Keeping Cool – Using Flowmaster to Quickly and Easily Simulate Complex Fluid Piping Systems

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Flow networks in cooling circuits, process plant or utility supply systems are made up of a multitude of assemblies, sub-assemblies and individual component parts and are subject to a series of extremely complex inter-relationships and dependencies. Increasingly manufacturers and service providers are making use of numerical-empirical based CFD applications for their network definition and damage analysis. Flowmaster Group is a leading supplier of such programs, its systems being used by many well known companies worldwide.

Everyone remembers those images of raised car bonnets disappearing amidst clouds of steam whilst accompanied by the hiss and crackle of over-cooked radiators. Luckily this ultimate testimony to the thermal failure of those much maltreated cooling systems have been long since banned to the realms of nostalgic memories from those alpine holidays of yesteryear. But even if today's radiators no longer boil over, it still does not mean that the cooling system is working with maximum effectiveness. Be it the cooling system in a motor vehicle, the fuel system of an aeroplane or the wide-spread pipe networks at a utility provider, from a fluid mechanics and thermal dynamic perspective their design is an extraordinarily complex matter needing to reflect the varied conditions under which they operate.

Complicating this still further, increasingly ecological/economical aspects and statutory regulations have to be considered in addition to the purely functional requirements. Whilst working to meet all these various design parameters, development departments are further under massive pressure to shorten development cycles and reduce cost. This push and pull of needs can no longer be mastered by the development engineer using conventional methods. More and more companies are turning to a simulation technology called Computational Fluid Dynamics or CFD to satisfy these growing and very sophisticated demands. Engineers can now use CFD to model, analyse and test the flow mechanics and thermal behaviour of their systems on their computers at an early design stage. They can define and virtually test variations and so reduce the number of prototypes needed.

Differing Approaches to CFD

In principal there are two approaches to CFD. The first of these is the three dimensional CFD simulation, whose colour images are familiar to a wide audience. 3D CFD programs are able to make extremely detailed statements as to flow mechanical and thermal conditions in or on a particular component part/assembly. As impressive as the possibilities and results might be, however, they are also built upon extensive CAD-data-based models and require a lot of computing power to calculate: single runs of several hours are not uncommon. This effectively puts them outside the realms of possibility and practicality when complex systems with numerous assembly parts have to be simulated. The real strength of 3D simulation lies therefore in the highly detailed analysis of individual components or of systems of a manageable size.

The second type of simulation is that of the so-called 1D systems, based on a numerical-empirical approach. These use schematic models of the flow systems in which each individual component's behaviour, such as a pump, valve, pipe, etc., is either defined by the underlying physical formula or by pre-determined characteristic diagrams. The parameters for these can either be provided by the component manufacturer or be determined through the engineering company's own experience and tests. The advantage of this approach is its independence from CAD-data, with the resulting speed and ease with which even complex networks can be modelled and the simulation run. Processing time is often no more than a few minutes and this speed and ease of use makes it possible to use the technology at a very early stage in the development process to design complex flow systems, together with their associated control and regulation procedures and to consider "what if" scenarios and test variations.

Flowmaster – a Leading Supplier

Flowmaster®, a software solution from a UK company of the same name, has been leading the way in the field of system simulation for many years. The reason for this history of success, apart from the mature and universally applicable software code itself, is the company's constant and close contact to its customers, suppliers and research institutes. The result has been the continued expansion and refinement of its database of standard component core data. In over 20 years of development Flowmaster has thus become the application of choice upon which leading manufacturers, e.g. from the automotive, aerospace, shipbuilding and process industries as well as companies from the energy sector, rely upon to solve their highly complex design and development problems.

The program provides a comprehensive suite of tools for the calculation of thermo-hydraulic and thermo-pneumatic piping systems. For example, both stationary as well as transient, i.e. time dependent, analysis with compressible or non-compressible media are possible, the system calculating temperature, pressure, volume and mass flows for each component and every node across the defined system.

Another of Flowmaster's strong points is its pipe system tuning functionality. Mass and volume flow rates can be defined using the Flow Balancing module and control components inserted and/or expressly calibrated, e.g. for valve position, pump speed, to ensure the required operational parameters. Another feature which stands out is the Priming module, used to simulate the filling process as typically experienced when starting up plant where any remaining air has first to be pressed out of the pipes. In addition Flowmaster offers a series of specialised applications to address the discrete requirements of specific industry segments and/or areas of design, e.g. for climatic control in motor vehicles and airplanes.

Working with Flowmaster is simple and in-line with the normal way of working of an engineer in practical work process: there is no need for the engineer to master additional IT-know-how to get results. With a user-interface heavily orientated to the already familiar Windows standard, users fast come to terms with the program and are able to generate extensive flow system models quickly. Required components can be selected and inserted from over 20 standard part libraries using simple drag and drop commands. Each component is defined by a mathematical-physical model whose menus are clearly laid out and which enable the operation method and performance to be adapted to the required situation, e.g. the opening of a valve, pump performance, surface roughness, etc. Individual component parts are connected using nodes to which attributes such as height, temperature, etc. are attached.

Parameters key to the actual model calculation, the calculation period or, for transient analysis, time increments for example, are also documented and managed using menus. Each element's results for pressure, temperature and mass and/or volume flow rates, etc. can be depicted either dynamically in a schematic model or can be captured in nearly any type of text and/or graphic format the user wishes. Exporting results to MS® Office applications poses no problem so that detailed reports can be quickly created.

Integration and Co-Simulation

The breadth of real-world tasks to be mastered in any complete development cycle means that different programs may be best suited and should be used at various times during the development process. Potentially, 3D systems offer themselves as the most apt tool to optimise individual component parts, for example In practice, however, such an optimised part will hardly, if at all, effect the performance of the total system.

Engineers can use Flowmaster to analyse any such correlations, identify critical areas in the piping network and make any changes necessary. Although Flowmaster has its own expansive standard part libraries, the user is not limited to these and can use the inbuilt COM-technology (Component Object Module) to bi-directionally exchange object data between Flowmaster and other simulation products (3D simulation solutions like Fluent and Star CD or Mathcad®/Simulink® for simulating monitoring and control systems) – functionality which not only benefits Flowmaster users.

For example, the conditions at the entry and exit points need to be known to be able to correctly optimise a cylinder head cooling jacket using 3D CFD but these are influenced in turn by the radiator and water pump. Flowmaster can be used to quickly calculate the required values.

The term 'Co-simulation' has been coined to describe this system openness, a keyword often used to describe a common problem found with CFD simulation. In order to carry out realistic and therefore meaningful simulations, often many applications have to be used and these need to work together, to be complementary and not mutually exclusive. As described above, Flowmaster has an answer to this problem and has been able to show in numerous customer projects that their implementation of the complimentary ideal does indeed also work in the production environment.

Conclusion

Simulation of complex flow systems is becoming increasingly important in many and varied areas of industry but 1D simulation solutions have seemed to remain hidden in the shadow of 3D-CFD with its more spectacular results representation. However appearances can be deceptive, as not least witnessed by the large Flowmaster customer base. Flowmaster provides solutions for a considerably broad range of requirements and in doing so has been able to significantly improve the development process within its large user base – with Co-simulation functionality to other simulation products playing a major role.

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