TEARING MODE STABILITY OF STEADY-STATE SCENARIO PLASMAS IN DIII-D


Background
Tearing mode stability is crucial for high-performance scenarios intended for steady-state operation. The appearance of tearing modes in DIII-D discharges leads to loss of energy confinement, and to a redistribution of the current profile that is not recoverable with the available non-inductive current drive sources. It has been routinely observed, namely in high-
β quasi non-inductive DIII-D discharges, that ECD can prevent the mode formation, without a direct island stabilization.

Goals and method
☐ Observation of current density profiles -> identify patterns in the current evolution towards stability/instability:
  • what type of evolution characteristics unstable discharges?
  • what regions of the current profile are important?
☐ Observation of the type of modes that end the high-beta phases:
  • what can act on the modes stability?
☐ Observation of the effects of the EC current:
  • location, profile shape, power, 
  • apply resistive stability models in order to assess what the patterns are supposed to do:
    • Evaluate stability of the equilibrium
    • change the equilibrium following the observed patterns
    • add ECD to the equilibrium
☐ Attempt a control of the discharge using the acquired predictive capability: ECD can correct the evolution of the plasma towards stability

1. The current profile evolution: impact of the current gradient on the mode destabilization

The current profile evolution towards the triggering of the mode shows:
1. a pattern inside \( P \approx 0.2 \)
2. a pattern between \( P \approx 0.3 \) and \( P \approx 0.8 \)
We will focus on (2), since the changes inside \( P \approx 0.2 \) are less likely to impact on the tearing modes (\( P > 0.4 \), but the actual importance of (1) remains an open question.

When ECD is not present (e.g. 234260) or the q-trip is (e.g. 234227), a “hole” is left in the profile, and the negative gradient

2. The nature of the modes affecting the confinement

- Tearing, slow growth (\( \geq 100 \) ms)
- no burst of MHD activity beforehand
- a single toroidal number
- Faster growth (\( \geq 10 \) ms); partly ideal?
- Bursts of MHD activity before the mode (\( f \approx 20-50 \) kHz)
- often \( n=2 \) is superimposed (e.g. a 5/2)

3. The action of ECCD

- Stabilization has been observed for off-axis injections (\( P > 0.25 \))
- A narrow deposition does not provide stability
- It is not a direct island stabilization!

A high current gradient, of either sign, appears to be related to mode triggering

<table>
<thead>
<tr>
<th>Negative gradients:</th>
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<tbody>
<tr>
<td>• The rise of internal beam power (( \Phi )↑)</td>
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<tr>
<td>• The current diffusion</td>
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<tr>
<td>• The sudden loss of ECD (q-trip) can peak ( J_\rho ) at the centre, and take away current at ( P \approx 0.2-0.4: )</td>
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The EC current prevents \( J_\rho \) from dropping at \( P \approx 0.2-0.4 \) and avoids the negative current gradient

<table>
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<th>Positive gradients:</th>
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<tr>
<td>• The ECCD power does not seem to be important for stability</td>
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<td>• A few counter-examples for both narrow and broad depositions exist</td>
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</table>

3. Summary and conclusions

The current density profile and evolution have been analyzed for high-\( \beta \) discharges with and without off-axis ECCD, and with different ECCD depositions, to assess their impact on the discharge stability.

- A pattern in the \( J_\rho \) evolution has been identified, in the external part of the profile: the unstable discharges are characterized by a high or negative \( \nabla J_\rho \) close to the mode location
- A few counter-examples exist: a transient high\( \nabla J_\rho \) may not lead to instability
- The modes are mainly \( n=1 \) tearing instabilities: \( \Delta \) is sensitive to \( \nabla J_\rho \), \( \nabla \Phi \), AND the equilibrium
- A broad ECCD deposition can prevent a negative \( \nabla J_\rho \), while a narrow one may cause a greater \( \nabla J_\rho \) close to a rational surface

The stability analysis of “phase 2” should focus on the region \( P \approx 0.35-0.65 \) of the current profile