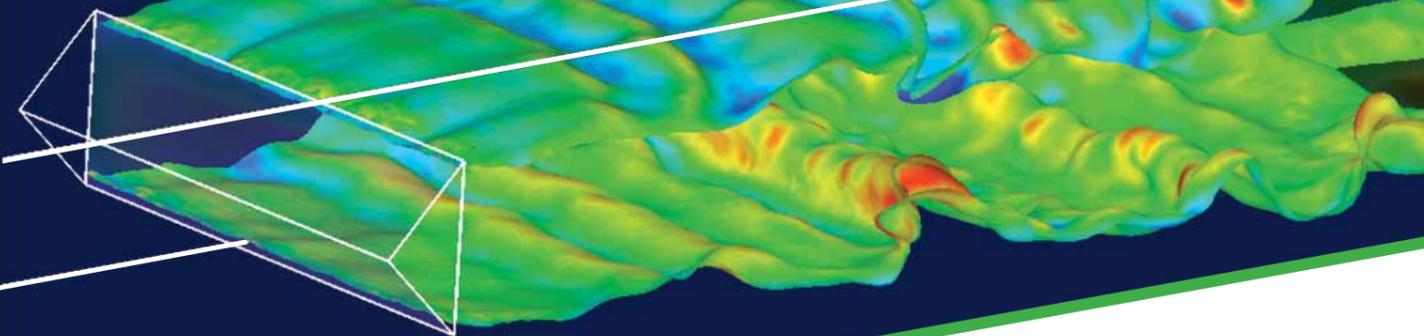


THE FOCUS PROJECT WAS CARRIED OUT BETWEEN 2005 AND 2007 BY THE EM2C LABORATORY OF THE ECOLE CENTRALE OF PARIS AND THE IDRIS TEAM AT CNRS IN FRANCE. USING DEISA RESEARCH INFRASTRUCTURE WITHIN THE DECI PROGRAMM, THE RESEARCHERS HAVE DEVELOPED A NEW METHOD FOR SIMULATING COMBUSTION PROCESSES THAT WILL HAVE A REAL AND PRACTICAL IMPACT ON A NUMBER OF INDUSTRIAL APPLICATIONS.



A new coupling method for simulating combustion processes

Damien Lecarpentier

The image depicts a flame held by a flameholder. The FOCUS project simulations have demonstrated that taking radiation into consideration when making calculations modifies the dynamics of the flame.

Combustion is involved in more than 80% of primary energy conversion processes worldwide. It is used, for example, in aeronautical and ground transportation, waste incineration and in various other industries in which burners and engines are required.

For industrial applications, the type of combustion that is most often used is called turbulent combustion, characterized by turbulent flows that aid the mixing process between the combustible and the oxidizer. It remains, however, a complex phenomenon, characterized by many instabilities and side-effects (such as pollutant formation and radiative heat transfers), which need to be better understood.

"Understanding turbulent reacting flows, including elements such as pollutant formation and radiative heat transfers, is crucial for many practical industrial applications", explains **Olivier Gicquel**, a researcher at the EM2C laboratory and one of the leaders of the FOCUS project.

"Optimization of burners has led to increased levels of complexity and design innovation. This very complexity, however, increases the likelihood that the burners will malfunction, for example through combustion instabilities. These instabilities generate limitations in the operating domains of systems, and can significantly increase noise levels. They can even reduce the lifespan of burners or engines".

"Reduction of pollutant emissions is a key issue in the field of energy production. Legal constraints are becoming more and more important for fixed energy sources, such as boilers or gas turbines, and for transport applications, such as automotive engines or air jets", Gicquel adds.

"Understanding and predicting these phenomena is thus a central concern in the development of low emission systems", he concludes.

Numerical simulation of combustion processes is necessary

Because the developments of industrial prototypes can be very expensive, numerical simulation of combustion processes has become compulsory.



Olivier Gicquel, researcher at the EMC2 Laboratory of the Ecole Centrale de Paris and leader of the FOCUS project.

Various different methods exist for performing these simulations. The most recent is called Large Eddy Simulation (LES), and can be viewed as an intermediate technique between direct numerical simulation and classical modelization. Under this approach, larger turbulent motions of the flow field are explicitly computed and resolved, whereas the effects of the smaller ones are only modelled.

"This method appears to be a promising tool for such simulations", says Gicquel "Under this approach, cold fresh gas zones and hot burnt gas zones, which behave very differently in terms of pollutant formation and radiative heat transfers, and which are the most

crucial areas in which we need information, are identified at the resolved scale level", he explains.

The physical phenomena involved in combustion and radiative heat transfers are, however, very different: "Flow fields, (e.g. temperature, chemical species, velocity) are generally described in terms of balance over small volumes (finite volume context), whereas radiative heat transfers involve long distance interactions".

"Accordingly, reacting flows and radiative heat transfers codes have a very different structure. Combustion codes are generally parallelized by domain splitting (in which each processor "sees" only a small part of the physical domain), whereas parallelization by wavelength ranges and/or by radiation directions is more appropriate for radiation (where each processor needs to work with the whole domain)".

To gain a better insight into the full process, the researchers of the FOCUS group have developed an original approach:

"The proposed approach takes advantage of an efficient coupling between an LES solver and codes devoted to radiative heat transfers, where data exchanges occur at time intervals controlled by the physical times of each phenomenon", explains Gicquel. "This project is innovative both from a theoretical point of view and in terms

of the numerical aspects, with the development of new models in state-of-the-art simulations".

Numerical simulations also require large computational resources

Numerical simulations of turbulent reacting flows including pollutant formation and radiative heat transfers require not only well-adapted models, but also large computational resources.

Research infrastructures like DEISA are therefore very much needed in this area. It has played a crucial role in the development of the FOCUS project: "The DEISA project gave us access to the coupling technology that we required. It also provided us with computational resources to run the simulations", says Gicquel.

"The DEISA infrastructure provided two important resources for the FOCUS project", he continues:

"It allowed for the collaboration of two engineers with computer science backgrounds from the IDRIS team, which meant that we were able to improve the speed of our code by a factor of close to 10. This great improvement was crucial in enabling us to run the final simulations. Within the DECI framework, we were provided 300 000 CPU hours on the IDRIS super-computer, and we had dedicated access to up to 400 processors to run the coupled simulations".

"Taking advantage of the opportunity afforded by the DEISA research infrastructure and the DECI programme, 3D simulations of combustion processes – including the radiation phenomenon – have been carried out. The impact of radiation on the flame dynamics, which was one of our primary concerns, has been clearly investigated and evidenced".

From simulation to practical applications

The results obtained during the FOCUS project will be of benefit to many applications in which combustion processes are involved:

"The results we have obtained are of great interest for designers of gas turbines and furnace burners", notes Gicquel. "It will help lessen the likelihood of combustion instabilities developing within the combustion chamber, meaning that engine components will last longer", he explains.

"The new method that we have developed in this study may also be of relevance in various computational codes. The models will be available to aid the design of high performance – that is, safer, cleaner and more reliable – combustors for various industrial applications".

"Thanks to the DEISA framework, the EM2C laboratory is now one of the leading teams in the international combustion community in the key domain of the impact of radiative heat transfers on flame dynamics", Gicquel concludes. ■