Impact of the Pedestal on Global Performance and Confinement Scalings in I-Mode

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Overview
Fusion reactor characterized by three requirements:
• high energy confinement – sufficient self-heating
  • low particle confinement – long enough to avoid high-Z
    • high electron temperature
avoid, suppress, or mitigate large ELMs
• number of discharges exist:
  • engineering solutions – RMP, pellet pacing
  • physics solutions – x, QM, QSD, EDA-H-mode, high-
    • recycling H-modes, small ELM regimes
I-mode an attractive new option for reactor regime
• high energy confinement – sufficient self-heating
• strong pedestal
• successful suppression of ELMs on other devices (see Hubab talk, KZ-00505), extrapolation in performance

I-Mode Profiles and Responses

Following practice of ITER50, ITER56 confinement scalings, express I-mode energy confinement in the form

\[ \frac{\tau_E}{\tau_NPL} = \frac{C_{H98}}{C_{\tau}} \left( \frac{B}{B_{\text{norm}}} \right)^{\alpha} \left( \frac{I_p}{I_{\text{p nom}}} \right)^{\beta} \left( \frac{\psi}{\psi_{\text{NPL}}} \right)^{\gamma} \]

Reduced parameter set (omitting fitting in \( \tau, \gamma \)) provides minimum-complexity fit to C-Mod data only

Possible Covariances

\[ \tau_E \propto \tau_NPL \]

\[ \tau_E \propto \psi_{\text{NPL}} \]

\[ \tau_E \propto I_p \]

\[ \tau_E \propto B \]

\[ \tau_E \propto \psi \]

Possibilities

• strong \( B \) dependence – suppression of H-mode tran-
  • weak degradation of \( \tau_E \) with heating power empirically
  • observed in I-mode discharges

New \( \beta \)-Factor Trends

Question remains: how does this performance extrapolate to other devices?

References & Acknowledgements

[3] This work is supported by U.S. Department of Energy grant DE-FG02-98ER54512, using Alcator C-Mod, a DIII-D office of inertial coil test facility.

Alternate Scalings?

Alternate forms for scaling laws – Mirani et al. [3] derived via genetic programming a fit of the form

\[ \tau_E \propto \left( \frac{\psi}{\psi_{\text{NPL}}} \right)^{1.0 - 0.25 I_p} \left( \frac{B}{B_{\text{norm}}} \right)^{0.45} \left( \frac{\psi}{\psi_{\text{NPL}}} \right)^{-0.55} \]

Capturing a saturation term dependent on density and magnetic field, fitted to the ITPA H-mode database:

• Mirror H-mode over I-mode for C-Mod, AUG H-
  • mode, \( \tau_E \)
  • symmetric fit of on lower-field devices, Mir-
  • an fit to other machine inputs, power degradation, con-
  • trol to I-mode observations

Attempts re-fitting to same functional form with new pa-

Conclusions

Behavior desirable for reactor regimes:
• Strong response to fueling, heating power – desirable
  • operator control, not limited by MHD, transport, re-
  • lated in global confinement response
• Consistent with access, \( Q \approx 10 \) operation on ITER
• Temperature pedestal without density, pedestal desirable
  • for reactor operation – high core pressure, stability ben-
  • efits, good impurity handling
Scalings consistent with observed behaviors
• Confinement scalings capture strong field dependence,

Possibilities

• range in power bracketed above H-mode thresh-
  • old range covered below limit

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