Self-consistent modeling of edge plasma dynamics with active wall

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Introduction and Outline

Why working on self-consistent model for edge plasma with active wall?
• It may offer new insights on boundary plasma physics, for fusion devices and beyond
• It may help us understand better plasma-material interactions, for transient phenomena, e.g., ELMs
• It may help us investigate new approaches for addressing tokamak divertor heat exhaust challenge

How is it implemented?
• Coupling of edge plasma model UEDGE with active wall model FACE
• Implemented with multi-physics framework IPS

What are the results?
• Coupled UEDGE and FACE provide a functional simulation model for transient PMI processes
• Using it for modeling of tokamak strike point sweeping is encouraging, shows potential for dealing with divertor heat exhaust challenge

Coupling of UEDGE and FACE

• UEDGE is an established 2D fluid simulation model for boundary plasma transport
• FACE is a 1D simulation model for particles and thermal energy transport in material wall

Thermal energy transport
\[ \rho C_v \frac{\partial T}{\partial t} = \nabla \cdot (\lambda \nabla T) + \dot{q}_{\text{rad}} \]

Particle species transport
\[ \frac{\partial n_i}{\partial t} + \nabla \cdot (n_i \mathbf{v}_i) = \dot{\rho}_{\text{in}} - \dot{\rho}_{\text{out}} \]

IPS is a multi-physics code coupling framework

Strik point sweeping model

• Simplified geometry but captures main features of X-point divertor
• Boundary conditions set to mimic divertor in a high-power tokamak
• Peak power flux on target plate \( \approx 40 \text{MW/m}^2 \)
• Power flux profile width on the plate \( \approx 1 \text{cm} \)

Simulations results

• Using sweeping amplitude 10 cm, frequency 10 Hz
• Time evolution settles down on driven oscillations
• Comparing results for coupling step dt=1e-4 and dt=2e-4: convergence to \( \approx 1\% \)

Coupled time-stepping strategy: "fractional step method"

Summary and conclusions

• Coupling of UEDGE and FACE via IPS has produced a new computational tool IPSUF for studying dynamic phenomena in boundary plasmas
• Application of IPSUF to modeling of tokamak strike point sweeping shows that for realistic sweep parameters (frequency 10 Hz, amplitude 10 cm) the temperature on the plate can be maintained below 1500 K
• However, using sweeping alone, without plasma detachment, target plate sputtering remains a problem
• For given sweep parameters, “dynamic wall” works in terms of the thermal transport but not in terms of the hydrogen particles transport, due to strong disparity of rates of transport of heat and hydrogen particles in the wall

References

• R.D. Smirnov et al., FUSION SCIENCE AND TECHNOLOGY v 71 (2017)

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