Case Study

Automotive

BMW Motoren

BMW Motoren, Steyr couples 3D CFD with 1D Flowmaster analysis

BMW Motoren GmbH designs and manufactures automotive engines for use in passenger cars. Steyr, in upper Austria, is a traditional location for the metalworking industry. BMW opened an engine factory and a development centre for diesel engines there in 1979. The enterprise assumes the following functions:

- development of diesel engines and diesel engine technology.
- production of petrol and diesel engines.
- selling of BMW engines worldwide.
- purchasing for the BMW company in Austria.

The factory at Steyr manufactures over 60% of all BMW's engines.

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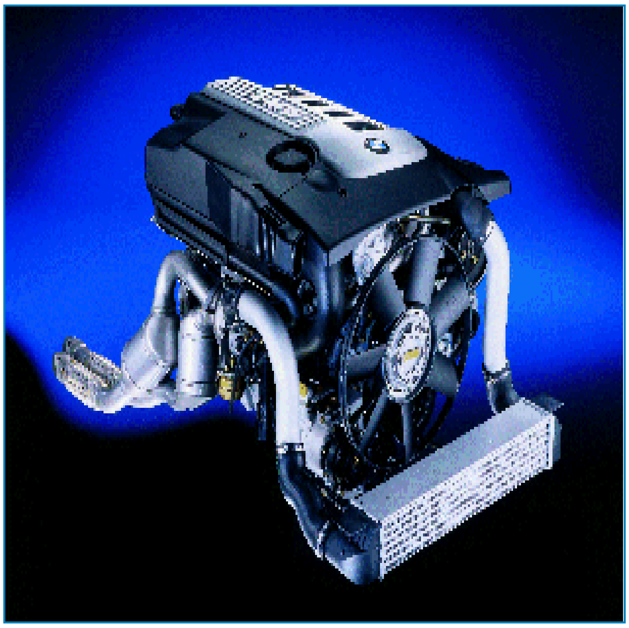
Introduction

A large reduction in time-to-market can be achieved by reducing the time spent on producing and testing physical prototypes. This can be achieved

through the use of computer aided design and simulation. Engine cooling simulation has been done for several years with 1D tools being used to determine pressure losses and rates in cooling circuits. The more complex flow patterns in cylinder head and jacket are simulated with full 3D CFD to determine convective heat transfer coefficients.

BMW simulates the vehicle's coolant flow with Flowmaster, which enables a one-dimensional description of the whole system. Flow in the engine coolant jacket, which is much less predictable, is described three-flow dimensionally by the CFD programme STAR-CD, from Computational Dynamics.



BMW 3,0L, 6-cylinder DI Diesel engine.

Co-simulation Analysis

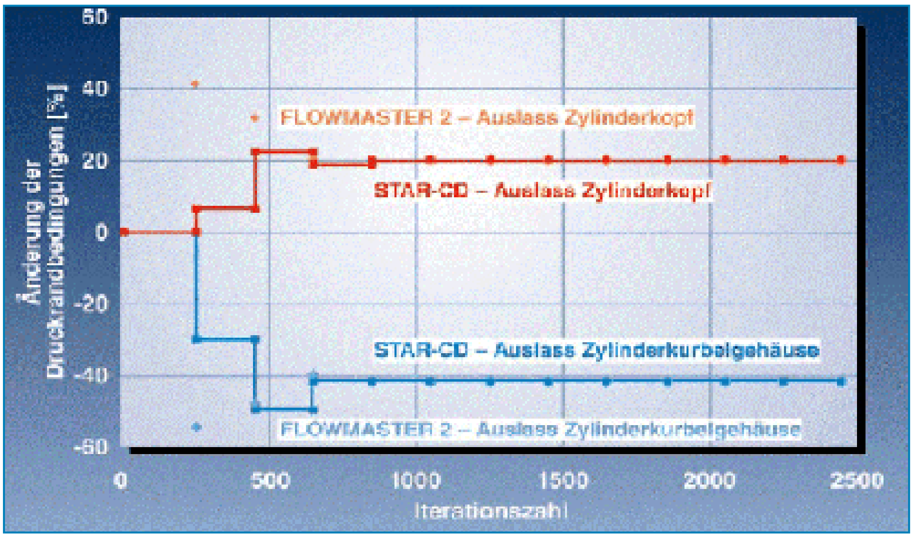
As the latest generation engines require various heat exchangers for engine oil, transmission oil, alternator and passenger cabin heater there are usually more than one outlet from the engine-cooling jacket. BMW's engineers determined that the two flow regimes, engine and external system, are not independent. The 3-D computation must use the global flow conditions as boundary conditions for the detailed local flow calculations and the local pressure drops must be used in the global flow calculations. Therefore, an iterative process is required for a solution of the overall system. In general, a single iteration is insufficient for convergence and so the process must be repeated.

The data transfer was originally performed manually. The shortcomings of this process, slowness, cumbersome and error prone, led to the development of a programme interface, which improved the productivity but still required setting set-up for each case. The interface was built with standard Flowmaster utilities -Command Line Interface and Electronic Data Interchange Format, and STAR-CD user subroutines.

BMW's engineers applied the method to the cooling system of a six-cylinder diesel engine. The cylinder head and cylinder cooling-jacket was modelled with STAR-CD and the external cooling circuit with Flowmaster.

There were three connections between the two codes - water pump, cylinder head and cylinder-jacket.
The systems were analysed independently to derive the boundary conditions, mass flow rates, for the co-simulation analysis. Good agreement between the boundary mass flows was achieved after three iterations. Convergence, where the boundary mass flows from both codes were within the specified tolerance, was achieved after 12 iterations.

Figure showing percentage change from initial pressure boundary conditions. As each data transfer takes place the two computations converge.



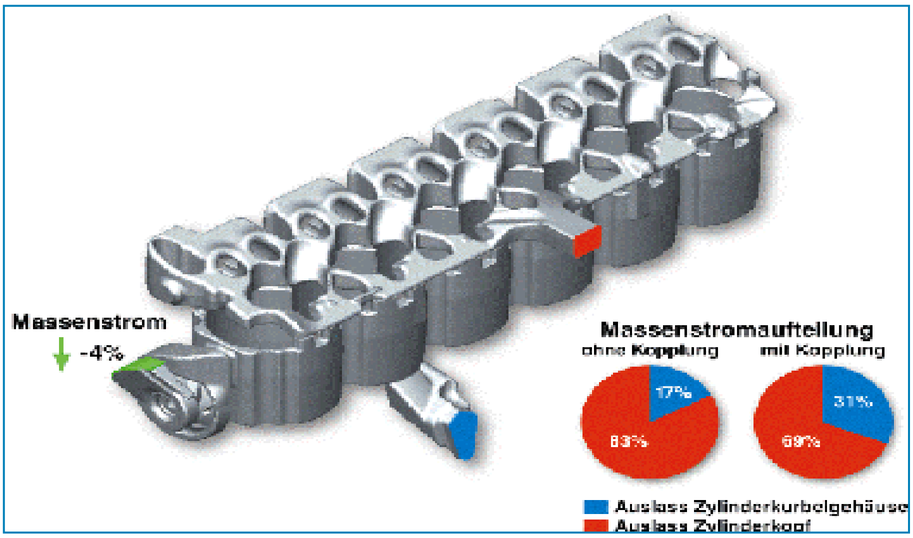
Cylinder head: orange - Flowmaster, red - STAR-CD. Cylinder-jacket: light blue - Flowmaster, medium-blue - STAR-CD.

Results

The figure shows the percentage change in pressure boundary conditions versus iteration count during the iterative analysis. As each data transfer takes place the two computations converge. The upper line represents the cylinder head - red for STAR-CD and orange for Flowmaster. It can be seen that the changes are large for the first two couplings but converge quickly. Also, the converged STAR-CD values show about 20% change from the initial estimate. The lower line representing the cylinder jacket shows a similar trend but the final change is much larger - about 40%.

The results, with coupling, were very different from the original values without coupled analyses. The mass flow at the water pump was 4% lower than assumed. However, the flow distribution between the cylinder head and jacket was very different. The split was originally predicted to be cylinder head - 83%, cylinder-jacket - 17%, but the results of the coupled solution showed it was cylinder head - 69%, cylinder-jacket - 31%. This result was unexpected and as a result the design was modified to increase the cylinder bore centres allowing increased cylinder-jacket size.

The diagram shows the flow split - cylinder head/cylinder jacket - without (ohne Kopplung) and with coupled analyses (mit Kopplung). The significant change is apparent.



Cylinder-head/jacket showing the change in flow rates at the outlets.

Overall mass flow rate was reduced by 4% and flow split was changed from 83/17 to 69/31 when the coupled solution was used.

Conclusion

BMW Motoren GmbH, Steyr, has combined 3D with 1D analysis to analyse the cooling system of a six-cylinder automotive diesel engine. They found that results of the co-simulation were an improvement over the independent analyses. The results showed that the original assumptions were inaccurate and that original design had been sub-optimal.

STARLink

After the study was completed BMW Motoren suggested that Flowmaster Ltd. should produce a utility based on the methodology that would be easier to use, require less set-up and be more flexible and therefore be more productive. This would lead to a more productive design environment for future engine programmes.

Acknowledgements

Flowmaster Ltd. gratefully acknowledges BMW Motoren's contribution to the STARLink project and for their permission to publish this case study. This case study is based on an article in ATZ 4/2000 by kind permission of ATZ. Images by kind permission of ATZ. Visit the ATZ portal www.all4engineers.com

CLI & EDIF

All the functionality that was provided by Command Line Interface and Electronic Data Interchange Format is now provided in Automation Functions.

In basic terms, Automation Functions enable other user-written software applications to start Flowmaster remotely and perform, from within the software, most tasks that can be performed using the Flowmaster GUI. For example, it is possible for a software application to start Flowmaster, open a project, then open a network within the project, edit some data, run an analysis and then read and manipulate the results.

Automation Functions are based on Microsoft's Component Object Model (COM) and provide a simple set of hierarchical classes. These provide access to all the major GUI functions. For example, the Command Line Interface functions allow you to create projects and networks, create and run batch jobs and print results, etc.

Other functions, such as those in the Project class, allow you to access networks and database items owned by a particular project. Functions in the network class allow access to components and nodes within the network and to result sets that have been produced by the network.

The Automation Functions can be called from many different software languages that support COM, including Basic, C++, JavaScript, etc. Other applications such as Microsoft Word, Excel and Access, all of which support Visual Basic for Applications (VBA), can also access Flowmaster Automation Functions.

The Automation Functions provide a means of using Flowmaster's powerful analysis without using the graphical user interface. Typical applications include using Flowmaster analysis as part of an overall design package.

STARLink

Flowmaster STARLink utility provides a mechanism for Flowmaster and STAR-CD, a 3D CFD code from Computational Dynamics, to perform a co-simulation (coupled) analysis.

STARLink permits all the set up to be performed in a single user interface. It also controls the starting of the Flowmaster analysis and all communications between the two codes. The co-simulation makes use of the most productive and economical platforms by executing Flowmaster on PCs under Windows® and STAR-CD on workstations under Unix. Communication medium is Ethernet LAN.

STARLink manages all data-flow between the analyses, including format conversion. Platform specific user subroutines libraries are supplied for STAR-CD.

Finally, the advantages of both codes - global and detail calculations - can be combined for a truly productive design tool.

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