Scenario Development and Exploration of Operating Space for CFETR Plasma

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ABSTRACT

• Chinese Fusion Engineering Testing Reactor (CFETR) is aimed to bridge the gaps between ITER and the first commercial fusion power plant.
• Target plasma at flattop phase is modeled by 1.5-D simulations based on physics theories and efforts are made to optimize the performance of the scenarios.
• A hybrid scenario with flat q profile in the deep core and a steady-state scenario with local reversed shear at mid-radius are developed.

OUTCOME: Baseline case for CFETR hybrid scenario

• Neutral beams and EC waves
  • 1 MeV beams
  • 250 GHz EC waves
• Enhanced confinement
  • Flat q profile in core
  • Including EM stabilization effect

Comparison of plasma performance between different H&CD for CFETR hybrid scenarios [2]

<table>
<thead>
<tr>
<th>Case Note</th>
<th>Baseline(EC)</th>
<th>LHCD</th>
<th>ICCD</th>
</tr>
</thead>
<tbody>
<tr>
<td>P_{NBM} (MW)</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>P_{EC} (MW)</td>
<td>50</td>
<td>↓40</td>
<td>↓30</td>
</tr>
<tr>
<td>P_{UL} (MW)</td>
<td>0</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>P_{IC} (MW)</td>
<td>0</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>f_{BS}</td>
<td>0.45</td>
<td>0.41</td>
<td>0.4</td>
</tr>
<tr>
<td>H_{BHY02}</td>
<td>1.14</td>
<td>1.12</td>
<td>1.11</td>
</tr>
<tr>
<td>P_{BS05} (MW)</td>
<td>952</td>
<td>↓819</td>
<td>↓788</td>
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<tr>
<td>Ψ_{SHINE} (VS)</td>
<td>250</td>
<td>↑284</td>
<td>↑322</td>
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<tr>
<td>n_{e,line}(10^{20}/m^2)</td>
<td>1.01</td>
<td>0.98</td>
<td>0.96</td>
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</tbody>
</table>

OUTCOME: Steady-state scenario

• Neutral beams and EC waves
  • Like hybrid scenario
• Local reversed shear controlled by ECCD
  • Enhanced confinement ITB*
• No-wall beta limit f_{BS} = 3.0

CONCLUSION

• Target plasma at flattop phase is modeled by 1.5-D simulations based on physics theories and efforts are made to optimize the performance of the scenarios.
• For Hybrid scenario
  • The q profile in the deep core region is flattened by the combination of NB&CD and ECCD.
  • Replacement of ECCD by ICCD or LHCD yields performance degradation.
• For Steady-state scenario
  • Local reversed shear is controlled by localized ECCD to have an ITB at mid-radius.
  • All the deconstructive low-n modes are stable in the optimized position of the local reversed shear.
• Sensitive studies with the calibrated 0-D study show that the extension of plasma bulk towards LFS does not yield better plasma performance. [see the manuscript]

ACKNOWLEDGEMENTS / REFERENCES


The efforts and contributions by the members in CFETR team and the international partners are greatly appreciated.

METHODS

Core-pedestal coupling workflow in OMFIT used to model target plasma

Steps for optimization

Step 1. Optimize density and Zeff at pedestal
Step 2. Tailor q profile for each scenario with the H&CD methods with the highest priority in engineering design

Step 1. Scan of density and Zeff at pedestal to get the highest fusion power [2]