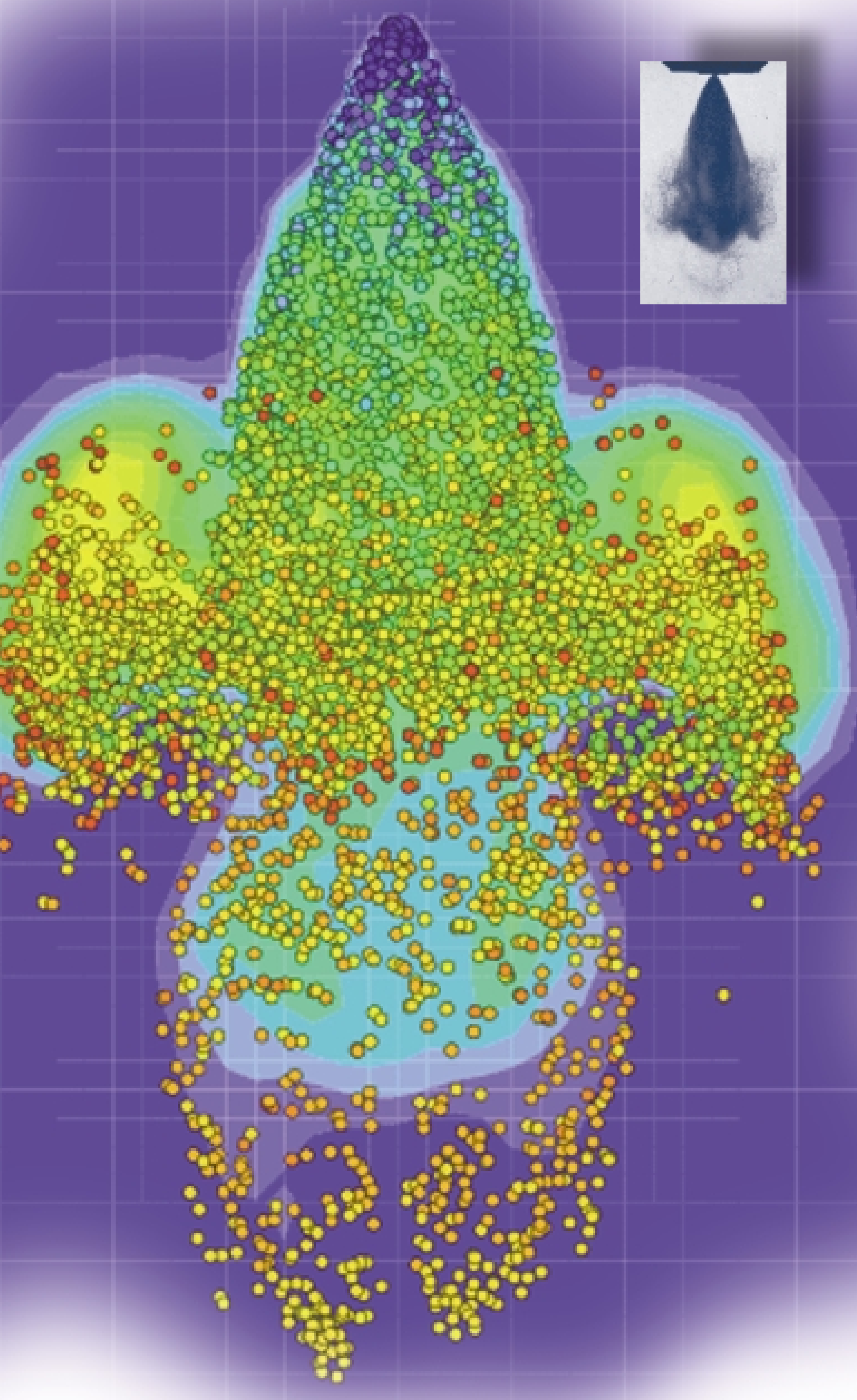
STAR-CD DYNAMICS

The Newsletter of Computational Dynamics



Issue 11 Spring 2000

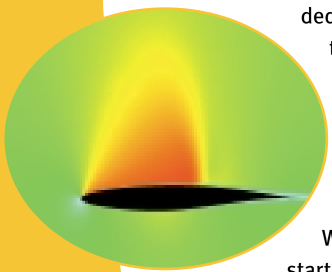
NEWS
IN BRIEF

ISO9001

Our ISO9001 accreditation promotes product quality in areas such as STAR-CD code traceability and also helps us improve our support services. However, even more important is our commitment to "Quality" in its broadest sense, namely "meeting your needs and expectations".

"Trust" in CFD is another issue. Trust in STAR-CD has been earned over the years as a result of developments being carried out with the benefit of feedback by literally thousands of users of the code. Although much of this feedback comes through confidential industrial CFD cases, our developers are able to respond by improving the code in ways that benefit all users. Putting this another way, STAR-CD can be viewed as a single "vehicle" that evolves through innovation yet is controlled by industrial validation from all industry sectors.

Broadening the definition of "Quality and Trust" even further, we have considered ways in which STAR-CD users could gain from the wider experience of users of other CFD codes, whether commercial or academic. Perhaps, there are generic questions such as "when should I use a higher order turbulence model?" or "what level of trust can I have in this safety-critical CFD analysis?", that could be answered usefully in a generic way for any CFD code.



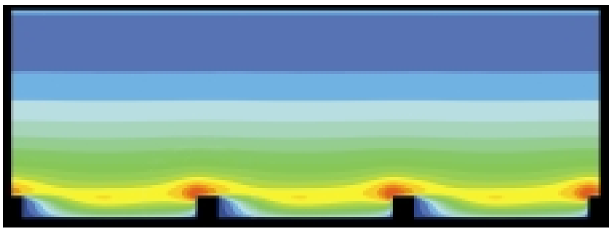
With this opportunity in mind, CD has joined a consortium of 40 industrial companies and leading academic institutes dedicated to helping engineers achieve quality CFD solutions using codes such as STAR-CD. We have already contributed as a member of ERCOFTAC's Special Interest Group to a document "Best Practice Guidelines for Quality and Trust in Industrial CFD" published by ERCOFTAC. Our involvement in this ERCOFTAC work will continue for the next four years, linked also with a parallel Framework-5 CFD quality project, "QNET-CFD". In these actions we will be supplying further cases, such as the RAE2822 aerofoil shown on the left, for a generic database of industrial CFD examples, and contributing to the production of a "CFD Applications Procedures" document.

We believe that this initiative will ultimately enable new users of STAR-CD to be better prepared when they start to use the code, and we recommend these documents to our users.

V2F TURBULENCE MODEL

V2F

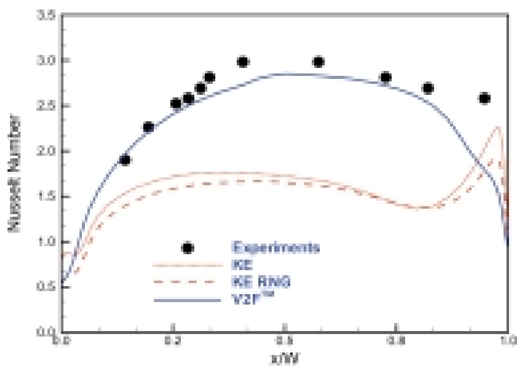
CD has signed an agreement with the US company Cascade to market a STAR-CD implementation of their V2F turbulence model. The V2F model accounts for anisotropy of near-wall turbulence, but retains the eddy-viscosity assumption. For certain types of flow it can provide a more accurate representation quantities such as friction and heat transfer than the standard k-epsilon model. V2F has some of the merits of Reynolds stress models, although remaining computationally attractive. It is available on a trial basis in 2000 as a patch Version of STAR-CD 3.1, and will be incorporated as a fully supported option in version 3.2.

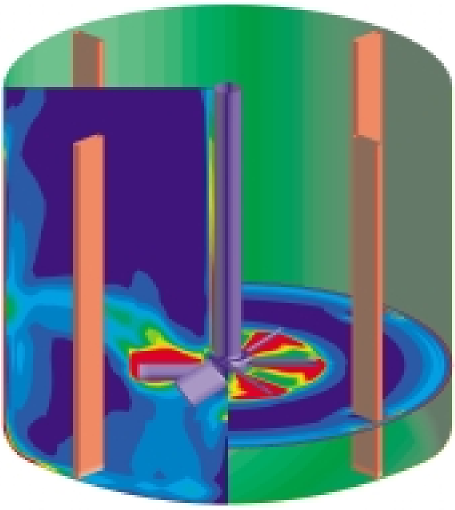


FLUID/STRUCTURE COUPLED ANALYSIS

MpCCI

With the completion of the EU project "CISPAR", opportunities now exist to perform fluid/structure interaction problems through the coupling of STAR-CD with FEM codes. A generic Coupling Communications Interface (MpCCI) is used. Initially the coupling has been fully implemented and successfully demonstrated with parallel PERMAS and PAM-Crash codes. Examples have been demonstrated from various industrial sectors, including automotive industry (flap bending and torque converter), marine (wave impact on hulls), aerospace (propulsion system) and biomedical (artificial heart valve). Links to ANSYS, ABAQUS, MARC and MSC/Nastran will follow in response to user demand.





Courtesy of Axiva

NEW MIXING TANK MESHING TOOL

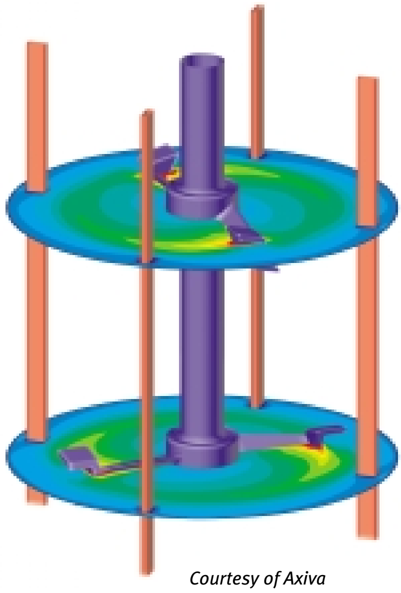
mixpert

CD has signed an exclusive global marketing agreement with Axiva to distribute their automatic mesh generation tool "Mixpert" for turbulent and laminar mixing vessels. MixPert allows block meshes to be created very quickly for stirred mixing tanks of all types (turbine, pitched blade and dispersion impellers, propeller and helical ribbon mixers, etc). The tool was developed by Axiva, a subsidiary of the German chemical company Hoechst, who have used STAR-CD for a number of years.

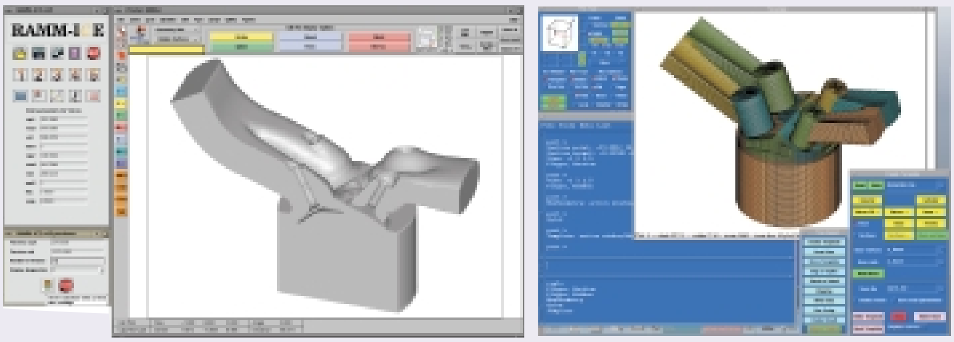
AUTOMATIC MOVING MESH CREATION

RAMM-ICE
PRO-ICE

RAMM-ICE and PRO-ICE provide complementary tools used to automate the setting up and running of moving mesh calculations. The former is intended as a "low cost entry option", which stresses openness to general meshing tools. For users of ICEM, a RAMM-ICE GUI has been developed by ICEM Technologies to help the setup process for producing hexahedral, tetrahedral and prismatic meshes. For those preferring to stay within the STAR-CD/PROSTAR environment, the PRO-ICE alternative offers a self-contained solution providing a complete GUI-driven automatic moving mesh system for STAR-CD.



Courtesy of Axiva

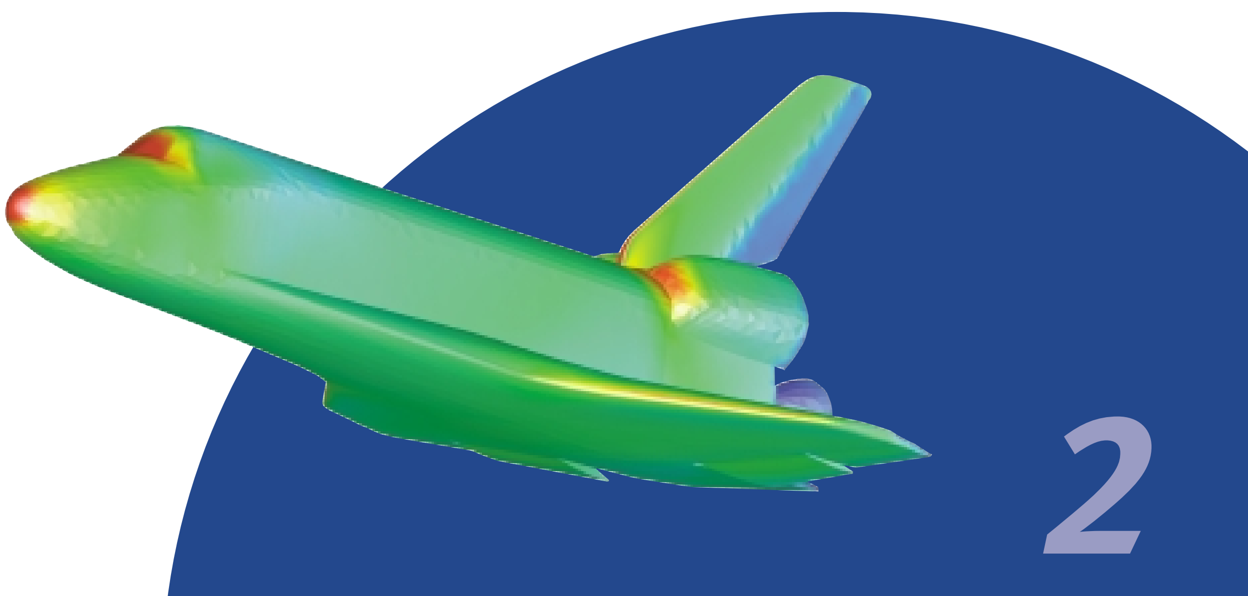


Courtesy of Adapco

NASA AND BOEING PRESS FOR CFD DATA EXCHANGE VIA CGNS

CGNS

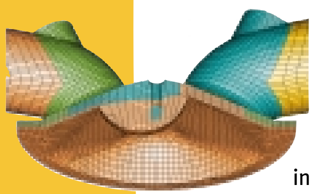
CD is now represented at the steering committee meetings of CGNS (CFD Generalised Notation System), an initiative conceived by NASA, Boeing and McDonnell Douglas, which aims to rationaliseCFD data exchange in aerospace and other industries. It is possible that CGNS will become the ISO standard for CFD data exchange, perhaps in preference to STEP.



ENGINE SIMULATION SEMINARS IN NUREMBERG AND BOLOGNA

CD recently hosted two seminars for our automotive clients on the simulation of Internal Combustion Engines,organised by the staff of CD's offices in Nuremberg, Germany, and Bologna, Italy. More than 100 engineers from around Europe attended the two-day events which covered topics from mesh generation to physical modelling aspects for one of the most complex CFD applications of the automotive industry.

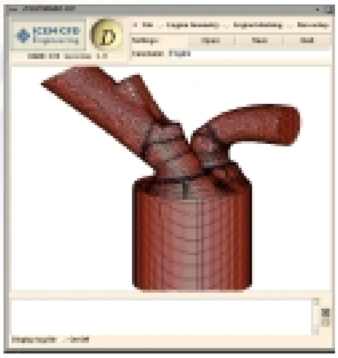
The first part of the seminars gave us the chance to present in detail the fundamental aspects of mesh motion in STAR-CD and the two advanced meshers RAMM-ICE, from Computational Dynamics/ICEM CFD Engineering, and PRO-ICE from adapco. The second part of the seminars focussed on the physical modelling aspects of In-Cylinder Simulation, hosting additional inputs from FEV (see article on page 7), Gamma Technologies (coupling of STAR-CD and GT Power), ICEM CFD Engineering, adapco and CD-adapco Japan.



PRO-ICE from adapco

Both events were closed by a presentation from Professor David Gosman, Director and co-founder of Computational Dynamics, on the current capabilities and future developments in STAR-CD in the field of Internal Combustion Engines simulation.

Those of you who have missed this seminar but would like to obtain the seminar proceedings should contact Maeve O'Brien at Computational Dynamics (Germany) – **maeve@cd-germany.de**



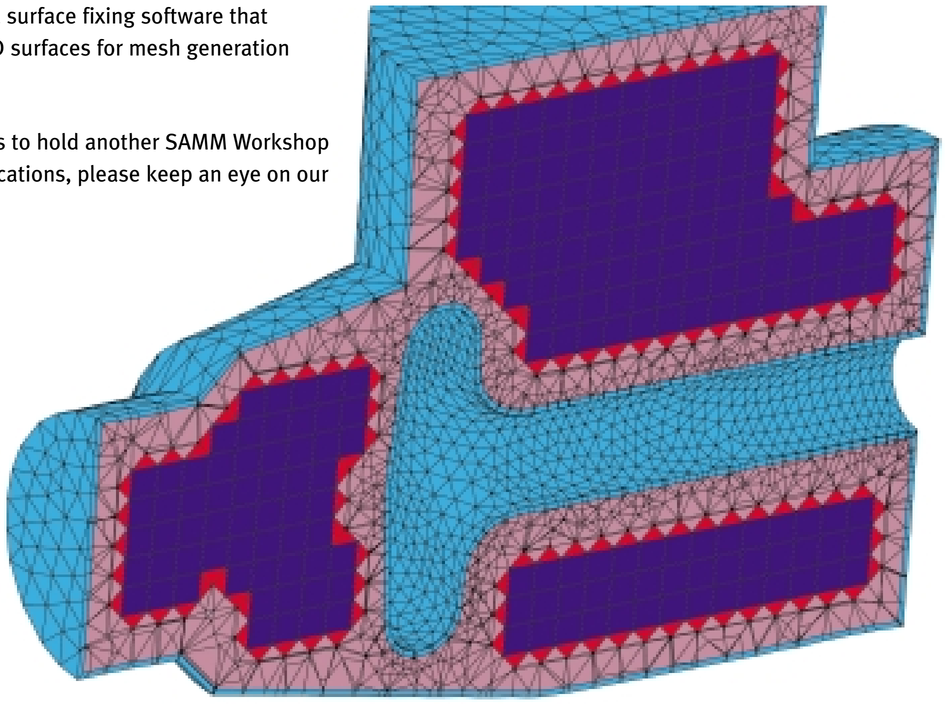
RAMM-ICE from CD and ICEM CFD

3RD SAMM WORKSHOP IN NUREMBERG

In September Computational Dynamics organised in Nuremberg, Germany, the 3rd SAMM Workshop. More than 25 users from Europe used the opportunity to gain hands-on experience with the latest version of adapco's mesh generator. New features of SAMM include resurfacing capability, variable subsurface thickness, local mesh refinement to allow for variable mesh density, a new tetrahedral mesher and a new extended GUI.

During the event, Maria Nordgren, of DeskArtes, presented the latest version of Rapid Tools, a surface fixing software that accelerates the transfer of CAD surfaces for mesh generation into SAMM.

Computational Dynamics plans to hold another SAMM Workshop during 2000. For dates and locations, please keep an eye on our website **(www.cd.co.uk)**.

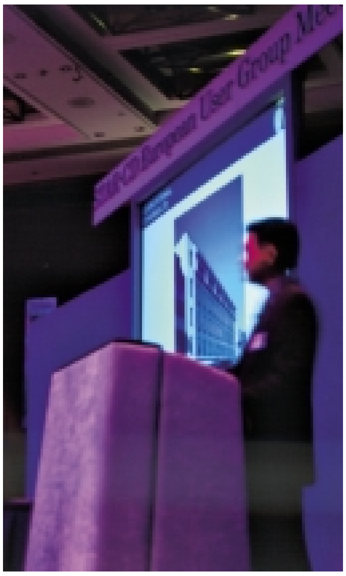


Hybrid mesh example produced with the latest version of SAMM. The case highlights the new capability of the software to blend hexahedra, tetrahedra, pyramids and prisms.

LATEST MIX !

STAR-CD Applications Presented at European User Group Meeting

The 8th Annual STAR-CD User Group Meeting, hosted by CD at London's Millennium Centre on the 22 and 23 November, was well attended by over 200 engineers. A broad mix of CFD applications was presented. Here is a brief summary of some highlights for those who could not attend.

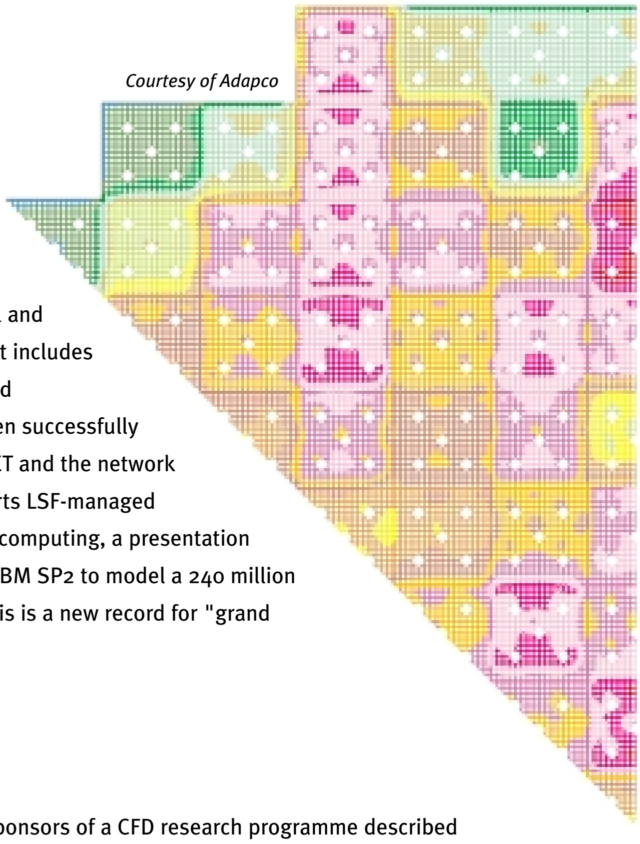


Combustion, turbopower and marine propulsion

NATIONAL POWER'S presentation described combustion modelling using STAR-CD in furnaces and combined-cycle gas turbines. The presentation concluded that the results were useful but that combustion modelling is difficult and "not for the faint hearted"!
A presentation by FORSMARKS described how to incorporate "level-set" technology into STAR-CD and to apply it to a range of advanced free surface flows. The LIPS JET Holland presentation described a STAR-CD analysis using a 3D parametric model to optimise the design of water inlets of an awesomely powerful (4 x 7200 kW), 80 km/hr, catamaran. Flow details were correctly predicted for both low- and high-speed propulsion modes. Best results were obtained using the MARS discretisation scheme and STAR-CD's cubic k-epsilon turbulence option.

LATEST MIX!

European User Group Meeting ***continued***



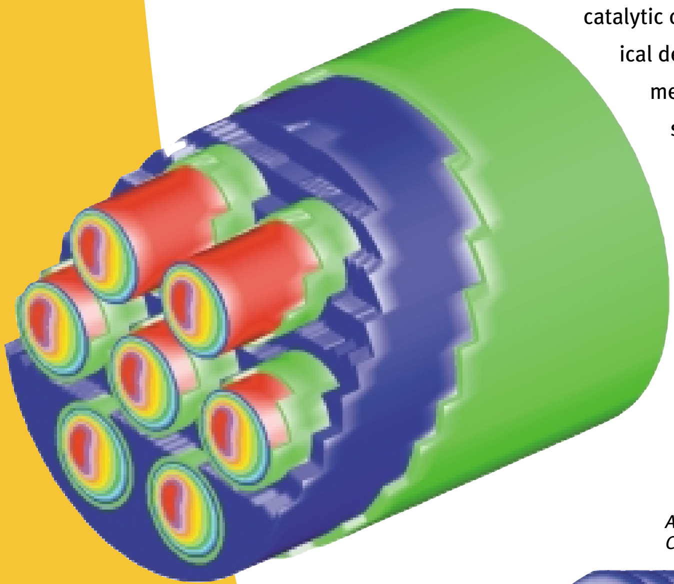
Courtesy of Adapco

Advances in computing with STAR-HPC

SAAB AUTOMOBILE use STAR-HPC for underhood, intake/exhaust and in-cylinder flows, climate control and external aerodynamics. Their computing environment includes 100 networked Sun Ultra 60 workstations. Distributed clusters, typically with 20 CPUs per person, have been successfully run as a low-cost computing resource using STAR-NET and the network management system CODINE (STAR-NET also supports LSF-managed networks). Representing the high ground of parallel computing, a presentation by adapco described their work on a 200 processor IBM SP2 to model a 240 million cell nuclear reactor cooling case using STAR-HPC. This is a new record for "grand challenge" CFD!

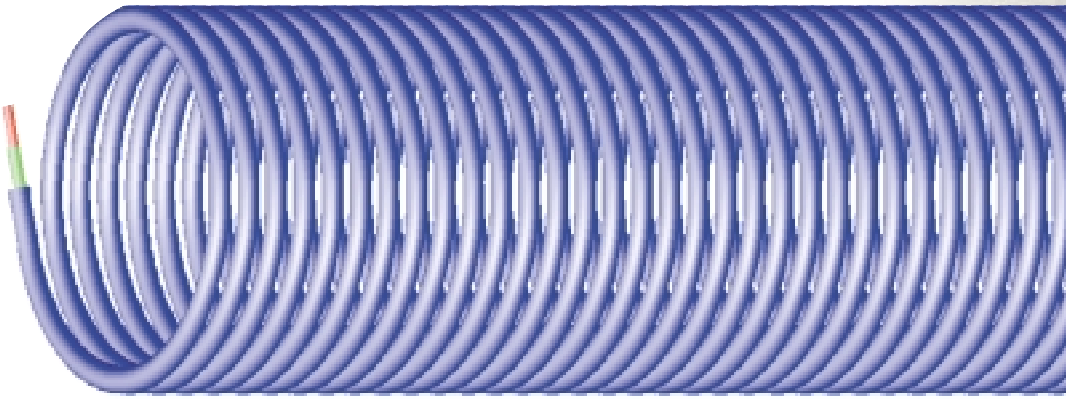
Process development, valves and pumps

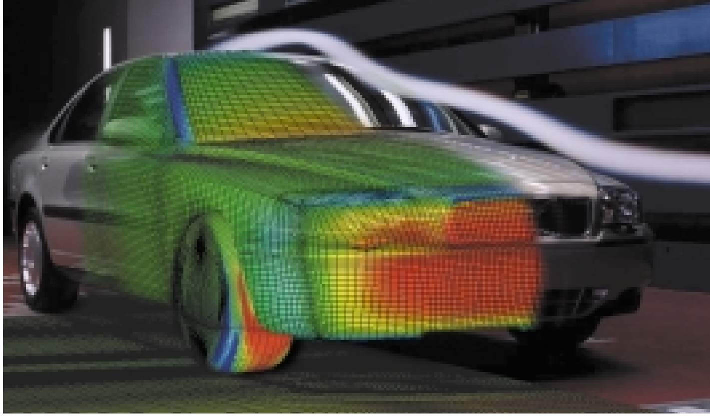
STORK and NATIONAL STARCH AND CHEMICAL are sponsors of a CFD research programme described by the TU Eindhoven. The effect of curvature on flow in a coiled steriliser was successfully analysed using STAR-CD to predict phenomena including the delayed transition to turbulence, increased pressure drop and heat transfer. Future work will include modelling the gelatinisation process in starch solutions. Ageing of catalysts was the subject of a collaboration between FORD MOTOR and Coventry University. Their presentation gave a review of deactivating mechanisms in catalytic converters, including poisoning, sintering, fouling and mechanical degradation. A STAR-CD model was described suitable for parametric studies of ageing mechanisms. DANA AUTOMOTIVE's presentation described CFD work to improve the performance, avoid cavitation and reduce noise in the flow control valve of a power-assisted steering pump. Geometrical details were successfully refined to optimise the design. A presentation from CD's partner CD-adapco Japan explained the use of STAR-CD's new barotropic cavitation model. Excellent results were achieved modelling cavitation in a centrifugal water pump.



Axial velocity profile of custard in a curved 7-pipe heating section of a STORK Sterideal steriliser.
Courtesy of University of Eindhoven

A counter-current 37-winding cooling coil.
Courtesy of University of Eindhoven

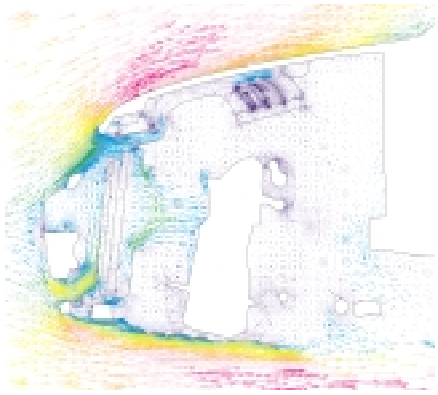




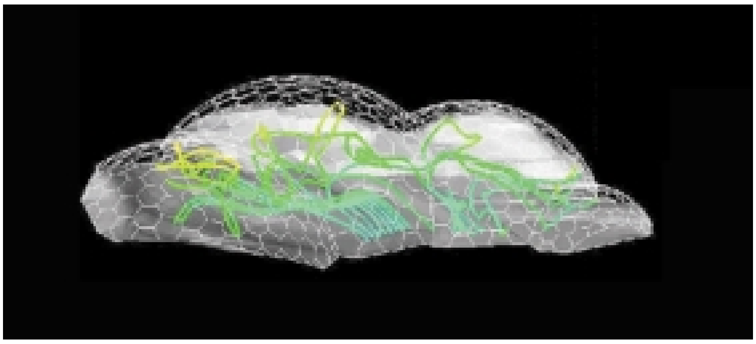
Courtesy of Volvo

Mainstream automotive design

VOLVO Car and DAEWOO gave impressive overviews of the broad usage of STAR-CD in automotive companies, ranging from engine combustion and cooling, aerodynamics and wind noise, and climate control, to brake cooling and dirt deposition. For STAR-HPC preprocessing VOLVO prefers ICEM CFD and ANSA, and for postprocessing, ENSIGHT. Use of CFD at VOLVO is rapidly expanding, and the company sees it as an essential "virtual development tool". At DAEWOO also, CFD is no longer treated as R&D. It is now "fully integrated with all development programmes". The benefits reported by these users include "better programme support, cost reduction and shorter design times".



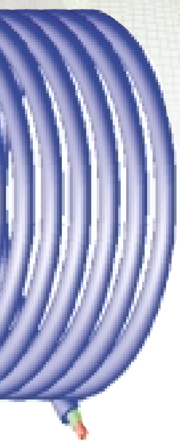
Courtesy of Daewoo

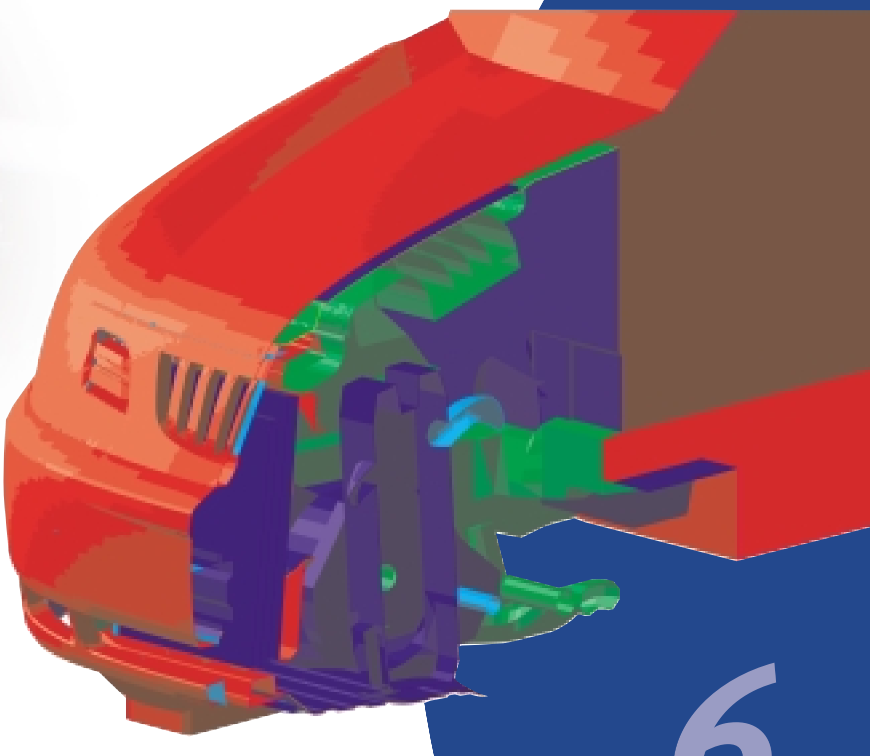


Courtesy of Ove Arup & Partners

Climate control - in automotive applications and the environment

For passenger comfort analysis, a software system INKA/TILL based on a BMW development, has been linked with STAR-CD. A presentation by P+Z Engineering showed the results of using this combination to good effect to predict thermophysiological comfort factors for passengers. OVE ARUP & PARTNERS presented STAR-CD simulations of internal temperature and air quality in an igloo and also showed climate models for the "biomes" of the Eden Project in Cornwall. The "biomes" are a collection of dome shaped greenhouses almost 1 kilometre in length to be used to create artificial climates for tropical and temperate flora.





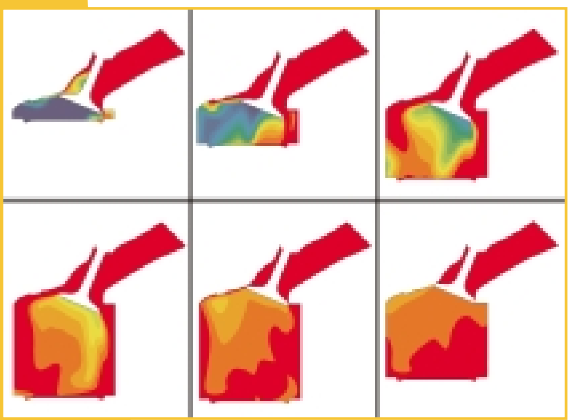
Courtesy of Daewoo

MOVING MESHES IN STAR-CD

SINCE ITS conception over 10 years ago, STAR-CD has always offered a moving mesh capability, and this functionality is applicable to all physical models and mesh types. This feature has been used and validated in many cases over the years and examples of such include

- power units, both reciprocating and rotating, such as a four-valve GDI engine
- fluid machinery, such as pumps, fans and compressors
- fluid-structure interaction, e.g. in an artificial heart valve
- general motion problems, such as pipe failure and subsequent gap growth in nuclear power plant
- fluid control systems, such as spring-loaded ball valves

The first thing one should understand when looking at moving problems is that STAR-CD offers solutions to many problems without resorting to moving meshes. For wind tunnel models, the moving roads and wheels used in the automotive industry can be applied via boundary conditions and many rotating machinery examples can be modelled by using the multiple reference frame approach that adds body forces in a regionwise manner.



If the calculation really requires moving mesh then STAR-CD offers the ability to change the mesh in two ways: by distortion and changes in connectivity.

You can distort a mesh by moving its vertices, either by user coding, by a series of PROSTAR commands, or using any other software you have available.

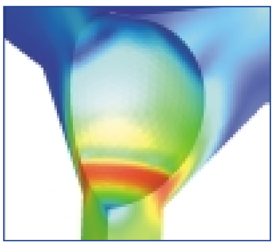
You can change the connectivity of the mesh in a number of ways.

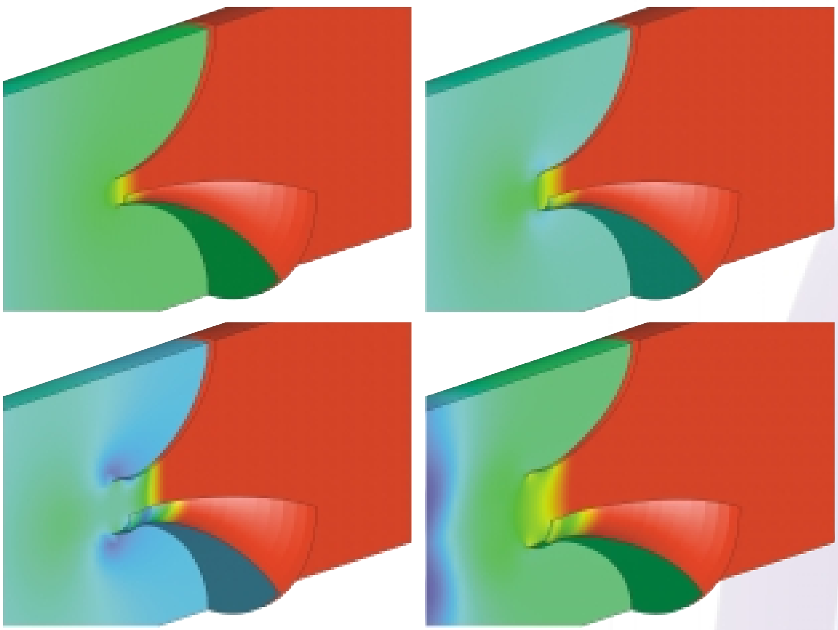
In an in-cylinder calculation, simple distortion of the mesh could result in cells being extremely compressed when the piston is at its highest point (or conversely extremely stretched at its lowest point) so you can overcome this by adding or removing cells as the calculation progresses.

In a flow controlled by a reed-valve, the valve will only open when the pressure differential across the valve is great enough to overcome its spring force, this condition can be modelled in STAR-CD and again is a connectivity change.

STAR-CD has a multiple stream capability and this extends to moving meshes, two streams of fluid can be joined together and later separated all in one smooth calculation. This is useful in applications with valve openings and closures.

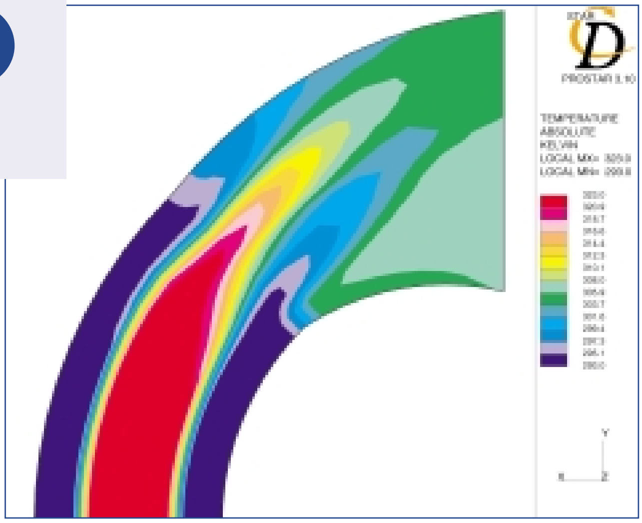
The main factor that has restricted the use of STAR-CD in these areas in the past is the hardware limitations, but these have reduced with the new generation computers and the speed leverage of STAR-HPC.
It is time now to revisit these application areas and make the most of STAR-CD.

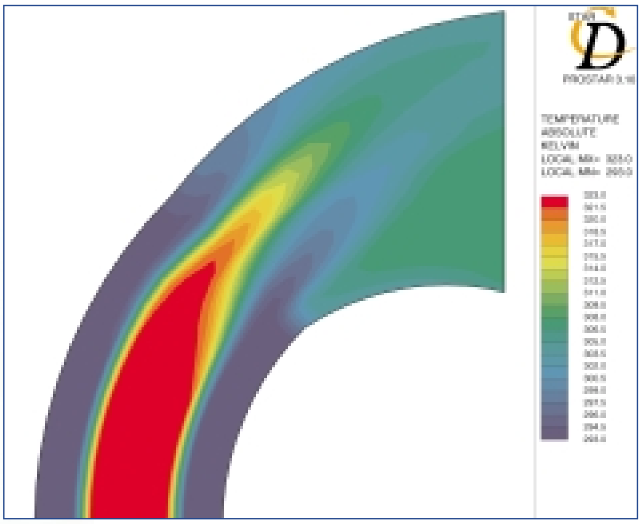




Simulation of a heart valve

THE ART OF USING COLOURS





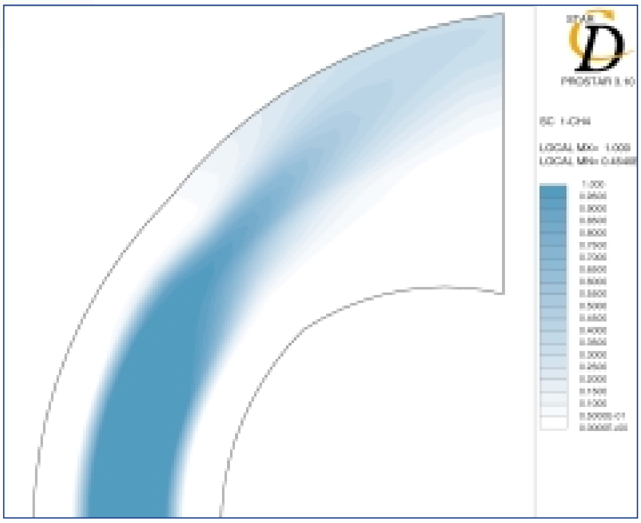


FIGURE 1 shows a plot of vertex-averaged temperature at the centreline of Tutorial 5. This uses the default colour map (`clrtable default`) and colour scales (`cscale 14 auto`). These give clear bands of colour and make it easy to relate the colours on the plot to the scale as adjacent colours are quite distinct.

For a smoother plot we do two things: use more colours and make the transition from one colour to the next much smoother.

Here we switch to 20 colours:

```
cscale 20
```

Now we switch the 20th colour to a dark blue and then fill using hue, light, saturation (`hls`) which gives a rainbow type of fill from red to the dark blue.

```
clrtable post 20 0 0 .5
clrfill post 1 20 hls
```

The plot is much smoother and there is more of an impression of hot and cold, this is helped by the transition from red to blue as well as from fully saturated to half saturated.

We also solve for methane as a scalar and here we show a plot of its concentration. The colours we have set up are good for hot to cold but here we want to show where the scalar is and is not, so we use a single colour (a blue/green) where we have gas and blend this to white to signify no gas. Again the `clrfill` command is used

```
clrtable post 20 1 1 1
clrtable post 1 0 .7 .7
clrfill post 1 20
```

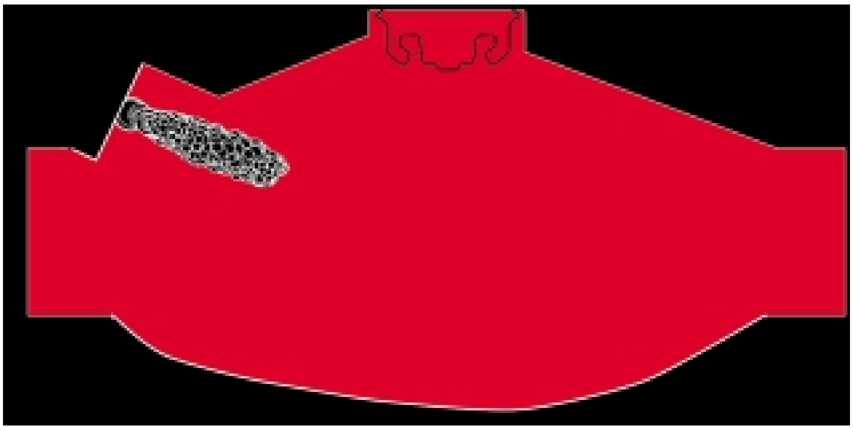
SPRAY PROPAGATION & MIXTURE FORMATION IN THE FEV DISI ENGINE

by Werner Willems from FEV

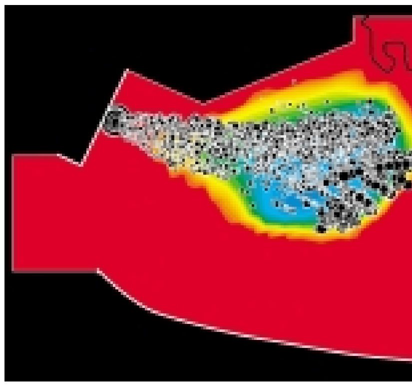
One of the most promising approaches for achieving a distinct reduction in fuel consumption for SI engines is direct fuel injection. At part load operation, Direct Injection Spark Ignition (DISI) engines combine the benefits of lean combustion with a nearly throttle-free operation.

THIS IS a major step in overcoming the principal disadvantages of SI engines compared to Diesel engines. At full load operation the in-cylinder charge is cooled by the fuel spray evaporation. This increases both volumetric efficiency and reduces knock sensitivity, which results in higher full-load performance.

FEV has developed a charge-motion controlled DISI combustion system where the in-cylinder charge motion is used both for mixture preparation and transport to the spark plug. This concept avoids fuel wall-film formation and maintains a compact and central position at the piston bowl. Both are beneficial to the combustion process and reduction of pollutant formation. The air-guided, stratified charge mode of the FEV DISI engine requires an exact control of the charge motion to ensure that the fuel vapour cloud reaches the spark plug at the time of ignition. Charge motion is controlled by a Continuously Variable Tumble System (CVTS), which allows controlled blocking of the lower half of the split intake port. The calculated flow distribution near the intake valve is shown in Fig. 1, revealing the effect of the closed CVTS.



The advantages of such directly injected gasoline engines have to be weighed against a higher degree of system complexity. Here, CFD simulations are very useful in gaining process understanding and in investigating effects like the CVTS switching position and the injection parameters (e.g. injector type and position, injection timing) on the engine behaviour. STAR-CD is used to simulate in-cylinder flow and mixture formation in part-load conditions. The transient simulation covers the complete intake and compression stroke, taking into account valve and piston motion. The hexahedral mesh used consists of several subgrids connected by arbitrary sliding interfaces. PROSTAR events are used to generate the grid motion and cell layer addition or removal.



To simulate the fuel spray propagation and evaporation, STAR-CD´s built-in Lagrangian two-phase treatment is used to describe droplet motion and evaporation as well as droplet break-up and collision. These capabilities are extended by user routines for spray atomisation modelling developed by FEV. This atomisation model describes the break-up of the liquid sheet formed at the nozzle exit of the high pressure swirl injector and determines the size and velocity distribution of the primary droplets.

An exact description of the primary droplet characteristics and their subsequent break-up is essential for an accurate simulation of momentum, heat and mass transfer between droplet and gas phase in the combustion chamber.

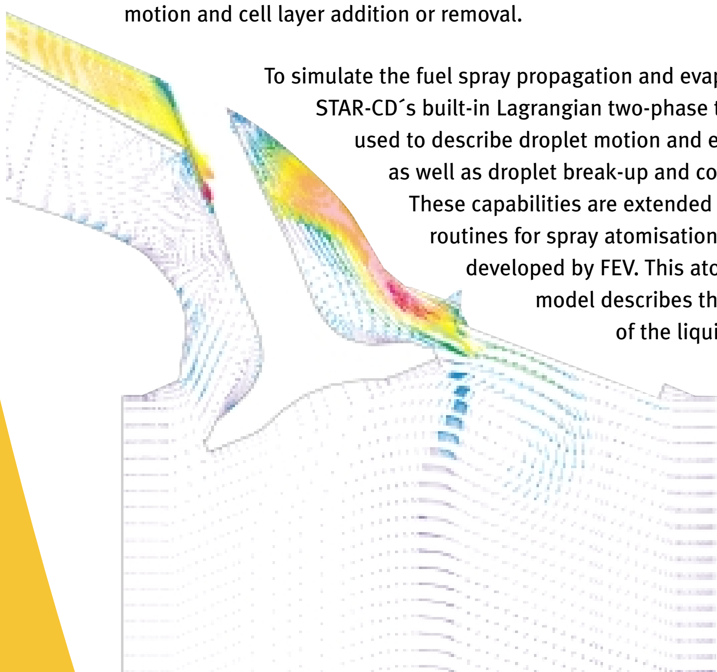
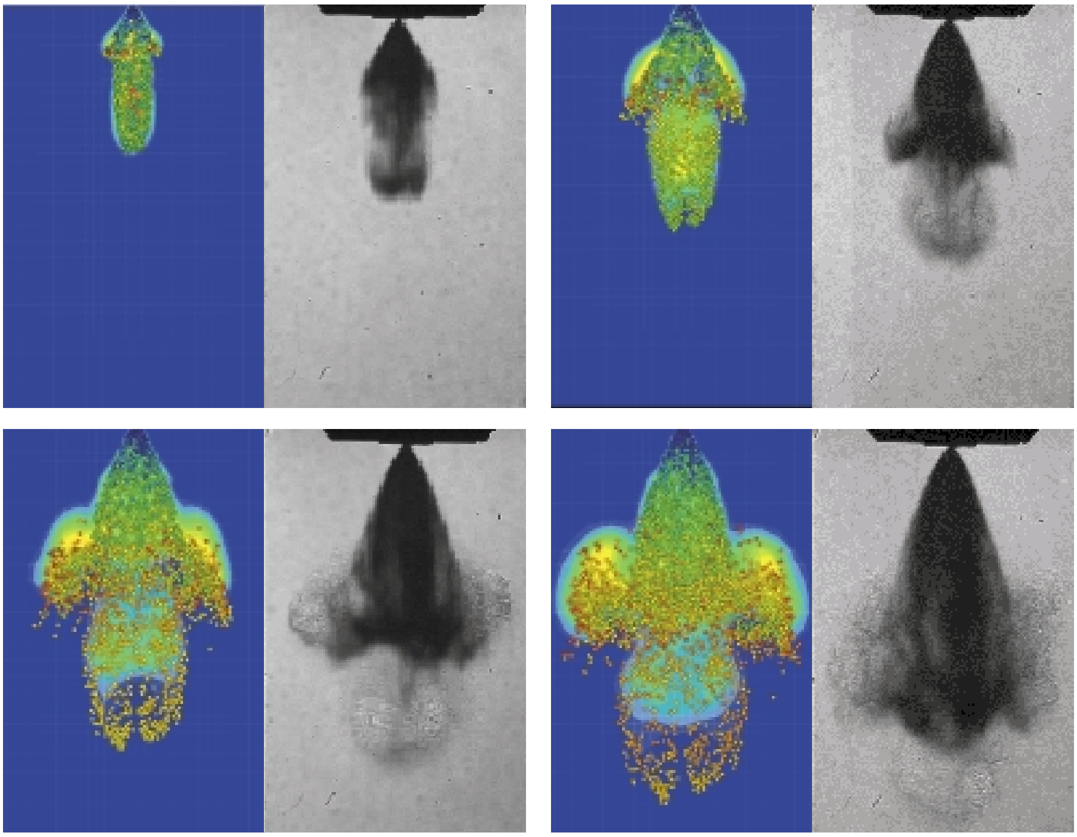


Fig.1: In-cylinder flow field at closed CVTS device

Therefore, the CFD model and its results have been carefully compared with experimental data. These have been obtained in a high pressure - high temperature injection chamber with optical access to the spray.

In Fig. 2, STAR-CD results for spray propagation and evaporation are directly compared to Schlieren spray images at discrete time increments after the start of injection. Due to temporal delay of the swirl flow development during injection, the injection starts with a straight pre-jet and subsequently turns to a hollow cone spray. This effect is clearly seen in the visualisation of analysis results and accounted for in the FEV atomisation user routines linked to STAR-CD.

Fig.2: Comparison of CFD injection simulation vs. experimental Schlieren spray visualisation



Using the validated DISI injection model, full simulations of the in-cylinder processes are performed. The aim is to investigate the interacting effects of tumble charge motion and spray propagation on mixture formation. The results of an optimised engine design in Fig. 3 show the spray and fuel vapour distribution at an early injection phase, at the end of injection and ignition timing.

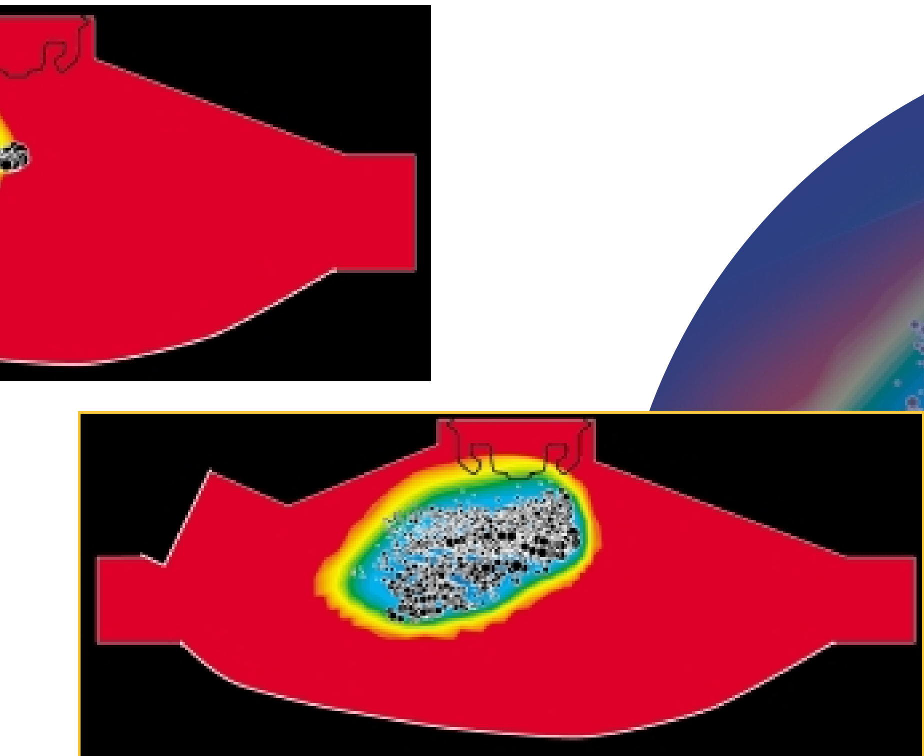


Fig.3: DISI spray propagation and mixture formation at 2000 rpm / 2 bar

IN CONCLUSION, **it can be stated that the use of STAR-CD helps to improve our understanding of the interaction between flow field, spray propagation and evaporation. In effect, this enables us to guide the optimisation of the flow control and to predict optimised injection parameters.**

European Training Courses

STAR-CD Basic Training Courses

U K

Course Dates	*Course ID*
15-17 February 2000	B 145
14-16 March 2000	B 146
11-13 April 2000	B 147
16-18 May 2000	B 148
13-15 June 2000	B 149
11-13 July 2000	B 150

Germany

Course Dates	*Course ID*
22-24 February 2000	BT 0200
21-23 March 2000	BT 0300
11-13 April 2000	BT 0400
23-25 May 2000	BT 0500
27-29 June 2000	BT 0600

Advanced Training Courses SAMM

U K

Course Dates	*Course ID*
24-25 February 2000	S 150
23-24 March 2000	S 151
20-21 April 2000	S 152
25-26 May 2000	S 153
22-23 June 2000	S 154
20-21 July 2000	S 155

Germany

Course Dates	*Course ID*
16-17 March 2000	ST 0200
11-12 May 2000	ST 0300

Advanced Training Courses ICEM

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Course Dates	*Course ID*
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20-21 March 2000	I 167
17-18 April 2000	I 168
22-23 May 2000	I 169
19-20 June 2000	I 170
17-18 July 2000	I 171

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