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Modelling of enrichment of a binary gas mixture in acoustically induced oscillatory flows with a customized mass flux boundary condition

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In acoustically induced oscillatory flows, the viscous boundary layer in the vicinity of the solid boundaries interacts closely with the thermal boundary layer, created by the compression and rarefaction of the acoustic wave or an externally applied temperature gradient. In closed resonators, where the mass flux has a zero mean in the oscillatory flow, the species enrichment happens by the combined effect of thermodiffusion and the close interaction of the viscous and thermal boundary layers. The separation of binary mixtures of noble gases in acoustic resonators has been demonstrated experimentally [1-6]. But our current understanding of this complex separation process is limited by the steady-state one-dimensional models available so far.

Therefore, this work aims to develop a numerical model to test this process with a case study of the separation in an equimolar mixture of Argon and Helium in a two-dimensional channel. For this purpose, OpenFOAM standard thermophysical transport models for binary gas mixtures need further development, and appropriate mass transfer boundary conditions should be applied for the correct performance of the numerical model. This work reports on the customization process of a zero-mass-flux boundary condition based on the equilibrium of mass diffusivity and thermodiffusion at the solid boundaries of the acoustic resonator. Additionally, the key features of the thermoacoustic flow in the resonator are analyzed for the purpose of outlining the performance of the separation process in the acoustic boundary layer.

Finally, the methods developed in this work can be extended to the analysis of several cases where oscillatory induced flow conditions exist, with relevant applications such as the study of mass transfer effects in thermoacoustic engines and refrigerators performance; the design and optimization of thermoacoustic separation devices; and further applications in the numerical analysis of acoustic instabilities in combustion flow problems.

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