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The State of the Art in C.F.D. for Ventilation Design

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CFD (Computational Fluid Dynamics) is a phrase that has been bandied about in the field of building services design for at least the last decade and throughout the 1990's it is a technology that has come to be accepted by a significant number of engineering consultants and building end users.

In fact, there is nothing new about CFD. The aerospace and the nuclear industries have been using it since the mathematics describing the dynamic properties of fluids first became practical along with the advent of computers in the seventies. So why has the building services industry lagged so far behind? The main reason for this is the perception that CFD software is difficult to operate and an expert knowledge of fluid dynamics is a pre-requisite to be able use it efficiently and accurately. Historically, CFD has grown up in a world where companies have large R&D budgets and lengthy timescales. There is little room for this type of philosophy in the highly competitive ventilation design world where margins are minimal and timescales short. In this environment, calculating the temperature in a room to the n^{th} degree of accuracy using all of the sophisticated mathematical algorithms in the CFD world is not necessary. What is required is a software tool that can be picked up quickly and used with sufficient detail in the model to be able to make design decisions.

As an example of this philosophy, consider the design of an aerofoil section by an aeronautical engineer. The slightest changes to the profile of an aircraft wing can upset the fine balance between lift and drag dramatically. In this case, therefore, the engineer must represent the geometry with little tolerance and use the most sophisticated mathematical algorithms, turbulence models and solvers to obtain accurate data.

Now consider a building services engineer designing an office building with a displacement ventilation system. First of all, the tolerances he is working with are far greater. It is unlikely that he will be able to ensure that all of the occupants are comfortable and must therefore aim to have as low a percentage as possible dissatisfied with their environment. This automatically allows several degrees tolerance in the design temperature of the space. In addition, the location of furniture, occupants etc. is rarely known at the design stage and adds another variable into the equation. Remembering that a computer model is only as good as the boundary conditions with which it is supplied, there is no advantage to be gained by using sophisticated gridding techniques and mathematical models to artificially try to increase the accuracy of the simulation.

CFD has been with us now for almost 30 years and over this time has developed into an invaluable tool for predicting fluid dynamics. Given the turbulent and chaotic nature of fluid motion there is a limit to how accurately it can be predicted using an ordered computational system. Although countless academics and research engineers still aim to make better predictions through the use of ever more sophisticated (and normally computationally unstable) mathematical models, in many areas we have already achieved a state where it is unclear whether errors occur in the simulation or in the experimental measurement. The state of the art in CFD, therefore, lies not in predicting fluid motion with degrees of error so small that they are difficult to measure, but in making this complex but useful technology available to a wider user base.

Engineers in many fields have struggled for centuries basing their design decision on gut feel, rules of thumb and past experience. Only in the last 20 or 30 years have they started to use computers as to carry out the necessary design calculations faster and more reliably. In the building services industry this started with the calculation of pipe sizing, duct sizing and heating & cooling loads. CAD provided a tool to replace the drawing board and dynamic thermal modelling allows engineers to predict at exactly what time of the day peak loads will occur to enable the sizing of more efficient plant. Nowadays, wherever you look in a building design, engineers are doing all manner of calculations using the software tools available to them. So why should predicting the airflow be any different? The answer, of course, is that it should not be different and engineers should have the same access to carry out a CFD simulation in the same way as they would simulate any other part of the design.

What, therefore, are the criteria for developing such a tool? Here are some of the requirements which engineers should seek in a CFD software for modelling airflow in buildings:

- A user interface which is intuitive and easy to navigate around – The software is likely to be used intermittently and so being able to pick it up again after a break is essential. An interface similar to the CAD tools the engineer already uses would aid this process.
- Grid which is easy to apply and does not cause instability in the solution – Gridding is a big issue in the CFD industry and one that is not entirely understood by any except the CFD researchers and software developers. The fact of the matter is that body fitted or unstructured meshes are complicated to apply, cause a tremendous amount of instability in the solution and use an enormous amount of system memory. A structured cartesian mesh is quick to create, can be adapted for changes in the geometry, enables a fast and stable solution, has more than sufficient accuracy to make the design decisions that engineers need to make.
- A solver which is tailored to the needs modelling incompressible, low velocity airflows – Most general purpose CFD codes are designed to solve many different types of problems and incorporate all encompassing solvers. Building services engineers work with a very small subset of these applications and developing a solver to their specific needs makes for a faster and more stable solution.
- A post-processing facility which enables the user to communicate his results effectively – The purpose of carrying out an airflow modelling study is to demonstrate the feasibility of a design to both engineers and non-technical personnel from a number of different backgrounds. These may be the architect, the client, the structural engineer, even the quantity surveyor.

- Libraries of plant and equipment from manufacturers which can be inserted into the model – Manufacturer's data for diffusers, for example, are presented in their catalogues but are based on the performance of the air terminal in a controlled set of conditions. The correct modelling tool would allow the diffuser manufacturers to calibrate models of their own products and make these available for engineers to download from the internet. This would enable the engineer to assess the performance of the diffuser in his own CFD model and see the changes in characteristics when changing the supply temperature for example. All of this would be a difficult goal to achieve as it would mean the involvement of the equipment manufacturers. As airflow modelling evolves in the building services industry, however, this would be a natural progression of the technology.
- An intelligent interface to CAD tools – Although an admirable goal to try and achieve it should not be forgotten that there were similar ideals 15 years ago or so when CAD tools were headline news. Then the ideas surrounded the fact that with a standard CAD tool, the architect, structural engineer and services engineers could all work from the same set of electronic drawings and yet this hardly ever happens today. The requirements of a CAD drawing for services installation and the geometry of an airflow computer model are quite different in terms of their level of detail. This means that a degree of simplification will be necessary at some point in the interface. Added to this is the fact that geometry for an airflow model has to be a solid three dimensional representation. Most CAD models fall way short of this being two dimensional at their simplest and three dimensional wireframe at their most sophisticated. In this area there are moves in the right direction but it is as much a case of defining a standard way of working as it is in developing the software to achieve the desired goals.
- Training and technical support from likeminded engineers who are familiar with the types of application encountered in building services design.

What the above demonstrates is that the requirements of a general purpose CFD tool for use in research and development are quite different to the needs of the engineer. Instead of trying to achieve the last word in accuracy at the expense of the amount of time it takes to achieve this, the engineer needs to achieve results in the shortest possible time to enable him to make the design decisions he needs to. In this environment CFD is not the be all and end all of building services design but simply a tool to enable the design engineer to do his job more effectively and with more confidence that the final installation will achieve the criteria set out for the design.