Role of Pedestal in Hybrid Discharges in DIII-D

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with
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Does the H-mode Pedestal Play an Important Role in the Physics of the Hybrid Discharge?

- Hybrid discharges in DIII-D provide better performance than conventional ELMing H-mode discharges
  - H89 factors typically greater than 2
  - $\beta_N$ values typically in range of 2 - 3.5
- Hybrid is obtained by careful tailoring of q profile early in discharge
  - Thus, q-profile may control some of the physics
- It is also plausible that pedestal physics plays a role
- Pedestal characteristics in hybrids have been examined
  - Does pedestal pressure height increase as heating power is increased?
  - Alternatively, does pedestal beta increase as core beta increases?
  - What is effect of plasma shape (triangularity) on pedestal and on core?
Initial Survey Showed That There Is a Trend for Pedestal Pressure to Increase With Heating Power

Plasmas had same shape, current, field and density

Pedestal pressure ($p_{\text{ped}}$) includes ions, electrons and carbon

Pedestal pressure roughly follows power dependence of IPB98(y,2) scaling

Improved core confinement also observed at high power

Dataset assembled from data-mining; discharges span several years

\[ I_p = 1.2 \text{ MA} \]
\[ \langle \delta \rangle = 0.5 \]
\[ p_{\text{ped}} \sim P_{\text{NET}}^{0.31} \]
New Data Have Been Obtained for Power Scans in Hybrids in 2 Shapes – Moderate and High Triangularity

- Experiment led by C. Maggi of IPP-Garching and performed as joint ITPA experiment
- Observed unexpected trend - pedestal pressure did not increase with power in high triangularity shape
  - This result is atypical and not understood
  - However, core pressure did increase - plasma was not perfectly stiff
  - Thus, core physics must be invoked to explain the results - possibly increased ExB shear or Ti/Te
- Higher triangularity provided a wider and higher pressure pedestal
- Higher triangularity discharges had higher H98(y,2) confinement enhancement factor
  - Partly a pedestal effect; possibly some core effect also
- Higher triangularity discharges had ELMs with longer periods and pedestals which recovered more fully from ELM crashes
Long Steady-state Discharges Were Produced in Two Shapes

AUG shape

DIII-D shape

Analysis intervals

$\beta_{N,\text{tot}}$

$\delta = 0.3$

$\delta = 0.5$

$n_e \left( 10^{20} \text{ m}^{-3} \right)$

$P_{\text{inj}} \left( \text{MW} \right)$

$H_{98}(y,2)$

Time (ms)

0 1000 2000 3000 4000 5000 6000

128244

128200

DIII-D shape

AUG shape

$\delta = 0.3$

$\delta = 0.5$
Power (Beta) Scan at High Triangularity Shows That Profiles Are Not Perfectly “Stiff”

- Core pressure increases with power even though pedestal pressure does not.
- Core effect - perhaps increased rotation (ExB) shear or $T_i/T_e$ ratio allow core pressure to increase without change of pedestal pressure.
These results also imply that lower triangularity shape has higher fraction of energy in core

- Another indication that core physics is playing a role in performance
For Fixed $\beta_{N,\text{tot}}$ Higher $\delta$ Shape Has Higher Normalized Confinement

- Higher pedestal at higher triangularity may lead to higher H-factor due to stiffness of profiles.
ELM Frequency Is Much Lower for Higher Triangularity Discharges

Average pedestal height is higher for lower frequency, larger ELMs - as seen in other studies

For sufficiently stiff core profiles, we expect higher stored energy for higher average pedestal - also seen in other studies
For Lower Frequency ELMs, Pedestal Height Recovers More Completely After ELM Crash

Data assembled from many ELM cycles to show pedestal evolution between ELMs.

Higher δ plasma has higher time-averaged pedestal.

If core is “stiff” to some degree, higher average pedestal would provide higher H-factor.
Role of Pedestal in DIII-D Hybrid Performance

- **Plasma shape can be used to improve hybrid performance through pedestal effects**
  - Higher triangularity helps provide higher pedestal pressure
  - May confer a benefit in confinement quality (H-factor) and thus reduce power requirement to achieve a given global $\beta$

- **Higher pedestals are correlated with lower ELM frequencies**
  - Lower ELM frequency may allow more complete recovery of pedestal after an ELM and thus higher time-averaged pedestal pressure
  - Physics relation between high $\delta$ and low ELM frequency not clear

- **Hybrids exhibit some confinement enhancements which cannot be attributed to pedestal**
  - Core stored energy can increase even when pedestal pressure does not increase with increased power
  - Thus, some of the performance is due to core physics
  - GLF23 analysis has shown ExB shear is important in hybrids