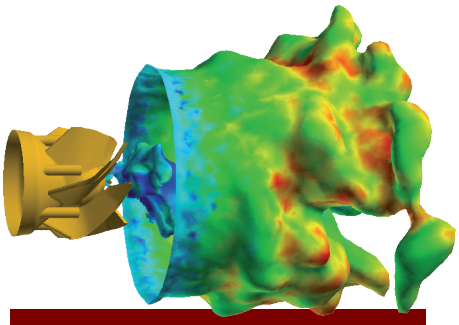
Numerical solutions for industrial combustion systems

Many factors have to be taken into account by researchers into industrial combustion systems, making their development complex. **Dr Bénédicte Cuenot** of the ECCOMET project explains why her training for doctoral students and European PhDs is crucial to the progression of the field

Industrial combustion systems are defined by their complexity. A wide range of variables must be taken into account in the development of individual systems, each of which has a direct effect on the other, meaning that a delicate balance must be maintained if the impact of such systems on the environment is to be minimised without compromising performance. Against this backdrop the work of projects like the EU-funded, Marie Curie Action supported ECCOMET (Efficient and Clean Combustion Experts Training) initiative takes on real significance. "Combustion systems are very complex," acknowledges Bénédicte Cuenot, the overall coordinator of the project. "One constraint we face in their development is the urgency of the pollution issue. This is a huge problem as it changes the efficiency and stability of the chamber. For example, one way to improve efficiency is to increase the pressure because it helps combustion. However, this has many other side-effects too. If you increase the pressure then you change the flame structure in the system and therefore change the emissions of pollutants. The temperature of the burnt elements will be higher, and then you will have more nitric oxide. On the other hand decreasing the flame temperature can lead to what are called combustion instabilities and end up destroying the system. These things are very much linked together, we aim to find an optimum between them."

The complexity of this work poses real challenges to ECCOMET; nevertheless, the project is determined to tackle them head-on. As such ECCOMET is committed to recruiting the most promising young scientists from across Europe in pursuit of its overall goals, which focus on developing a numerical tool capable of simulating the combustion chamber that can be found in propulsion systems. The revolutionary 'numerical tool' being developed by ECCOMET will be adapted to suit the systems found in planes, helicopters, rockets and cars, and for her part Cuenot is optimistic it will be able to achieve a better balance through the theoretical computations it performs. "A good proportion of our students are working on the code itself. But to improve the physical models run by the code, it is necessary to better understand the mechanisms that are involved: this is the reason why, in cooperation with ONERA, some researchers work on experiments" she explains. "We also have a group of students who are working on theory in collaboration with IMFT (Institut de Mécanique des Fluides de Toulouse). So they are developing the theoretical concepts which are the basis of the formulations that, in turn, are implemented in the codes."



LES of a premixed industrial burner. ©L. Selle, CERFACS/SIEMENS

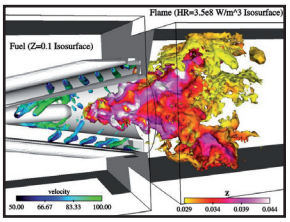
Increasing mobility

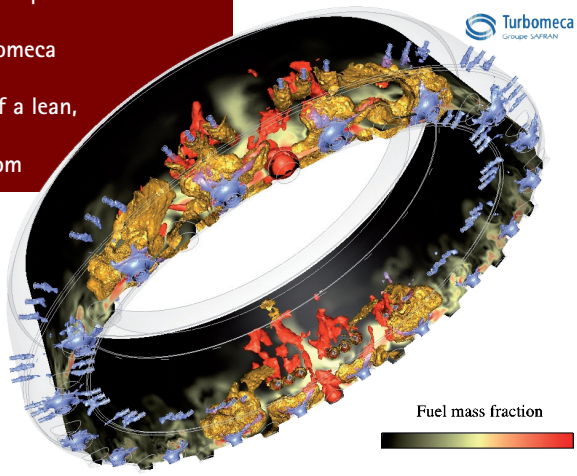
This focus on providing training is particularly relevant given the urgency of the environmental issue, and the associated need for ongoing refinement to meet evolving needs. However, the project is focused not only on training young scientists in a particular scientific domain, but also on increasing their mobility. To illustrate, ECCOMET currently has 12 researchers on board, none of whom is French (the project's home country), an approach which Cuenot says has its roots in practical concerns. "We are working to enhance the visibility of our activities in Europe. One reason why we train so many students from outside the EU Member States is so as to publicise our work more widely across the continent. The other reason is that quite simply it's difficult to find young European scientists now," she admits. "This is because fewer and fewer students are choosing to study science, and that's also another major difficulty."

It is difficult to overstate the importance of this area, as enhancing the visibility of ECCOMET is crucial to the project's prospects of eventually commercialising their work. Being a privately run research project this is a key consideration for ECCOMET, and thus the initiative has established very strong ties with Cerfacs' industrial partners, ties from which both parties benefit. "Combustion is a field where there is a lot of research, and the need for targeted, specific research is particularly acutely felt by our commercial and industrial partners," explains Cuenot. "Our partners often lack information about their own systems to guarantee a better design and better performances before testing – they really need to improve their knowledge of how combustion happens in the chamber. So they push us to work towards meeting their practical needs, which in fact often

LES of ignition of a full helicopter combustor: reaction rate isosurface.
© M. Boileau,CERFACS/Turbomeca

(Inset) LES of combustion of a lean, partially premixed burner.
© P. Schmitt, CERFACS/Alstom





converge with our own research needs. This is beneficial for us because we can pursue our own research objectives and be confident that it will be directly applicable to the problems of our industrial partners. This allows us to directly transfer knowledge between our tool developers and the eventual users of these tools."

Nor are the benefits these links bring limited to the organisational level. Indeed, Cuenot is keen to highlight the positive effect the close relationship between commercial and industrial partners has on the individual researchers themselves. "Our industrial partners have very important research needs themselves. They are continuously faced with problems they cannot solve with existing tools, a context in which people with PhDs are highly valued. As such companies are keen to employ people with PhDs – people with a PhD have a proven ability to conduct effective, innovative research," she stresses. "There is always big demand for these kinds of skills, and so many of our students find really good jobs at our industrial partners very easily."

Large Eddy Simulation techniques

The pioneering nature of the project explains just why the young researchers are in such demand. As such ECCOMET is keen to maintain its place at the cutting edge of research, and is thus using tools grouped under a term called 'large eddy simulation techniques'. These tools allow researchers both to create virtual combustion chambers corresponding to industrial geometries without having to build them, and also to give correct answers within a reasonable timeframe. This represents a significant breakthrough according to Cuenot. "In our institution we are developing tools for large eddy simulation that are now being transferred to our industrial partners. This means that engineers in industry use the same tools that we are using for research," she outlines. "This standardisation, or 'direct transfer of knowledge', is much sought after in the commercial and industrial sectors. Our industrial partners can take the tools that we are developing directly. We just add what we call an MMI – man-machine interface that makes the users lives easier, but that's all. The code itself is the same."

At a time when concern about environmental pollution occupies a prominent place on the political, social and economic agenda, such work takes on great importance. However, although very much aware of the wider implications of ECCOMET's research, Cuenot is nevertheless keen to stress that her project is not limited to environmental issues. "One of the reasons we want to develop numerical tools for such systems is so as to be able to predict emissions or their impact on the environment," she says. "But of course we also want to progress on other issues, that have direct or indirect consequence on the formation of pollutants. Combustion systems include a lot of different parts, and of course that demands a lot of different areas of physics expertise. There is great potential for further improvements in combustion engine simulation, potential we are determined to fulfil." ★

At a glance

MARIE CURIE ACTIONS

Full Project Title

ECCOMET: Efficient and Clean Combustion Experts Training

Project Objectives

The project proposes a high-level training programme for doctoral students to a European PhD in the field of industrial combustion systems. The objective is to promote at the highest international level the European scientific research and technological knowledge in this field, in order to support the European industries in the key sector of energy and transport

Project Partners

The project is implemented through an inter-related group, involving CERFACS, IMFT laboratory (Institut de Mécanique des Fluides) and ONERA

Contact Details

Dr Bénédicte Cuenot
CERFACS
42 Av. G. Coriolis
Toulouse cedex
T: +33 5 61 19 30 44
F: +33 5 61 19 30 00
E: cuenot@cerfacs.fr
W: www.cerfacs.Fr

Dr Bénédicte Cuenot

Head of the Combustion Group at CERFACS

Dr Bénédicte Cuenot graduated from Ecole Centrale de Paris in 1990. She obtained her PhD from INP Toulouse, France, on turbulent combustion modelling in 1995. She started at CERFACS in 1996, where she is today the head of the Combustion Group. She now shares her time between teaching, project leading and research and authored more than 20 journal papers.