MFEM-Based Tokamak Equilibrium Solver

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Georgia Tech Open Source Program Office

https://github.com/tangqi/mfem/tree/tds-gs/miniapps/gslib

State of the Art

Plasma fusion: the process of charged particles colliding to releases energy

Benefits

- Low-impact energy generation
- Faster and longer-distance space travel
- Scientific studies

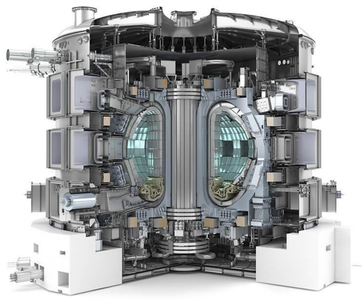
Challenges

- Develop devices that can contain and withstand high temperatures
- Plasma expands and cools—need to stabilize to keeps it hot and long enough for fusion

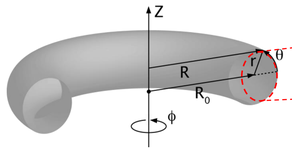
Ongoing Efforts

- Magnetic Confinement: Trap plasma with strong magnetic fields
- Inertial Confinement: Uses lasers/beams for rapid compression of particles

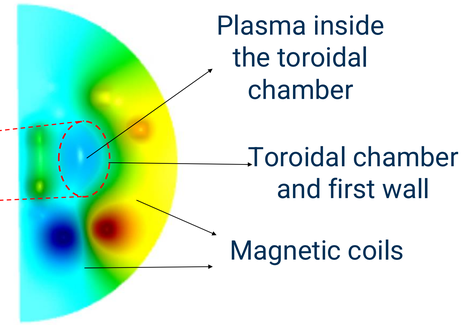
Project Goal: Develop a **free boundary** tokamak **equilibrium** solver for the magnetic confinement fusion community



Tokamak: Device for magnetic confinement fusion



Toroidal plasma chamber of tokamak



Solution simulation via MFEM

Free Boundary

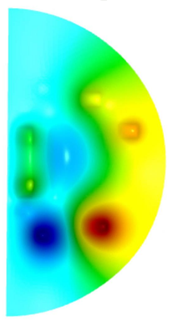
- Unknown plasma shape & boundary conditions
- Modeled using MFEM (mfem.org), an open-source finite element library for solving partial differential equations on unstructured and adaptive meshes

Equilibrium

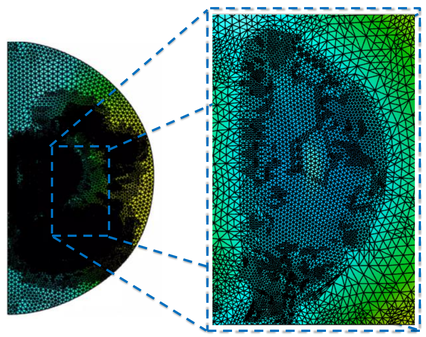
- Stabilize plasma and avoid contact with walls
- Modeled by the Grad–Shafranov (GS) equation, which describes magnetohydrodynamic equilibria in axisymmetric, toroidal plasmas

Current Work: Using G-EQDSK file format, develop and integrate an EFIT writer (code used to reconstruct plasma equilibrium solutions) into MFEM

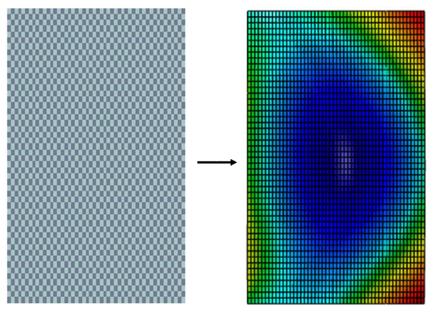
Equilibrium solution on default triangular mesh



Identify and isolate the plasma region



Generate a standard rectangular mesh and interpolate the solution onto it



Gather the needed EFIT parameters from MFEM

- Computational grid
- Magnetic axis
- Plasma state
- Plasma boundary
- Poloidal current and flux
- Safety factor
- Limiter grid

Build EFIT writer

- Compute additional necessary values
- Output the metrics, with proper GEQDSK formation, to an exportable text file

Delivers a structured, portable set of key parameters for reproducing plasma equilibrium solutions, aligned with industry standards for easy sharing and integration

Future Work

- Test the GEQDSK file for potential errors
- Continue development of ITER tokamak solutions
- Expand to other tokamaks