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Towards the simulation of proton beam induced pressure waves in liquid metal using the Multiple Pressure Variables (MPV) approach

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The development of the liquid metal spallation target META:LIC (MEgawatt TArget: Lead bIsmuth Cooled) for the European Spallation Source (ESS) at the Karlsruhe Institute of Technology (KIT) is based on previously developed liquid metal targets such as MEGAPIE, MYRHA and IFMIF. Insights gained from the short pulse liquid metal targets at SNS and JSNS lead to increased sensibility towards undesirable effects of proton beam induced pressure waves. The current design of META:LIC includes dedicated design measures to limit the effects of these pressure pulses. These design measures are based on in the formation of internal free surfaces where the pressure waves are attenuated.
In order to allow for effective simulations during the design process and to gain a more detailed understanding the Multiple Pressure Variables (MPV) method [1,2] is proposed. The MPV approach is based on a single time scale multiple space scale asymptotic analysis derived for subsonic flow by an asymptotic series expansion in the Mach-number. Distinguished are the flow and acoustic length scales resulting in three pressure contribution, i.e. thermodynamic, acoustic and dynamic pressure which are discretized on numerical meshes of different resolution. The acoustics involving sonic wave evolution is resolved on a very coarse mesh allowing for relatively large time steps which are often suitable for the flow simulation living on much better resolved numerical mesh. Effects on different scales are coupled by coarse to fine interpolation and fine to coarse averaging.
The presentation will discuss the need for pressure wave simulations based on the META:LIC target. Then the MPV method will be formally introduced and its application within the open source tool box OpenFOAM is shown. A series of validation cases will be used to demonstrate the advantageous features of the method and in particular that often no time-step limitation beyond those enforced by the fluid flow calculation are imposed by the acoustics. Finally work in progress referring to target simulations will be shown.

[1] Munz C.-D., S. Roller, R. Klein, K.J. Geratz The extension of incompressible flow solvers to the weakly compressible regime. J Computers & Fluids 2003; 32:173-96.
[2] Klein R. Semi-implicit extension of a Godunov-type scheme based on low Mach number asymptotics I: one dimensional flow. J. Comput Phys 1995; 121:213-37.

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