Lid-driven cavity highly turbulent flow subjected to high magnetic field
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Lid-driven cavity highly turbulent flow subjected to high magnetic field
Determination of critical time-step for explicit MHD schemes

Control of fluid flow in CC:
- Electromagnetic braking and stirring in continuous casting, process of steel
- Coupled simulation in commercial software:
  - THERCAST® (Fluid mechanical solver)
  - MATELEC (EM solver)

A representative study case:
- Problem:
  - Highly turbulent flow
- Solution:
  - Impose a constant magnetic field to control and brake the flow
- Numerical procedure:
  - Lid-driven cavity benchmark
  - Relate the Stuart number (N) to the target braking level

Computational model:
- Electromagnetic Field:
  \[ \Delta \Phi = \frac{1}{\sigma} (\mathbf{u} \cdot \mathbf{B} - \mathbf{B} \cdot \mathbf{u}) = 0 \]
- Lorentz Forces:
  \[ \mathbf{f}_L = \sigma (\mathbf{u} \times \mathbf{B}) \times \mathbf{B} \]
- Navier-Stokes:
  \[ \rho (\partial \mathbf{u} / \partial t + \mathbf{u} \cdot \nabla \mathbf{u}) - \nabla \cdot (\mu \mathbf{u} - \mathbf{p}) = \mathbf{f}_L \]
- Anisotropic mesh adaptation.

Numerical instabilities:
- The Lorentz force is tracked explicitly.
- The excessive size of the time-step leads to completely brake the flow normally to \( \beta \) and to accelerate it in the opposite direction, i.e. \( \mathbf{u}(\beta, \eta) < 0 \).
- The CFL condition is not capable anymore to guarantee numerical convergence.

Determination of the critical time-step:
- Solution:
  - Computation of the limit time-step as the time-step which leads to a complete dissipation of the kinetic energy within one time increment when the magnetic field is normal to the velocity.

Conclusions & Perspectives:
- The flow is highly affected by the magnetic field and its direction.
- In some configurations, the CFL condition is not enough to guarantee the numerical convergence.
- A new time-step threshold which guarantees convergence in explicit schemes is proposed.
- An implicit modeling of the Lorentz force has to be included in the multiscale stabilized finite-elements solver.
- The braking effect will be taken into account in the complete simulation of electromagnetic stirring.

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References: