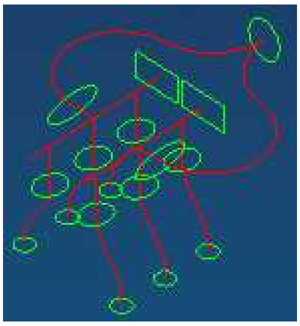
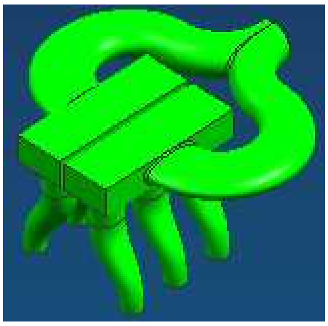
Conceptual design tool chain for branched network turbulent flow.





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Discipline: Engineering

Research Objective

The project aims to research the development of a tool chain for the conceptual design of branched networks containing turbulent flow conditions. The tool chain will streamline prototyping of possible network configurations by linking CAD (Unigraphics), meshing (Gambit) and CFD (Fluent) elements. This project was conducted solely as a VPAC CfCP project, however on completion the tool chain would have potential application to several contracted industry projects.

Motivation / Significance

The tool chain was originally conceived as a packaging together of software elements, such as CAD and CFD, commonly used in the conceptual design phase of turbulent flow branched networks (such as pneumatic pipe systems). By forming these elements into a single package operated through a single GUI the design process can be accelerated through automation of normally repetitive tasks such as the forming of volumetric geometry from altered centreline paths. Further, by embedding engineering knowledge into the tool chain the need for the operator of the tool chain to posses specialist knowledge in fluid flows, CAD and CFD operation knowledge can – to some degree, and with appropriate caution – reduced or eliminated. These two results of reduced time and user knowledge required would, in an industrial context, allow resources to be more efficiently employed on other more complex tasks, thus saving money and improving product performance.

Further significance is added to the development of such a tool chain as currently the only similar packages readily available operate much less sophisticated elements. As well as providing the full range of functionality, the use of sophisticated elements will also allow the conceptual tool chain files to be enhanced and updated, rather than entirely new models created as with a less sophisticated conceptual design package.

Science Background

Whilst there are several “mechanical” issues involved in development of the tool chain the main consideration behind them is the need to accurately model turbulent flow. This is notable since turbulent flow is far more sensitive to mesh density and structure than laminar. Essentially, there is more happening on a smaller scale, and in directions not always aligned with the surfaces over which the flow is acting thus turbulent flow requires more detailed resolution and less assumptions. One method to gain this is to increase the mesh density. However, this is somewhat of a “brute force” solution and this is reflected in the fact that runtimes will rapidly increase to unreasonable levels. This is of particular concern here since a key project objective is to reduce the runtime in order to facilitate use of the tool chain as a rapid prototyping package. Thus more efficient methods were sort to increase accuracy.

Methodology

- Research tool chain construction.
- Research turbulent flow in branched networks.
- Familiarise with Unigraphics.

- Familiarise with Gambit scripting
- Investigate Fluent case file set up.
- Investigate mesh construction for accurate simulation.
- Investigate application to optimisation.
- Investigate pipe join construction.

Modelling

In the course of the various investigations conducted as part of this project a large number of models were created and used, full details of their specification can be found in the relevant reports, however an overview is provided. All models were CFD simulations of various aspects of pipe flow, the diameter of the pipe used was always circular 75mm and the modeled surface plastic. Further, all model geometry and mesh was constructed in Gambit and run in either Star-CD or Fluent and only the mid portion of the model was analysed in order to avoid boundary layer establishment effects. From these points of commonality there were two sub categories of model type constructed – the first (800 000 cells) was a range of straight pipes used to investigate the sensitivity of result accuracy to mesh and solver settings, the second (70 000 cells) was a range of different curved sections all utilising the same mesh and settings in order to investigate the use of "stripped down" CFD to rapidly rank alternative configurations.

Tool

The majority of the project thus far has been utilising Fluent, and this will ultimately form a significant portion of the tool chain as well. For Fluent, pre-processing work is generally done in another package (such as Gambit), although Fluent does also have some pre -processing ability. The main core of Fluent is the solver engine which has numerous potential configurations all of which result in a iterative finite volume solution of differential flow equations. Once the calculation is complete Fluent then offers a full range of post-processing facilities including visualisation, plotting and numeric analysis of all key flow parameters. Star-CD was also used for some comparisons and operates in a fairly similar fashion, however it contains slightly more pre-processing abilities.

Results

The initial project goal was to actually develop the tool chain to at least an initial limited functionality level, however, as mentioned the software (Unigraphics development environment) intended for use to construct the main GUI was not available in sufficient time to learn, evaluate and utilise it. This meant that a more detailed investigation was conducted into the element requirements of the tool chain. Three main areas of investigation were conducted; looking at meshing and solver settings for accurate results from automated processes, consideration of a rapid configuration ranking version for optimisation and formulation of a method for construction of joins between pipes. In the first it was found that an unstructured mesh (800 000 cells) running second order k-ε equations gave pressure drops accurate to 5%. In the second a coarse (70 000 cells) unstructured mesh with first order Spalart-Allmaras modelling was found to rank all configurations correctly. Finally a method of creating reasonable performance intersections was defined using the Unigraphics swept function and inside/outside guide splines.

Discussion:

Given that the project evolved to be the forming of groundwork for later expansion into a fully functional tool chain, as originally envisaged for this project, the major points of interest to come from the project, as completed, involve what further work needs to be completed to construct the tool chain. As discussed above the majority of the individual elements of the tool chain have been investigated to the point were the requirements and available capabilities are sufficiently well understood for the construction of the tool chain. This means that the main tasks remaining involve forming the tool chain into a single cohesive unit operated through a single GUI. This will mean investigating the file passing between the various packages used; geometry from Unigraphics, to gambit meshing, to Fluent simulation and finally passing of results back into the main GUI. Construction of this file passing system will require consideration of compatable file formats, and possibly the use of generic formats to allow substituation of alternative software (Start-CD, HyperMesh etc.). As can be seen from this list the main tasks remaining are essentially a series of programming tasks as opposed to the more engineering and fluid dynamics centric work thus far.

Conclusion

The investigations completed in this project have found that all the elements are in place for production of an efficient and accurate tool chain for pipe network flow simulation. By using the geometric construction abilities of Unigraphics, an unstructured mesh tailored to optimise the Fluent wall functions and the k-ϵ viscosity model turbulent pipe flow can be simulated to a level of accuracy more than sufficient for the conceptual design phase. Further, it was found that by simplifying the mesh and solver settings (using the Spalart-Allmaras viscosity model) a rapid simulation could be run that, whilst lacking absolute accuracy, was capable of accurately ranking (in terms of pressure loss) various different pipe configurations. Thus, the final tool chain can be constructed from elements now well understood from the investigations of this project.

References

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