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GALES: a general-purpose multi-physics FEM code

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We present a versatile open-source FEM-based multi-physics numerical code GALES for volcanic and general-purpose problems. The code is developed/applied to a suite of problems in magma and volcano dynamics. The software is written in modern C++ and is parallelized using OpenMPI and Trilinos libraries. GALES comprises several advanced solvers for 2D and 3D problems dealing with heat transfer, compressible to incompressible mono and multi-fluid flows in Eulerian and Arbitrary Lagrangian-Eulerian (ALE) formulations, Elastic (static and dynamic) deformation of solids and fluid-solid interaction. Fluid solvers account for both Newtonian and non-Newtonian rheologies. Solvers account for transient as well as steady problems. Non-linear problems are linearized using Newton's method. All solvers have been thoroughly verified and validated on standard benchmarks. The software is regularly used for high-performance computing (HPC) on our local cluster machines at INGV, Pisa, Italy. Recently, we analyzed the performance of the code by a series of strong-scaling tests conducted on the Marenostrum supercomputer at the Barcelona Supercomputing Centre (BSC) up to 12288 cores. The results revealed a computational speedup close to ideal and above satisfactory levels as long as the element/core ratio is sufficiently large, making GALES an excellent choice for utilizing HPC resources efficiently for complex magma flow and rock dynamics problems.