Technische Universität Braunschweig

MUSEN

Recurrence CFD (rCFD) – a new member of the multi-scale model family

Lecture of

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Industrial processes commonly involve extremely differing length scales, ranging from e.g. particle to plant scale. Since these length scales often span several orders of magnitude, resolving all scales in the framework of numerical simulations renders impossible due to excess computational costs. Instead of detailing all length scales, multi-scale modelling paradigms have evolved, which resolve only the larger scales while smaller scales are addressed by specific sub-grid models. Such multi-scale simulation frameworks enable the numerical representation of multiphase flows at industrial plant scale.

In addition to the wide range of length scales, industrial processes also typically involve significantly different time scales, ranging from milliseconds (e.g. for resolving particle collisions) to minutes and hours (e.g. for determining residence times in industrial scale reactors). Therefore, an efficient time-extrapolation of numerical simulations can be regarded as an essential step from industrial plant scale towards industrial process scale.

Recurrence CFD (rCFD) aims at an efficient representation of long-term processes (e.g. heating, chemical conversion) which slowly evolve on highly-dynamic pseudo-periodic flow fields. In such cases classical CFD simulations fail due to excess computational cost associated with the resolution of the governing flow fields.

In the framework of rCFD, short-term full CFD simulation deliver recurrence databases of the governing flow at different operating conditions. Based on statistical reasoning, rCFD then exploits these databases in order to either develop (i) generic flow fields or (ii) generic transport fields, which subsequently serve as basis for the long-term process under consideration. We further present an interpolation methodology for the representation of unsteadily varying operating conditions (i.e. between existing recurrence databases).

In applying rCFD to a set of single-phase and multiphase flows, we experienced a computational speed-up of two (flow based rCFD) to four (transport based rCFD) orders of magnitude. In many cases this dramatic speed-up allows for faster-than-realtime simulations, although we didn't reduce the resolution of the original full CFD simulation.

Finally, we explore the possibility of incorporating such real-time rCFD simulations into process monitoring and control.