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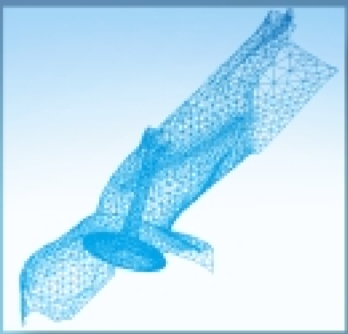
STAR-CD DYNAMICS

The Newsletter of Computational Dynamics

Lotus Uses STAR-CD to Help Evaluate an Innovative Intake Port Design



A MESSAGE TO ALL STAR-CD USERS

Recent years have seen rapid growth in the number of users of STAR-CD supported globally by the CD-adapco group. Following CD's move to larger premises last year, the rest of the group has continued its global expansion.

A new advanced development group "CDNA" has been set up in New Hampshire and is now working with our London-based developers on a new version of STAR-CD. Our Paris office has been strengthened and is now part of a unified European support network coordinated from London. Several new "satellite offices" have been added to the group. We have new offices in Sweden, South Africa and Russia reporting to CD in London. In the USA, adapco has expanded its subsidiary offices in Detroit, Schenectady, Cincinnati and Seattle. Meanwhile our Yokohama and London offices have been working together to expand the operations of our agency in Malaysia.

Our product strategy is to invest in STAR-CD whilst opening its environment to the most advanced CFD technology and best-in-class CAE tools. We are working with Academic collaborators on releasing the V2F turbulence model from Stanford, and a beta version of MOM3D, an automatic mesh adaption tool originating from research at Concordia University. We are soon to release aeroacoustics capability in STAR-CD following a collaboration with Karlsruhe University. To provide better solutions for the chemical process sector, we are making links to CHEMKIN and gPROMS. We are also launching MiXpert, a meshing tool for mixing vessels from Siemens Axiva. For CAD, in addition to several new interfaces, we are soon to release an interface to SolidWorks, a sophisticated CAD system for NT users.

From our partners adapco, we now have the Pro*am automatic meshing tool which integrates Prostar with "SAMM" technology. Our group strategy is to use Pro*am as the basis for the development of a set of application-specific pre- and post-processing tools aimed to facilitate technology transfer of engineering consultancy experience to users of STAR-CD. These "EZee" (American pronunciation!) tools will provide automatic meshing tools, input options and post-processing for special areas of engineering. The first to be released are EZAero and EZUhood for automotive applications. Further such tools are in the pipeline for other STAR-CD sectors such as turbomachinery applications.

This Newsletter touches on some of these developments and highlights some applications of STAR-CD. We hope you will find the articles interesting and informative. I personally look forward to meeting as many of you as possible at our European User Group Meeting in London, 20-21st November. Please track me down and come and say "hello"!

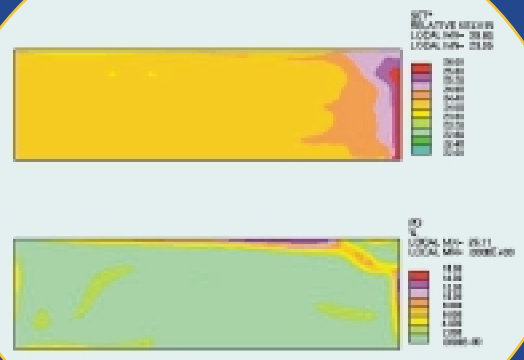
Chingzou Hsu
Managing Director

CONTENTS

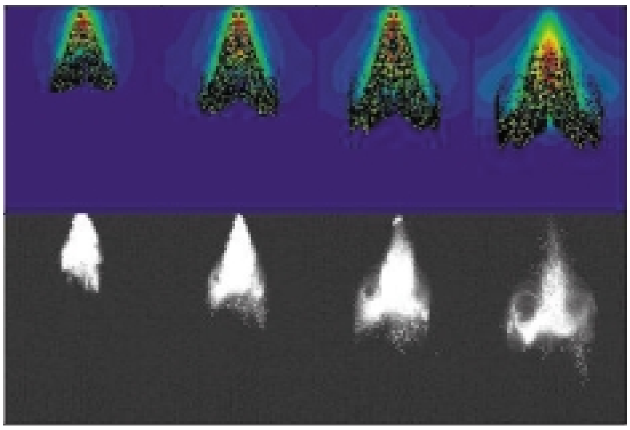
UGM HIGHLIGHTS

Recent User Group Meetings

The 2000 STAR-CD North American Users' Conference was held on the 1st and 2nd May at the Northfield Hilton in Troy. With nearly 200 attendees, STAR-CD users enjoyed a great variety of presentations from the automotive, power generation, medical, nuclear power, gas turbine, aerospace and HVAC industries.



An evening reception was held at the end of the first day. Day two concluded with answers to some frequently asked questions and the presentation of STAR-CD future developments given by David Gosman. A lot of interest was shown in the launch of Pro*am, EZAero and EZUnderhood, new pre-processing tools focusing on ease-of-use and technology tranfer.



Comparison of the calculated and experimental results of spray patterns from a presentation on 'Numerical Simulation and Experimental Validation of Pre- and Post- Treatment for a Design of Low Emission Vehicle' presented at the Korean User conference by Soo-Jin Jeong, Choong-Hoon Lee, Woo-Seung Kim and Ki-Hyung Lee

Korea. The positive turn in economic fortunes of Far Eastern industries was reflected in the large attendance for the Korean User Conference in Seoul. Around 150 Engineers and CFD practitioners attended the conference at 63 Convention Center on 20th June. As usual the main part of the program was dedicated to presentations by STAR-CD users, sharing their industrial experiences with colleagues.

The highly varied and interesting presentations included diverse application areas such as, external aerodynamic simulation of commercial vehicles, compressor modelling, rocket motor simulation, vehicle emission prediction and simulation of air flow in and around buildings. The range of applications presented clearly reflected the extensive and rapidly expanding use of STAR-CD in Korea, this relatively young CFD market.

Some of the users at the North American Users' conference

User Group Meeting

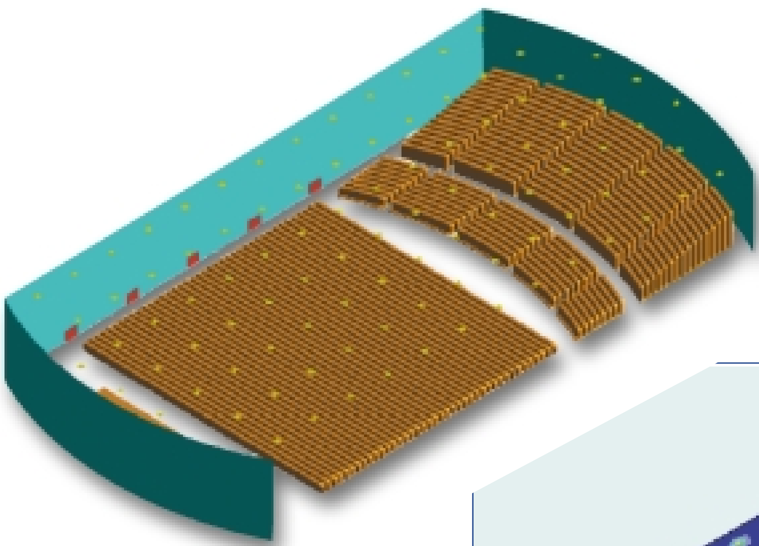
continued

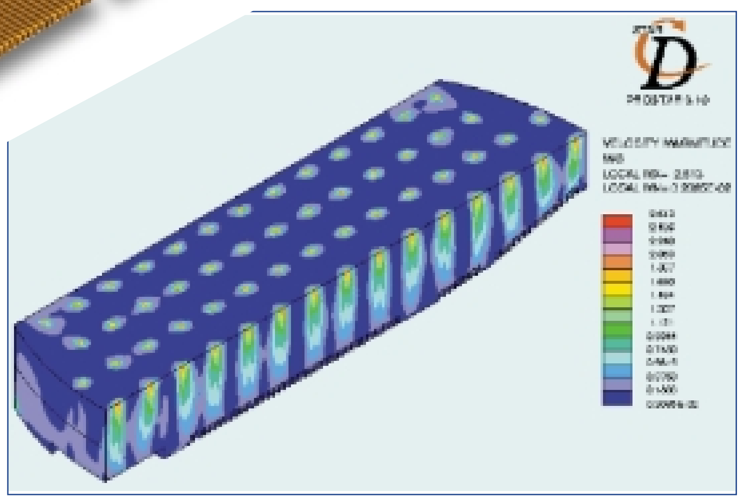
The growth of industrial CFD and dominance of STAR-CD in Japan has been remarkable, with STAR-CD being by far the widest commercial CFD code used there. This was reflected by the attendance of over 500 users at the 7th STAR-CD user group meeting at the Pan Pacific International Conference Center in Yokohama on 22nd and 23rd of June. The two day meeting was crammed with technical presentations from a wide range of industries and applications.

This year the key speech was delivered by Professor McRae of MIT who presented his vision of a marriage between CFD and complex modelling of chemically reacting systems and how STAR-CD and CHEMKIN are leading the way in this area. As usual the user presentations were of a high standard, with some specially interesting ones including, analysis of blood flow in artificial organs, cavitation flow around hydrofoils, prediction of wind loading on tower structures and simulation of two-phase reacting flows, to name a few.

As usual all conferences were attended by Professor David Gosman, a board member and one of the founding members of Computational Dynamic Ltd, who outlined the future development plans for STAR-CD. Many new products were also launched and demonstrated during these conferences, including application specific mesh generating and modelling products, EZAero and EZUhood from adapco.

All in all a very successful and buoyant start to the first half of the year with nearly a 1000 participants to our conferences so far, and there are still the French and Pan-European meetings left to go!





'CFD Application for Indoor Air and Temperature Distribution in Large Scale Space' presented by Seungeon Lee (Institute of Construction Technology)

PRODUCT NEWS

A Breakthrough in CFD Meshing for Industry

Computational Dynamics Limited and adapco have released a set of industry- focused automatic meshing modules for STAR-CD.

These tools are special pre- and post-processing systems created to capture the needs of particular industries and applications. Each tool has its own tuned Graphical User Interface (GUI) designed to lead the CFD analyst through the different stages of the setting up process. Automatic meshing and post-processing technologies are bundled in and pre-configured to handle the particular geometry and flow regime of each application.

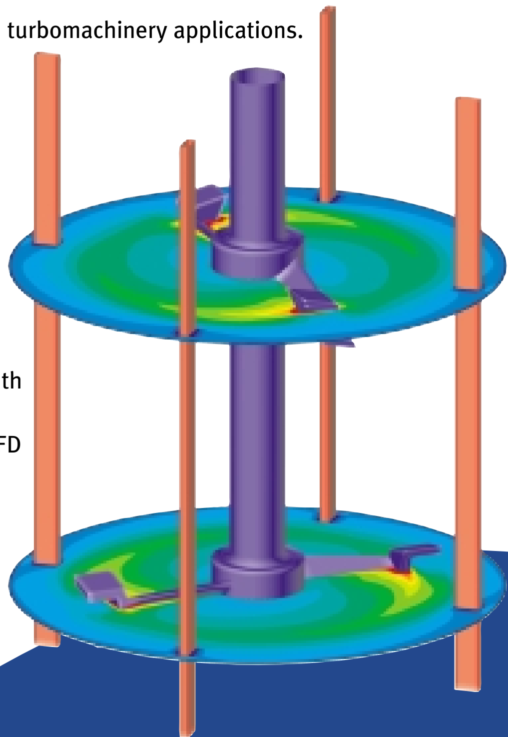
In a joint statement, CD and adapco announced the release of several of these new modules for use with STAR-CD.

EZAero introduces an easy way for STAR-CD users to generate external aerodynamics grids. Starting with a CAD surface, EZAero's GUI guides the user through the steps of importing and configuring geometry, preparing surfaces, generating templates, creating the mesh, running the STAR-CD code and post-processing the results. Meshing is done automatically using adapco's "pro*am" technology, resulting in a high quality mesh of predominantly hexahedral cells. Prismatic surface layers are extruded to aid near-wall turbulence modelling, enhancing the accuracy of aerodynamic calculations, including such parameters as lift and drag.

EZUhood is a similar system designed to help CFD analysts tackle the challenges of simulation of underhood (under bonnet) flow and heat transfer. This is one of the most critical areas of modern car design as the auto companies compete globally to optimise engine compartment design within ht technical constraints and stylistic considerations. For underhood CFD analysis, "the devil is in the detail" and geometrical detail is just what is captured by EZUhood, via automatic mesh refinement around the important components such as the grill and heat exchangers.

With EZAero and EZUhood, modification to vehicle and underhood geometry can be handled with minimum effort. These tools are already enabling major car companies such as DaimlerChrysler to use CFD more interactively in their design environment. Several other "EZ--" tools are in the pipeline from CD and adapco. These include EZTurbo (for pumps and turbomachinery applications) and EZBrake (for brake cooling simulation), and EZIce, launched to help STAR-CD users create complex moving meshes for engine design.

Not all the new tools are for automotive and turbomachinery applications. To help chemical process industries , CD in collaboration with a subsidiary of Hoechst, have developed a specialised tool called Mixpert for mixing vessel design. Mixpert's GUI simplifies the setting up of CFD cases for a wide range of laminar and turbulent mixers. A comprehensive library of impellers is included and Mixpert is particularly powerful in facilitating the assembly of different impellers, baffles and vessel shapes, enabling CFD models to be created very quickly.



Where is all this leading? Some industry specialists predict that technology such as this will become a major focus for industrial CFD, with increasing demand for such specialised "front end" tools. The ultimate goal, they say, is to create multiple packages which, when linked to a CFD code such as STAR-CD, can act as an "expert system" for each industry and application.

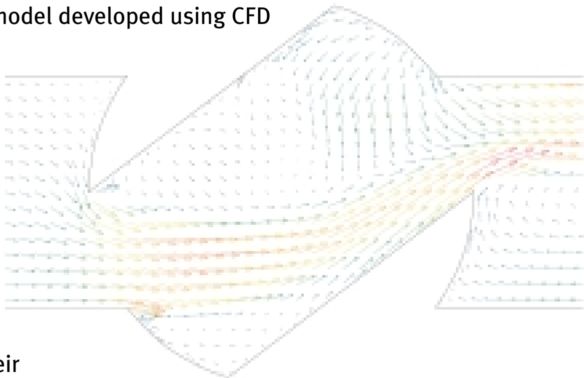
When looking at providing an integrated CAD capability for STAR-CD a few facts became quickly apparent.

SolidWorks Interface for STAR-CD

In the process of choosing a CAD partner we realised that established CFD users already have in-house CAD capability and do not want to use another CAD package just for CFD. This area is addressed by the extensive file import functions within Prostar and the Direct CAD interfaces offered via the ICEMCFD suite of products we support. Furthermore we realised that the majority of smaller companies without in-house CAD are working not on our traditional unix platform but on the emerging PC platforms.

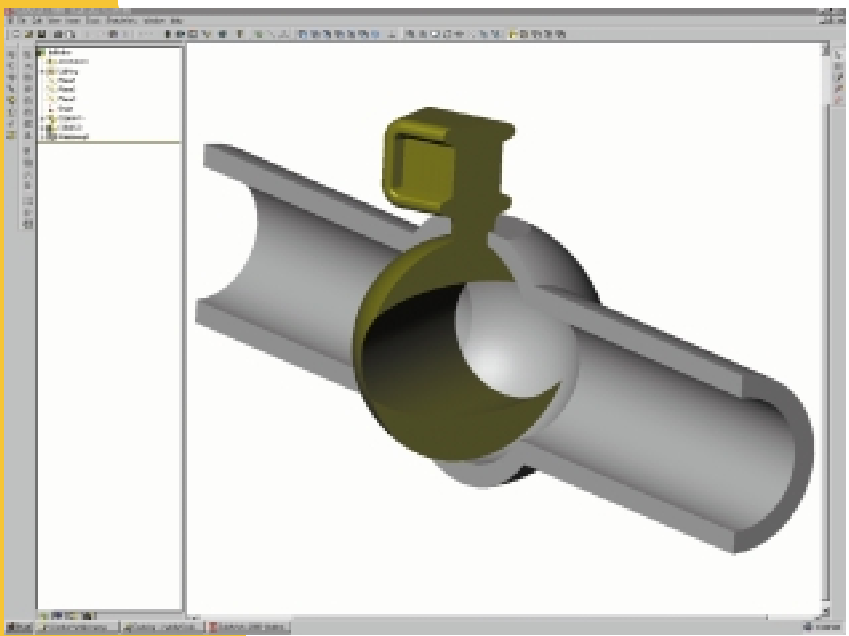
To develop CAD functionality on a PC, three routes were available to us: develop the functionality ourselves, integrate a CAD kernel into our software, or integrate our software into a CAD system. The first route smacks of “reinventing the wheel” and would be an expensive way to achieve a limited CAD capability, so we eliminated that option. This leaves the choice of integration, either a kernel into Pro*am or some of Pro*am into a CAD package.

Two factors swayed the final decision: the first is the rapid development of CAD packages: if the integration was done into Pro*am then as the kernel expanded it would require further integration and so there would always be a delay until the end-user received this benefit. The second concerned the wider business context: CFD does not stand on its own, it is part of a much bigger process. If a model developed using CFD is to prove useful then it needs to be machined and manufactured. By using a commercial package such as SolidWorks, the benefits of the CAD model developed for CFD can be used throughout the product cycle.



So we decided to mate Pro*am to the API (applications programme interface) of a CAD package, and SolidWorks was selected as the market leader in its field.

What does SolidWorks offer in terms of CAD functionality? Well the short answer to this is just about everything: a quick visit to their website www.SolidWorks.com will give you all the information you need.



What does the integration offer? Essentially SolidWorks acts as a geometry source for Pro*am. Each surface in SolidWorks appears in the Pro*am database as a set of shells with a unique cell table number. This allows selective picking of surfaces for extrusion layer thickness etc.
Any modifications to the CAD are done at a CAD level so are immediately available to other users of the CAD model without the use of intermediate format such as IGES. The codes are run seamlessly so when the CAD is ready it is sent to Pro*am and the CAD closes and Pro*am is open with the model ready for meshing.

Courtesy of University of Eindhoven

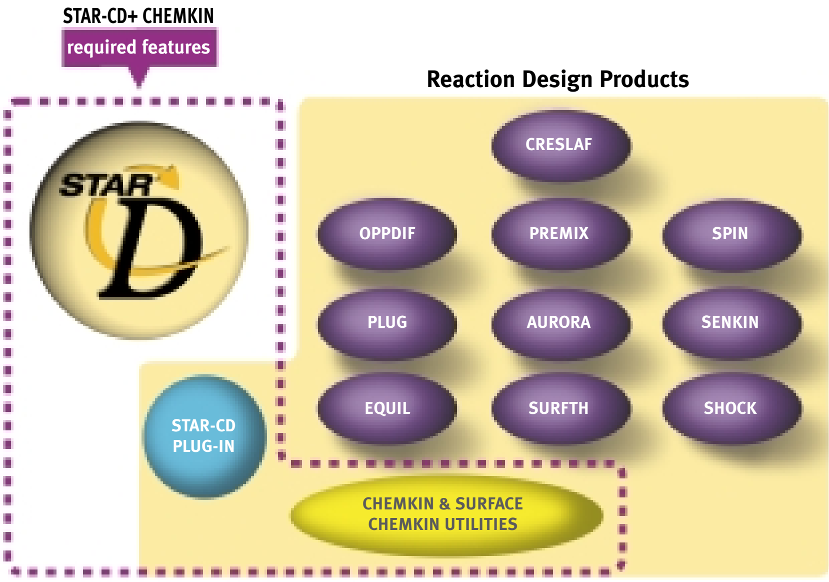
PRODUCT NEWS

STAR-CD couples to CHEMKIN

San Diego-based Reaction Design , New York-based adapco and London based Computational Dynamics are teaming up to combine STAR-CD, the leading code for multi-dimensional flow analysis, with CHEMKIN and SURFACE CHEMKIN, the leading codes for chemistry and surface chemistry analysis.

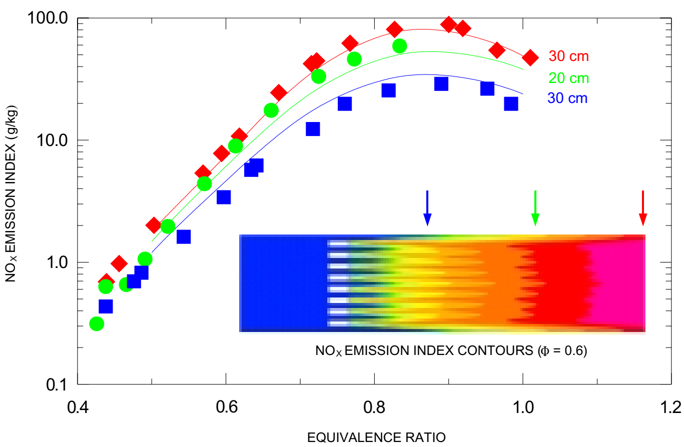
For CHEMKIN and SURFACE CHEMKIN users, STAR-CD will provide the capability of extending their analyses of chemically reacting systems to include full three-dimensional CFD simulations in geometrically complex systems with turbulence (including large eddy simulation), sprays, radiation, buoyancy, etc. as needed. Chemistry will be treated with a fast-coupled solver developed by Reaction Design. Thermal and transport properties will be evaluated as they are in CHEMKIN, while reacting boundary layer treatments will follow techniques developed in SURFACE CHEMKIN.

For STAR-CD users, a seamless methodology will now exist for developing and testing reduced n-step chemistry mechanisms using CHEMKIN and then applying these mechanisms directly in their multi-dimensional flow simulations. CHEMKIN will also provide a means of studying complex chemistry in a wide range of classic problems, such as perfectly stirred and plug flow reactors, as a prelude to reacting flow simulations with STAR-CD. Later developments will include the ability to directly couple CHEMKIN applications with STAR-CD to allow complex systems to be modeled with the most appropriate local models.



Schematic showing modular approach of STAR-CD coupling with CHEMKIN

SURFACE CHEMKIN will add a sophisticated means of incorporating surface chemistry in STAR-CD simulations. This will be particularly useful in modeling catalyst systems.



Development is well underway, including initial benchmarking and validation studies. As an example, the lean premixed/prevaporized (LPP) flame tube of Anderson used for NOX emissions studies (as described in NASA-TM-X-71592) has been analyzed with a 26-step reduced propane mechanism developed at the NASA Glenn Research Center. As the graph to the left shows, reasonable predictions are found over a range of equivalence ratios and residence times (as they are related to measurement locations downstream of the flame-holder). More tests with spray combustors, IC engines, catalytic converters, and chemical reactors are either underway or soon will be.

Lotus uses STAR-CD to help evaluate an innovative Intake Port Design

By Ian Postlethwaite, *Principal Engineer, Powertrain CAE, Lotus Engineering*

The design of a modern intake port geometry is a compromise between high speed flow and low speed tumble. The tumble is used at low speed to augment combustion at a time when the flow has generated little turbulence during induction.

As the speed/flow rate increases, the tumble increases and flow coefficients decay. At the higher speed/flow rates the flow has sufficient turbulence, and high tumble is not required. Therefore, a port designed to deliver sufficient tumble at low engine speed will produce a surfeit of tumble at the higher speed/flow condition at the expense of flow coefficient.

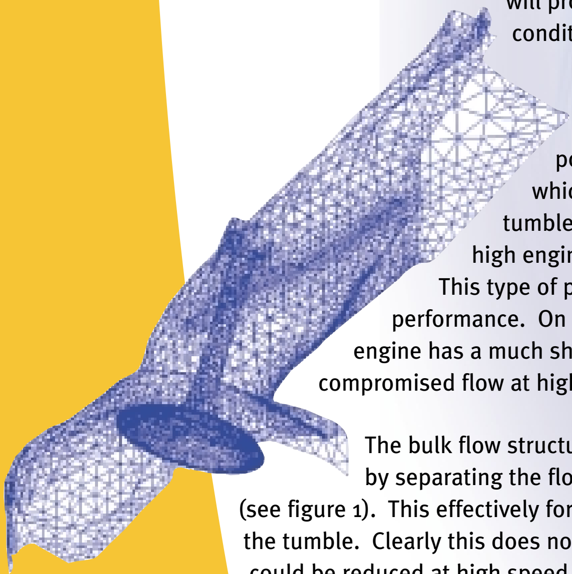


Figure 1 shows how the angle of the port varies depending on the application of the engine. The port for a high performance engine has a steep angle, which endows it with a good flow coefficient. The lack of tumble is not a shortcoming since, in this type of engine, the high engine speed and flow generate the turbulence required. This type of port would produce relatively poor low speed performance. On the other hand a port for a typical passenger car engine has a much shallower port giving good tumble at low speeds but compromised flow at high speed.

The bulk flow structure in the cylinder, described as tumble, is generated by separating the flow from the floor of the port just upstream of the valve (see figure 1). This effectively forces the flow over the top of the valve and produces the tumble. Clearly this does not use the full flow area effectively. If the separation could be reduced at high speed then the port flow capacity would increase.

With this in mind Lotus has developed an innovative port design (figure 2).

It has been tested on the steady flow rig and simulated using STAR-CD and has shown improvements in flow coefficient of about 8%. The CFD models contained in the order of 250000 cells. Both models were simulated using the MARS solver and the standard k(turbulence model.

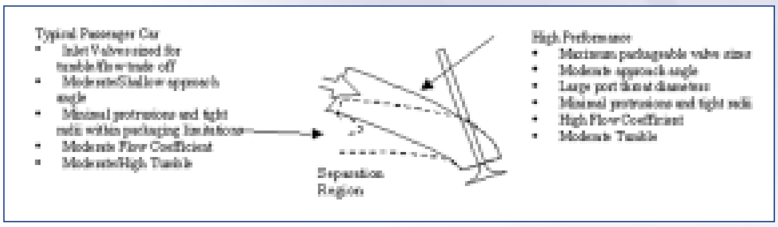


Figure 1: Engine Port/Valve Geometry

CFD analysis has highlighted the flow features that are responsible for the improvement in flow.

A section taken across the ports (figures 3 & 4) show the generation of vortices that draw the flow back towards the port floor and re-energize the boundary layer to offset the flow separation which causes the tumble.

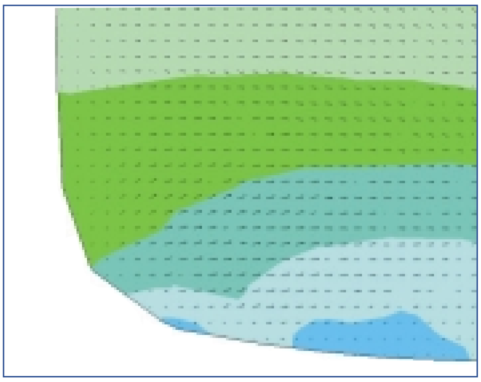


Figure 3: Secondary Flows through Base Port

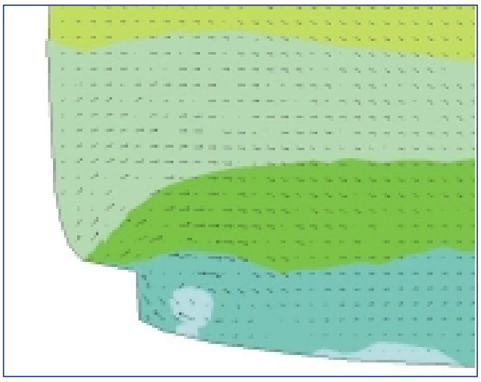


Figure 4: Secondary Flows through Modified Port

Figures 5 & 6 show the flow attaching more to the inner radius of the port with the modified geometry. The modified geometry shows a similar effect at lower speed and consequently reduces the tumble also. However, the reduction in tumble at low speeds is small and is more than compensated for by the increased flow.

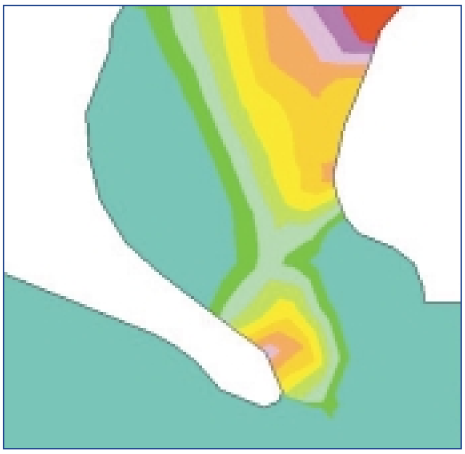


Figure 5: Base Port

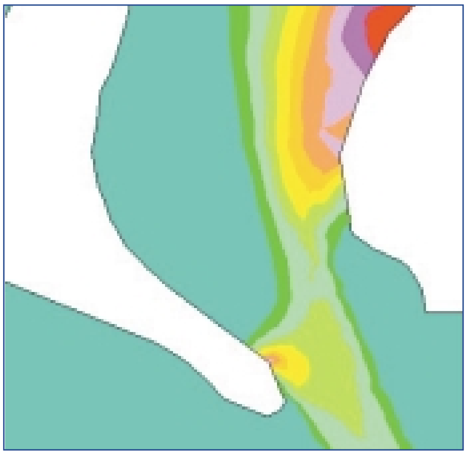


Figure 6: Modified Port

In conclusion, Lotus has used STAR-CD to enhance the understanding of flow within an innovative port design, which potentially improves the performance characteristics of a typical passenger car engine. Using STAR-CD Lotus can optimize the design for numerous package

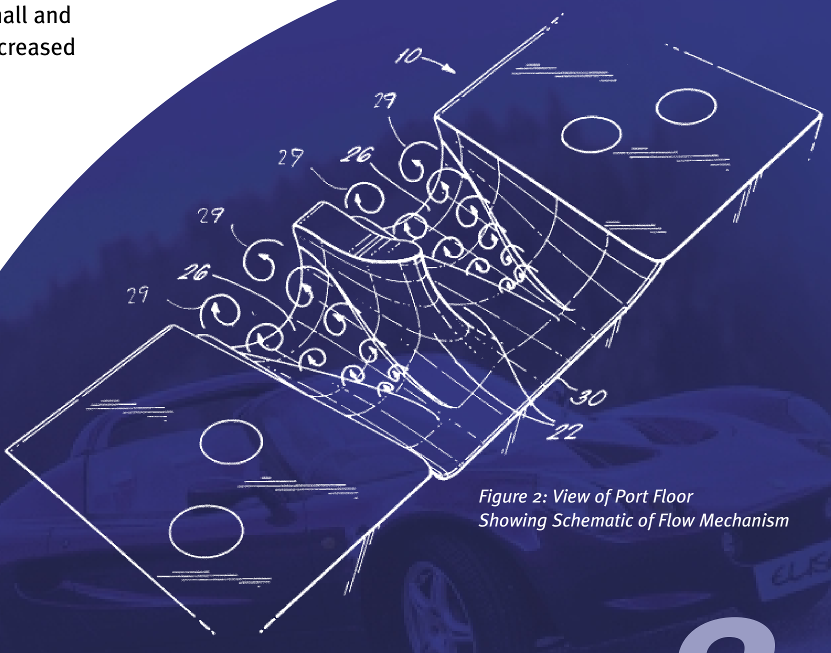


Figure 2: View of Port Floor Showing Schematic of Flow Mechanism

Computational Dynamics would like to thank Lotus Cars and Lotus Engineering for the kind use of images and the article.

WHY SANYO ELECTRIC CHOSE STAR CD

Our colleagues at CD-adapco/Japan (CDAJ) routinely send us minutes of meetings with the major corporations they support. We thought that readers of our newsletter might be interested to read a typical summary, in this case following meetings with engineering managers of the Tokyo-based Sanyo Electric (SE) company.

SE designs and manufactures domestic and industrial appliances such as refrigerators, air conditioners and compressors. They have been using STAR-CD since 1994. Typical design questions to be answered for their domestic refrigerators are “what happens to temperatures when the door is opened?”, and “when closed, what is the flow distribution in the ducts that carry air to the freezer and fresh food areas”. Similar design questions arise for SE’s range of open refrigerator cabinets. For all such products STAR-CD simulation is being widely used by SE to optimise designs before building protypes. For compressor design work STAR-CD is embedded with other CAE tools into an integrated system they call “C4P” (CAD, CAM, CAE and CAT&PDM), and is used in this environment as a general-purpose product design tool, for example, to optimise the positioning of components in condensing units. SE also use STAR-CD for what they call “special-purpose” CFD simulation. An example of this is the design of labyrinth seals. Despite being contactless, these seals achieve low leakage purely from turbulence induced by grooves in clearance. The grove interval and shape are critical to this process and these parameters have been successfully optimised at SE by means of STAR-CD simulation.

An open refrigerator cabinet with a cold air curtain on the left and without on the right.

Asked what features of STAR-CD were particularly important for their needs, several groups found arbitrary cell shapes and interfacing particularly helpful in modelling assemblies of sheet metal components in commercial refrigerators andopen refrigerator cabinets. Others commented favourably on the high accuracy of STAR-CD for radiation modelling, for example when optimising cooling efficiency in freezing/ air-conditioning systems. STAR-CD's multi-frame feature was also mentioned as being invaluable for modelling flows in rotating machinery. Mesh refinement was discussed in the context of embedding a fine mesh locally in a big space such as the inside of a refrigerator. All groups said that an important reason that they have continued to use STAR-CD has been the "helpful support and quick response" that they get from CDAJ.

However, when asked where improvements were needed, SE said that more information should be placed on CDAJ's website, including detailed descriptions of the wide range of STAR-CD analysis examples (comment from CD - a good idea in principle, however client confidentiality considerations can make this task difficult). They also requested a FAQ area on the CDAJ website (this is in process). Further suggestions for improvement included a request for better-organised and easier-to-understand manuals (comment from CD - translation to Japanese may not have helped!) and a demand for more tutorials with both simple and complex cases. Some users wanted a solid modeller in PROSTAR (comment from CD - we now have such an option with our SolidWorks/STAR-CD bundle).

In summary, SE is generally happy with the functionality of STAR-CD, and with the support they receive from CDAJ. However, we get the message loud and clear that ease-of-learning through better documentation and more tutorials will be of increasing importance as STAR-CD is more widely used in Sanyo Electric. We are working on it!

STAR-CD SUPPORT in Japan

CD-adapco/Japan (CDAJ) was formed in 1994 by Chingzou Hsu and his Japanese colleagues, with the involvement of CD's shareholders and investment from adapco. With 100% year-on-year growth it soon became the "Jewel in the Crown" for CD, such that in 1996 STAR-CD overtook all other CFD codes in Japan. STAR-CD continues to be market leader in CFD for the Far Eastern market, largly as a result of CDAJ's enlightened business model that aims to provide a balance of CFD consultancy and support. The concept is that consultancy should aim at making clients self-sufficient in their use of STAR-CD. CDAJ also develops and supports complementary software tools including the pre- and post-processor for the STAR-LT version of STAR-CD, and is currently developing a range of new CAD interfaces.

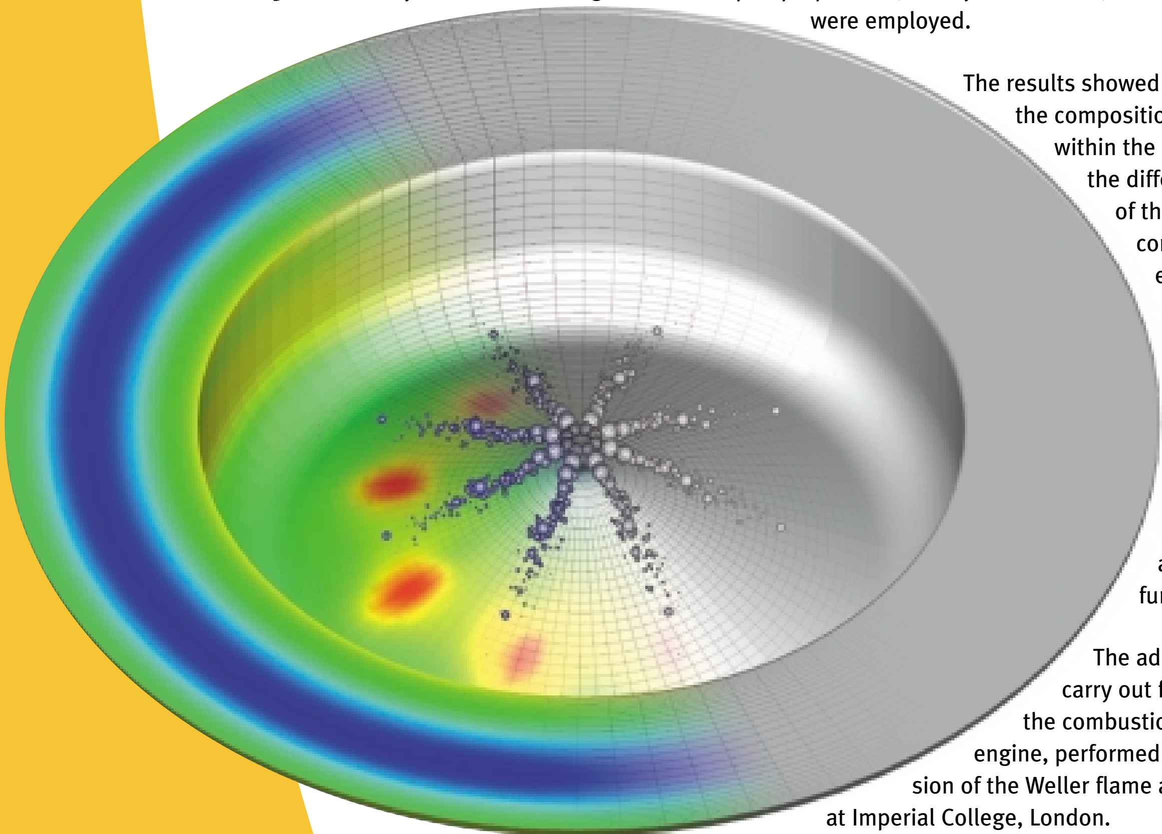
In 1997, CDAJ moved to prestigeous new premises with a dramatic view over Yokohama harbour. From this base the company continues to provide STAR-CD training and support to users in Japan, and coordinates its subsidiary offices in China, Malaysia and elsewhere in the Far East.

Multi-Component Fuel Spray Simulation

Although usually simulated in combustion CFD simulation calculations as a single-component fuel (typically iso-octane), gasoline is actually a mixture of many hydrocarbons. In recent work on an in-cylinder combustion analysis of a GDI engine, John Deur and colleagues at adapco (New York) represented the fuel in both the liquid and gas phases as a multi-component mixture.

In STAR-CD Sprays are treated via a Lagrangian approach with sub-models for break-up, turbulent dispersion, and collision. In this work, initial spray distributions were formulated to match available experimental data, although STAR-CD also incorporates semi-empirical models to create distributions from available injector geometry information. The standard k-_ model with wall functions was used to describe turbulence, while the mesh generation process, including the control of the piston and valve motion, was automated using ICE, an adapco product designed to reduce the time required to run such analyses.

In modeling a multi-component fuel with STAR-CD, the treatment of spray needed to be modified, although the spray module of STAR-CD is already capable of handling multi-component fuels to a certain degree. As a standard feature, droplets can be composed of up to ten components, each with different specific heat, heat of vaporization, and vapor pressure characteristics and each capable of vaporising to a different gas phase species. Other liquid parameters (density, surface tension, and viscosity) remain properties of the droplet. In this work, these standard features were used to describe the multi-component fuel droplets. The only new development was the creation of a user subroutine to provide the component properties needed for the different fuel components. The properties chosen came from the KIVA-3V fuel library. For the remaining common droplet properties (density and so forth), the values for iso-octane were employed.



The results showed a notable variation in the composition of the vaporized fuel within the cylinder resulting from the differences in the volatility of the individual components. As would be expected, concentrations of lighter hydrocarbons, such as butane and pentane, are high closer to the injector, while concentrations of heavier hydrocarbons, such as heptane and octane, are higher further away.

The adapco team went on to carry out further calculations of the combustion behavior in the engine, performed using a modified version of the Weller flame area model, developed at Imperial College, London.

The oldest trick and a new one.

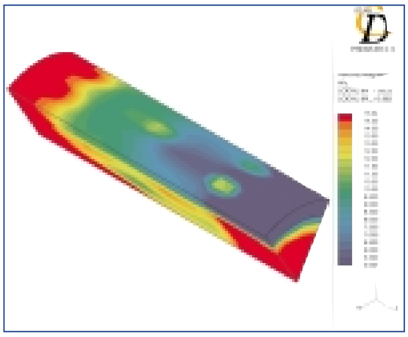
The most common question asked is “I have a part model, how can I post-process it to show the full model?”

Step 1: Get to your starting blocks.

This example uses Tutorial 9, which is a 60-degree segment. The .pst file is loaded and velocity magnitude is selected. (Temperature is put into register 5 to use later, don’t worry.)

```
load tut.pst
getc vmag
oper getc t 5
cset news fluid
cave cset
cset all
cplo
```

Step 2: Make some more copies.



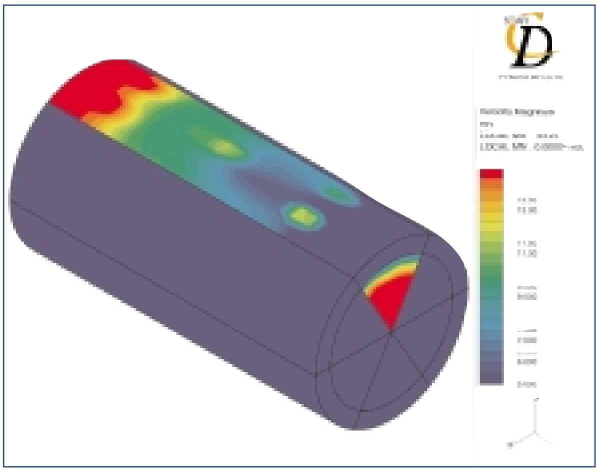
We have a one sixth model so need to make up the other five parts. We use the count command to see what we have.

```
UTIL*>
count,vertex

MAXIMUM VERTEX NUMBER    =   2310
NUMBER OF DEFINED VERTICES    =   2310
NUMBER OF UNDEFINED VERTICES    =   0
NUMBER OF VERTICES IN CURRENT VSET = 50
UTIL*>
count,cell

MAXIMUM CELL NUMBER    =   1980
NUMBER OF DEFINED CELLS    =   1975
NUMBER OF UNDEFINED CELLS    =   5
NUMBER OF CELLS IN CURRENT CSET =   1975

CELL TABLE TYPE  NO.OF CELLS NO.IN CSET
     1     FLUI  1800        1800
     3     BAFF  175         175
UTIL*>
```

This shows up a couple of things: (1) the maximum vertex is 2310 and (2) as well as 1975 defined cells, we also have 5 undefined cells.

We use the cgenerate command to make 6 instances of the model, the original plus five extra, and they are made by vgenerating the vertices in csys 2 by 60 degrees: this was covered in the last article.

```
cgen 6 3000 cset,,,vgen 2 0 60 0
cset all
cplo
```

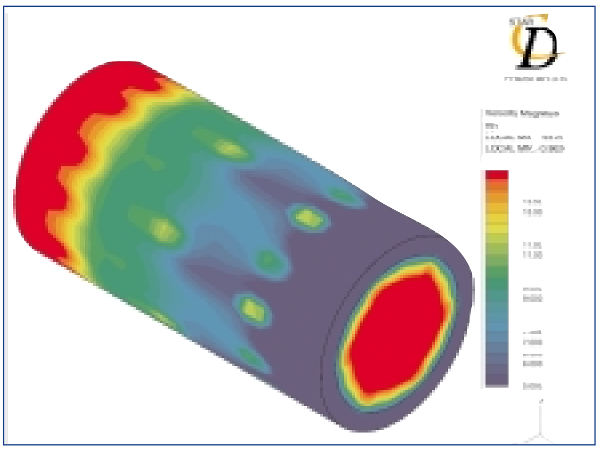


Step 3: Make some more results.

The dgenerate command is used to generate new sets of cell or vertex data. If cell data is loaded it creates new cell data, if vertex data is loaded: vertices. The command repeats the existing pattern of post data so we must be careful that the parts of the model we copy it to are identical copies else we get strange results. With this model the first 1980 cells contain 5 undefined cells. These are not copied in the cgenerate command so our new cells are not the same as the originals but our vertices are exact copies but just offset by 3000. This is an important point to note but preparation can help as if you use the ccompress command (before running the case) both cells and vertices are generated out as identical patterns.

We have vertex data loaded so do not have to worry, we just generate data using the same 3000 offset we used for vertices. (Note if we had cell data the offset is the number of cells we used to generate additional copies from and not the vertex offset used in the vgen or vref command.)

```
dgen 6 3000 1 3000 1
vmer all
cplot
```

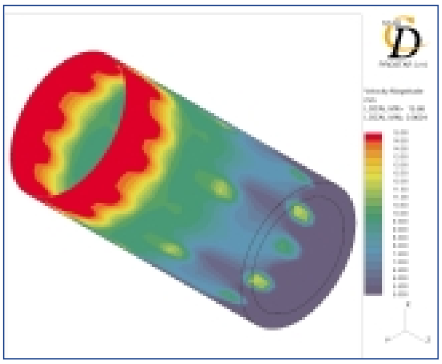


continued

Step 4: Something new.

It would be nice to plot a section of this to show some internal detail so we make a section plot in

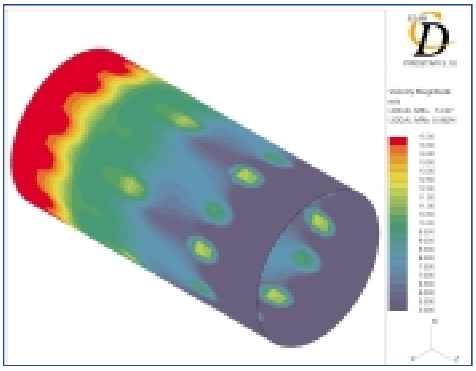
```
csys 2
spoi local 2 1 .25
plty sect
repl
```



This looks wrong and the reason is that for normal sections, Prostar does not depth sort them so the section created for the newly created cells comes after that of the original and overwrites it.

The new Prostar command, pscreate, allows sections to be manipulated in a much more powerful way than before.

```
pscreate 1 section outer
pmap allsec cset
cset news name outer
plty ehid
cplo
```



Step 5: Go silly.

Now we can make lots of sections and display them together and they intersect each other perfectly. The same applies to isosurfaces so remember we have temperature in register 5 lets do this

```
oper copy 4 6
oper copy 5 4
popt isos 375
pscreate 2 isos tiso
cset news flui
oper copy 6 4
pmap allsec cset
cset news name outer tiso
popt cont
cplo
```

Using the colouring techniques from a previous article we show an isosurface of temperature equal to 375 and a constant radius section both coloured by velocity magnitude, lit and transparent.

```
        0.113E+08  2.000   3000.000 ! JAM
CH2+OH=CH2O+H              0.250E+14
0.000      0.000 ! PG
CH+O2=HCO+O                0.330E+14
0.000      0.000 ! PG
CH+O=CO+H                  0.570E+14  0.000
0.000 ! PG
CH+OH=HCO+H                0.300E+14
0.000      0.000 ! PG
CH+CO2=HCO+CO              0.340E+13
0.000    690.000 ! PG
CH+H=C+H2                  0.150E+15  0.000
0.000 ! THORNE
CH+H2O=CH2O+H              1.17E+15 -
0.750      0.000 ! JAM,LIN
C+O2=CO+O                  0.200E+14  0.000
0.000 ! THORNE
C+OH=CO+H                  0.500E+14  0.000
0.000 ! THORNE
CH2+CO2=CH2O+CO            0.110E+12
0.000   1000.000 ! PG
CH2+O=CO+H+H               0.500E+14
0.000      0.000 ! JAM 2/87
CH2+O=CO+H2                0.300E+14
0.000      0.000 ! JAM 2/87
CH2+O2=CO2+H+H             0.160E+13
0.000   1000.000
CH2+O2=CH2O+O              0.500E
```

Figure 1

RESEARCH

Collaborative R&D Activities

In this article some of our current R&D activities will be highlighted.

As the applications of CFD grow and broaden, and as high performance computing becomes more affordable, more and more disciplines and industrial design, optimisation and simulations are falling within the boundaries of practical solution. To develop and test new technologies CD participates in and supports a number of Research and Development programmes which enable us to collaborate with leading academic groups. The objective is to benefit users of STAR-CD by implementing state of the art methods in CFD and related areas.

LES is an exciting area of research which we are actively pursuing. Professor Dominique Laurence of UMIST and EDF recently visited CD and gave an excellent presentation on LES and the relaxation turbulence model for RANS equations. He discussed some development and validation activities in France using LES for aeroacoustic source calculations. Dominique also gave a brief account of his activities on the combined use of LES and RANS equations.

Following Dominique's visit we next welcomed Professor Parviz Moin of Stanford and Cascade technologies to CD. Parviz gave a very comprehensive presentation on LES prediction of an axi-symmetric combustor. A dynamic Smagorinsky type model was used for sub-grid Reynolds stresses, variance of mixture fraction and heat flux. Laminar flamelet tables in conjunction with Beta probability density function were used. The results were impressive and showed that LES is able to predict large scale convective mixing which cannot be achieved with RANS calculations.

During the discussions, Parviz also presented some new developments for the V2F turbulence model. These include new terms in the model to mimic rotation effect on turbulence and non-linear stress strain relationship for modelling anisotropic effects. These new developments will be added to the V2F model within STAR when Cascade Technologies have concluded their validation studies. Parviz also described the activities within Stanford's industrial affiliate program at the centre for Turbulence Research, Centre for Integrated Turbulence Simulations, and the flow physics and computation division (CTR/CITS/FPC).

We have since joined the affiliate program, which will enable us to have access to publications and be informed about the research activities at one of the world's leading centres for research into turbulence.

In the area of combustion, we have continued to maintain excellent relations with the department of Fuel and Energy at the University of Leeds. Through this co-operation we have obtained the technology for predicting laminar flames. In this way tabulated solutions of an opposed jet flame for different strain rate are obtained and can be combined with the PPDF model for more realistic predictions of diffusion flames. In principle, the strain effects on flames that could not be modelled by use of chemical equilibrium can now be modelled. The capability of modelling complex reactions has also been implemented in STAR. A demonstration of STAR's capability to handle complex stiff chemistry, a simple diffusion flame with a methane mechanism consisting of 76 reactors and 22 species was simulated(Figure 1).

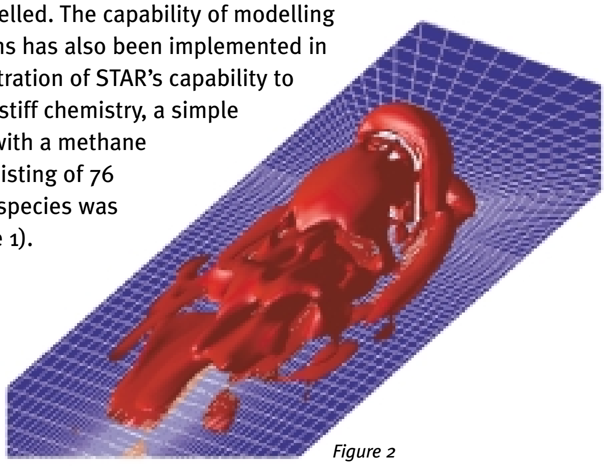


Figure 2

Collaboration with Professor Fabian Mauss has resulted in the implementation of his soot model in STAR-CD. The model is based on flamelet library approach. Due to the rather slow processes leading to soot formation / destruction, instead of taking the mass fractions directly from the flamelet libraries, the different source terms for soot are calculated and used in conjunction with a transport equation for soot mass fraction. The source terms were obtained by fitting correlations to the solutions of laminar counter flow flames using detailed models for gas phase species and formation and oxidation of Soot. Transport equations for mean mass fraction and mixture fraction variance are solved and the chemical source term is closed by use of a Beta probability function for mixture fraction and a log law or delta function distribution of scalar dissipation rate. The use of fitted correlation makes a detailed and complicated model particularly useful for CFD applications.

A model has also been developed for the prediction of acoustic sound source in quasi steady incompressible flows which are dominated by local shear effects such as flow around shear bodies or shear flow in channels. The turbulent instantaneous field is obtained from the mean velocity and turbulent length and time scales using the synthetic turbulence model of Kraichman and others. From the turbulent velocity field, the aeroacoustic source as defined in well known Lilly's acoustic equation is obtained. The approach was first used for aeroacoustic predictions by Dr Klaus Debatin (University of Karlsruhe) who advises CD on aeroacoustics. Figure 2 shows the aeroacoustic source around a surface mounted side mirror. The aeroacoustic source parallel to the surface wall is illustrated in Figure 3. The measured and predicted source in the plane of symmetry is shown in Figure 4. Considering that predictions linearly super imposed in the plane while the measurements using STSF(Acoustic Transformation of Sound Fields) Acoustic Holography superimpose the sources in a more complicated way (logarithmic scaling) and the spatial resolution of the measurements, the current approach is a reasonably accurate and a relatively fast method for prediction of the location of sound source and the impact of various design parameters on the source strength.

Further developments of other R&D type will be reported about in forthcoming issues of STAR-CD Dynamics.

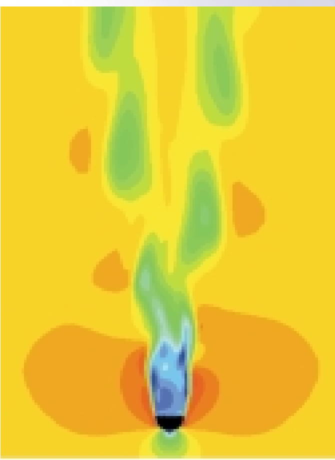


Figure 3

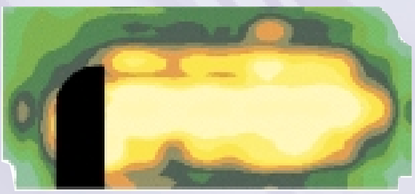
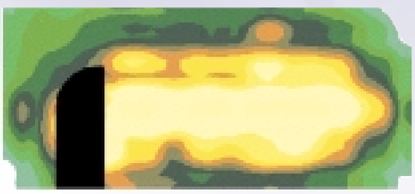


Figure 4



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