to be assured that their designs are progressing in a valid direction long before there is a complete product design. Therefore, they need ways to analyze and validate designs well before they can engage the analysis specialists.

For several years, tools have been available to help designers through structural and kinematic analyses. However, today's complex mechanical and electro-mechanical products increasingly require an understanding of cooling, hydraulics, and other fluid-flow issues. Performing comprehensive CFD analyses is key to ensuring that products perform as required. As product complexity continues to increase, CFD will need to be used by a broader range of designers and engineers.

2.1 CFD CHALLENGES

It is important to take advantage of lessons learned from implementing other major aspects of PLM so that the benefits of early use of CFD can be maximized.

When a large group of CATIA, Pro/ENGINEER, Inventor, and SolidWorks users[2] were asked why they didn't use CFD, the most common responses were (1) "most mechanical design engineers don't have the necessary expertise and knowledge to use a CFD code", and (2) "most mechanical engineers are not aware of what CFD can do for them." This reflects both a lack of education as to the value of CFD in designing better products, and the difficulty of using most CFD tools and solutions.

CFD analysis has historically been decidedly complex, requiring a great deal of CFD expertise to set up and run valid analyses. As well, the computer-based solutions that support CFD have been created with CFD experts in mind and have thus not been easy to use by non-experts, such as product designers and engineers. In order to expand the number of people that can perform CFD analyses, workflows must be developed that will guide and automate the CFD setup and analysis that in the past required a specialist's level of knowledge. This will guide engineers through the CFD process and ensure they follow CFD best practices.

As is true for many specialist-driven activities, knowledge of and accessibility to specialized CFD applications by a limited number of specialists has been a bottleneck in the product development process, especially when the specialists are not co-located with the product designers. Designers and engineers need to be given timely access to CFD tools so that they can use CFD earlier and more often in product development to achieve better design decisions faster.

To be effective, designers and engineers need to work in their normal environment and not have to learn new applications and user interfaces (UIs). Access to CFD should be embedded in their standard applications, e.g., either their CAD design tools or their PLM UI, and the CFD software should have the same look and feel of the user's main MCAD tool. Additionally, CFD solutions should share the same assembly tree hierarchy, etc., so the user is able to focus solely on the physical problem that he or she is trying to solve. Users must be able to seamlessly use CFD—setting up an analysis directly on their design geometry, executing it, and then reviewing the results while working within their native design environment.

[2] *ConnectPress Ltd. survey sponsored by Flomerics*

CFD information should be defined and managed within the overall PLM environment. CFD setups and results need to be captured and saved with product design configurations and versions, not only to assure that the data will be available in the future, but also to provide an audit-trail to support regulatory and legal compliance. Users should be able to find and re-use analysis inputs and then be able to compare the results of different analyses.

3. VALUE OF EARLIER USE OF CFD

There are many ways in which companies can benefit by using CFD early and frequently in their product development process. The overall opportunities for business value enhancement include:

- *Support Faster Design*—Allowing early simulation and evaluation of design decisions speeds up the design process and minimizes the unnecessary disruptions for the rest of the team that result when decisions are delayed until later in the process.
- *Improve Product Design*—Early and frequent use of CFD increases the likelihood that design issues will be discovered earlier, improving quality, and allowing more time for innovation and creating more compelling products. Designers and engineers can have a more complete and better understanding of design issues. They can make better design trade-offs earlier.
- *Avoid Rework*—Using CFD to validate designs helps avoid design errors that can result in very costly rework, especially when those errors are identified late in the product development process when they have much larger cost impacts.
- *Improve Quality*—Early analyses provide the information that allows designers to try more iterations, which can lead to better, higher-quality products that exceed customer expectations.
- *Reduce Prototypes*—Doing more frequent virtual analysis using CFD decreases the need for developing physical prototypes and running expensive physical tests—which can significantly reduce costs and decrease the time required to complete development.
- *Faster Time-to-Production*—Speeding up overall design time by improving communication, facilitating decision-making, and reducing errors allows products to be delivered to production earlier.

When engineers and managers were asked what were the most important benefits to the company from early and frequent use of CFD by design engineers, they replied[3]:

- 35% reduce prototyping and testing costs
- 22% improve product performance and functionality
- 17% reduce design time
- 15% reduce risk of design mistakes
- 5% improve reliability and lifetime
- 5% improve product efficiency

Each of these benefits is worth pursuing, but achieving any one of them requires not only the selection and implementation of a capable CFD analysis tool, but its implementation within an environment and process that assures that the tool is used to best advantage. The environment needs to be capable of managing both the product design (i.e., CAD) data including its variations and configurations as well as the test scenarios that are used to run CFD analyses and the results that are produced.

The process or workflow in which the CFD analyses are undertaken has to be well documented and must embody CFD best practices so that non-specialists can use CFD with confidence that the results are valid and appropriate.

[3] *EFD customer requirements survey sponsored by Flomerics*

Embedding the CFD process and data within a larger PLM environment will provide security and assure that it is available to those who need to use CFD.

The following figures illustrate the impact on the product development lifecycle due to the evolution to earlier and more frequent use of CFD during product development. Currently, CFD is performed after designs have been developed. There is a delay while it is being executed and the results are made available to the designers. During that time, design continues and that work may have to be redone based on the results of the analysis.

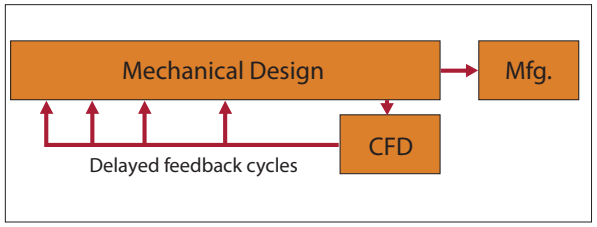

Figure 1—Product Development Delays Due to Late Analysis

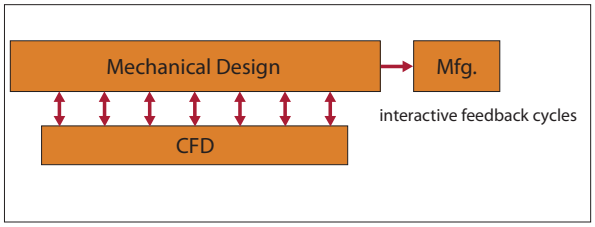

Figure 2—Frequent CFD Analysis Results in Shorter Product Development Times

In the future, early and frequent concurrent use of CFD by designers will enable them to explore more design options and make better decisions based on the results of the analyses—reducing the overall time of development and eliminating rework.

Another issue is that, as with all tools, the users of CFD need to be trained in how to execute the CFD process and when that process is appropriate in the context of their product designs.

4. MENTOR GRAPHICS' APPROACH AND CFD SOLUTION

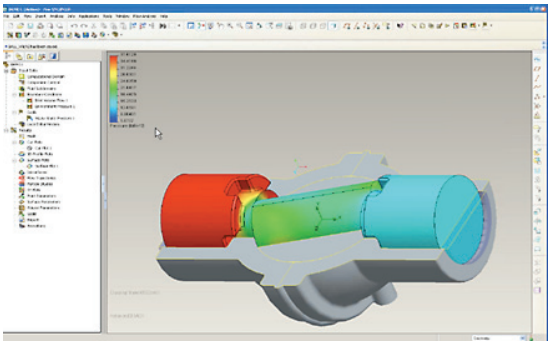

Figure 3—Near-Wall Pressure Shown in the Pro/ENGINEER Wildfire User Interface

Mentor Graphics has introduced a CFD solution that is targeted directly at designers of mechanical systems as well as electro-mechanical products. FloEFD is the result of Mentor Graphics' 2008 acquisition of Flomerics. Throughout its more than eleven-year development history, a key precept was that FloEFD should be easily accessible to non-specialist engineers. Mentor Graphics continues development of FloEFD with the strategy that it be available to non-specialist engineers within their MCAD environment.

To support this, the FloEFD solution suite is integrated within several Mechanical CAD (MCAD) solutions and provides guidance and help so that engineers who are not CFD specialists can perform fluid flow, cooling, and other analyses as part of their design process and within their product design tool.

FloEFD supports many types of CFD analyses including:

- Pressure drop in hydraulic and pneumatic devices, taking into account many physical effects such as surface roughness and/or cavitations.
- Flow analysis around solid objects such as air flowing over a car.

- Simulation of gases to solve high-pressure or low-temperature gas problems.
- Coupled heat transfer analysis including conduction, convection, and radiation.
- Electronics cooling analysis of single printed circuit boards and complete electronic products.
- Turbulent flow analysis using a laminar-turbulent-transitional turbulence model.
- Compressible gas flow analysis in subsonic, transonic, supersonic, and hypersonic conditions.
- Moving wall flow analysis for studying flows relative to a moving constraint.
- Non-Newtonian fluid flow analyses (e.g., for molten plastics, rubber, food, or biological liquids).
- Calculation of relative humidity and steam, based on a two-phase modeling approach.

FloEFD's direct CAD interfaces allow engineers to do CFD analyses directly within their CAD environment, while working on their product design. Today, FloEFD is embedded within CATIA V5 and Pro/ENGINEER Wildfire. The CFD capabilities are available directly from menus within these two CAD solutions. In addition, a version of the CFD solution called SolidWorks Flow Simulation is available for use with SolidWorks.

A standalone version of FloEFD, which is integrated with other popular CAD packages such as Autodesk Inventor, Siemens NX and Solid Edge, is also available. This version can directly read native CAD model data from many CAD systems.

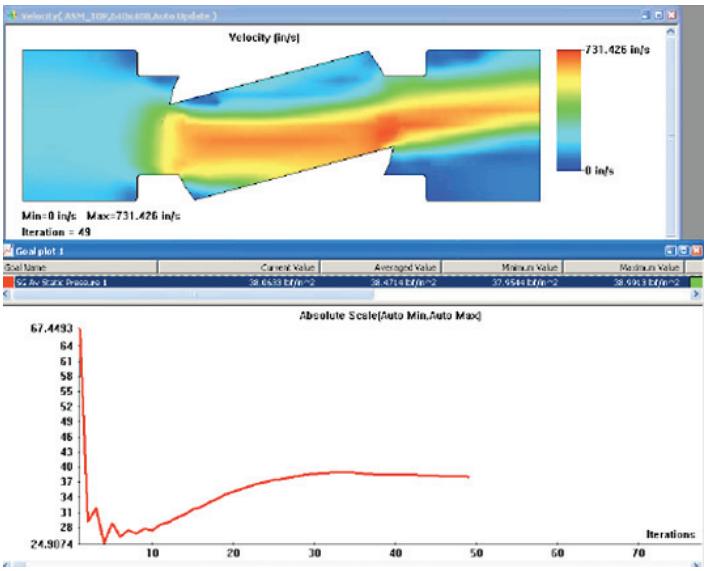

Figure 4—The Lower Chart Shows Analysis Progress Towards Convergence while the Upper Chart Reports the Current Conditions

Because most designers are not CFD specialists, FloEFD provides a wizard-based, automated analysis setup modeler. It guides the user through CFD problem set-up and works directly on the CAD geometry with tools that automate the identification and meshing of the flow volume and solid parts without the need for the designer to specifically model the flow cavity. FloEFD's key technologies allow the software to refine the analysis by, for instance, adjusting the overall mesh characteristics automatically. FloEFD's engineering user interface helps the designer to set the goals of the analysis (e.g., pressure drop or flow velocity) and to observe the convergence as the analysis progresses. All analysis results are shown directly on the CAD model and can be created in common Microsoft Office formats (Word and Excel) for documentation.

Designers can take advantage of previous CFD analyses by substituting a new product model for an older one and quickly running the same type of analysis as was done on the older model without reentering all of the setup data. This allows many "what-if" scenarios to be analyzed in order to achieve better designs more quickly and eliminate poor designs earlier.

A library of required materials such as fluids and gases is provided with the product. It provides material properties and characteristics for analysis setup definition, simplifying how these are entered into analysis projects.

FloEFD supports design optimization using CFD-based flow analysis results to drive changes in model geometry and other parameters.

All of the analysis parameters and data are stored in the CAD solution's project or assembly tree and become part of the design data set.

FloEFD runs on typical laptop or desktop computers running Windows. It runs in either 32-bit or 64-bit mode. FloEFD takes advantage of parallel processors when these are available.

5. SUMMARY AND CONCLUDING COMMENTS

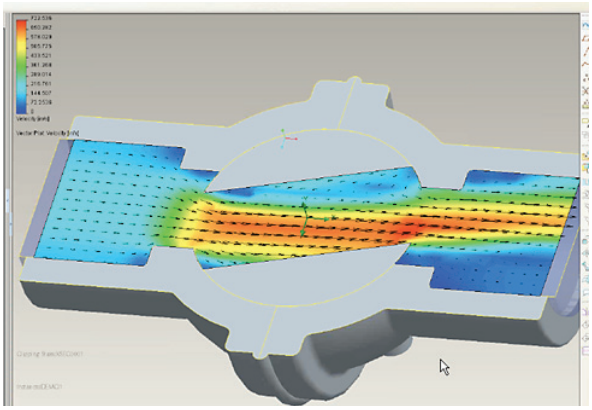

Figure 5—Flow Direction Vectors with Velocity

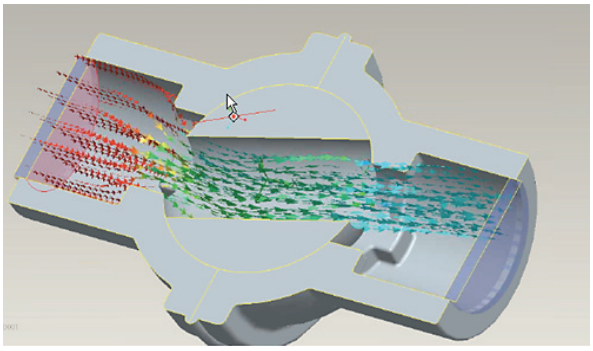

Figure 6—Flow Animation

CFD analysis continues to become more and more important to the overall product development process. As product complexity and the use of embedded software and electronics become more pervasive, being able to perform CFD analysis earlier in development can provide significant benefits. Improved product quality and reduced design time are but two of these.

However, there are many challenges to achieving broader use of CFD within the design community. Designers and engineers need to be better informed as to the benefits of earlier use of CFD during product development. And more importantly, CFD solutions need to be easy to use and better integrated and embedded within design environments—transforming it from a specialist tool to a standard capability usable by all designers and engineers.

Mentor Graphics, with its FloEFD solution, has taken a major step in moving CFD from the specialist domain to being a tool that designers and engineers can use to help develop better products faster. They have designed FloEFD to be used by non-specialist engineers within their native MCAD environment. Thus, it helps overcome the design complexity and timeliness issues raised earlier in this paper. Its user interface and wizards appear to be effective and straightforward for non-CFD specialists to use.

FloEFD has been effectively embedded within many of the leading design tools and provides a broad range of CFD analysis capabilities. Its usefulness will be enhanced when companies embed it within a well-documented product design process and support its use within a broad PLM strategy where the data and processes are secured, managed and accessible.

FloEFD complements other work that Mentor Graphics has been doing to enable better ECAD-MCAD collaboration, especially for mechatronics design scenarios. While FloEFD does not completely replace the need for CFD specialists in all companies, it does provide capabilities that product designers can use to help them be more effective.

CIMdata believes Mentor Graphic's FloEFD is a step forward to making CFD more accessible and usable by mechanical design engineers. It should help improve a company's ability to more quickly get innovative products to market while meeting the demands of increasing product complexity and efficiency.

ABOUT CIMDATA

CIMdata, a leading independent worldwide firm, provides strategic consulting to maximize an enterprise's ability to design and deliver innovative products and services through the application of Product Lifecycle Management (PLM) solutions. Since its founding more than 25 years ago, CIMdata has delivered world-class knowledge, expertise, and best-practice methods on PLM solutions. These solutions incorporate both business processes and a wide-ranging set of PLM enabling technologies.

CIMdata works with both industrial organizations and suppliers of technologies and services seeking competitive advantage in the global economy. CIMdata helps industrial organizations establish effective PLM strategies, assists in the identification of requirements and selection of PLM technologies, helps organizations optimize their operational structure and processes to implement solutions, and assists in the deployment of these solutions. For PLM solution suppliers, CIMdata helps define business and market strategies, delivers worldwide market information and analyses, provides education and support for internal sales and marketing teams, as well as overall support at all stages of business and product programs to make them optimally effective in their markets.

In addition to consulting, CIMdata conducts research, provides PLM-focused subscription services, and produces several commercial publications. The company also provides industry education through PLM certificate programs, seminars, and conferences worldwide. CIMdata serves clients around the world from offices in North America, Europe, and Asia Pacific.

To learn more about CIMdata's services, visit our website at www.CIMdata.com or contact CIMdata at: 3909 Research Park Drive, Ann Arbor, MI 48108, USA. Tel: +1 (734) 668-9922. Fax: +1 (734) 668-1957; or at Siriusdreef 17-27, 2132 WT Hoofddorp, The Netherlands. Tel: +31 (0)23 568-9385. Fax: +31 (0)23 568-9111.

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For the latest product information, call us or visit: www.mentor.com

Corporate Headquarters
Mentor Graphics Corporation
8005 SW Boeckman Road
Wilsonville, OR 97070-7777
Phone: 503.685.7000
Fax: 503.685.1204

Sales and Product Information
Phone: 800.547.3000
sales_info@mentor.com

Visit www.mentor.com/company/office_locations/ for the list of Mechanical Analysis Division Offices

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MGC 09-09 TECH9710-w