NUMERICAL STUDY OF PARTICLE-LADEN HIGH-TEMPERATURE FLOWS

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The VKI is interested in reliable numerical simulations of particle-laden high-temperature flows for two main reasons. First, such flows are encountered during hypersonic entry into the Martian atmosphere, which tends to be filled with dust (i.e. particles). Second, such flows are an essential part of the synthesis of nano-powders in thermal plasma facilities, such as the Plasmatron or the Minitorch.

The aim of this Diploma Course project is to allow computation of particle-laden inductively coupled plasma flows. For this reason, we coupled two existing numerical tools: the Lagrangian particle-tracking solver PLaS and the flow solver COOLFluiD (i.e. a data interface had to be designed, generalized and implemented).

The coupling of those numerical tools uses the Eulerian-Lagrangian approach, which consists to solve the flow field in a Eulerian frame and to solve the trajectories of the particles in Lagrangian frame.

As a first step towards this integration, we created a C++ application class, which facilitates the linking of the PLaS C-code to existing C++ flow solvers (i.e. COOLFluiD). A C++ driver program was then written in order to test the interfacing of PLaS and the C++ flow solver through the interface class. The application class was then linked with COOLFluiD. Since the relevant data (i.e. mesh, flow solutions, boundary conditions,...) was not stored in the same way by PLaS and COOLFLuiD, we adapted the data given from COOLFLuiD to fetch the data formats of PLaS. Validation of this interfacing was made by means of simple test-cases, such as the 2D lid-driven cavity, the 2D backward facing step and the 3D lid-driven cavity. The steady incompressible finite volume solver module of COOLFLuiD was used as flow solver, for the present implementation.

In the first stage, a one-way coupled approach of the physical interaction between the particles and the flow was used. The flow velocity field was the driving force for the particle motion while the back coupling of the particles onto the flow has not been taken into account. Since PlaS features the computation of the backcoupling source terms, two-way coupling can be included in the data-interface. This implementation was done in a second stage of the work. Since no unsteady test cases have been carried out, this implementation, still has to be validated.

Finally, PLaS has been coupled to the ICP module of COOLFLuiD, which is a high enthalpy low mach number finite volume solver for simulation of flow in plasma torches. The figure shows a qualitative picture of particles seeded randomly in the domain after 0.4 seconds.

Further developments, on the side of PLaS, could take into account compressibility effects and particle heat transfer. On the COOLFLuiD side, extension to unsteady modules could be performed. A literature survey was carried out to gain insight in the Eulerian-Lagragian approach for high enthalpy flows. Once compressibility and heat transfer is taken into account, Plasmatron simulations will be possible.