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DIFFERENT DIMENSIONS IN FLUID DYNAMICS

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ABSTRACT

Significant problems in fluid dynamics are often complex – those which are not having been solved many years ago. Teamwork between people of different disciplines and professions is usually necessary in order to solve these problems in a way which leads to an implementable solution. Specifically I would like to focus on the collaboration between CFD modellers, experimentalists and industrial practitioners in solving these complex problems.

Focusing questions might be:

Can complex flow fields be determined reliably by CFD a priori, and without detailed knowledge of the application being modeled?

Why have experimentalists played such an important part in determining heat and mass transfer rates?

What do industrial practitioners really know about the problem?

Let's start with the last question first. Practitioners know:

- What is preventing quality, safety, cost, or throughput objectives being reached. i.e. A definition of the problem which will lead to an economically valuable solution.
- What are the practical limits for operation of equipment with respect to flow parameters, power input, insulation, yield or production rate, heat up rate and what happens physically when these are exceeded. This provides the operating window and the equipment constraints.
- Areas of maximum and minimum heat flow or mass transfer.
- Effect of operating and design parameters on the heat and mass transfer and possibly the flow field. (e.g. effect of leaving a door open).

Of course it is possible to predict a solution to difficult problems without these practitioners. Testing the predicted solution and its underlying assumptions are almost impossible without feedback of a detailed, operational nature however. This starts to address the first questions posed. CFD models have developed from simple beginnings. In building these simple models – a necessary starting point - we have, in the past:

- Used imperfect understandings of the basic flow phenomena. Over time this has necessitated further visualisation through experimentation in scaled, room temperature regimes to establish the real flow behaviours – for example bubble release from under reduction cell anodes. More will be said about the role of experimentalists in making these visualisation and transport breakthroughs.
- Initially decoupled the various parts of each problem – with intermediate boundary conditions established through measurement – e.g. bath temperature could not at first be predicted in the first aluminium reduction cell model. Both practitioners and experimentalists have provided the data to allow this decoupling to be carried out.
- Idealised geometries – because of limited computational power and poor prediction of the resultant geometries – e.g. solidification profiles.
- Ignored the time dependence of flow and heat/mass transfer in industrial operations, resulting in mostly stationary solutions for systems with fluctuating operating conditions and flow phenomena. The economic damage, in industrial processes, is often done at the extremes.

A more holistic, linked approach to problems has evolved over time, partly through the application of computational modeling but with physical measurements on the industrial processes providing the catalyst for better models with the following characteristics:

- <u>Coupled flow and heat / mass transfer processes</u>, including interfacial transport mechanisms coupled to the bulk flows, and/or to other dynamic processes
- <u>Dynamic models</u> which combine the conservation equations with the rate controlling kinetics (or drumbeat) of the industrial process being studied. Often this requires compromise on the geometry being studied – relying on the judgement of practitioners and modelers with respect to which process characteristic is most important.
- <u>Capability for complex geometries</u>, (with unstructured meshes) in both finite element and finite volume computational regimes.

Successful collaboration between modellers and practitioners has not always been easy. Modeling is based on careful consideration of all conservation laws which can influence a given problem. It initially generates stationary solutions which convey a "time averaged" image of the predicted situation. Those of us who have worked with variation will know the pitfalls of this approach, particularly when the consequences of operation far from the average condition are serious. However the need to start with a simple hypothesis remains the central tenant of modeling and for good reason.

The people who run production equipment operate to a drumbeat based on the rate of generation of mass and energy from their process, and on the inputs to it. These businesses are intensive with respect to throughput because this determines return on assets, and on operating expenditure. Generally decisions must be made in days or even hours, and on the basis of limited data. Even for managers and practitioners with scientific training, the consequences of delaying a decision strongly influence their behaviour. It is also evident to operational staff that the process is constantly changing and that their intervention can influence the outcome or at least the trajectory of events. Interacting with a changing heat or material balance day on day produces a "can do" culture where decisions are taken in a timely but sometimes less scientific manner.

The gulf I am describing between the theoretical and the applied approaches to problem solving is never successfully addressed by written correspondence, or by one meeting a month to discuss "model building progress". Hypothesis building needs to happen first and it is usually the conflict between the views of modelers and experimentalists with the practitioner and his data/experience – viewed in the workplace – that provides the soundest basis for this hypothesis. Modeling is not an alternate reality. It is hypothesis generation and testing to provide insight into what may be happening in a process. Both the generation and the testing require robust interaction between modeler, practitioner and experimentalist and time spent "on the ground" if this insight is to be achieved. Outputs from these activities can be:

- Development of an appropriately structured and refined model, with a rough cut first.
- Targetted experiments which include similitude requirements and visualisation of key phenomena.
- Industrial experiments, which may move towards solutions well before the final model is built, and which take into account the variation embedded in the operation and the process kinetic timeframes which exist.