Plasma instability during ITBs formation with pellet injection in tokamak

P. Klaywittaphat\textsuperscript{1}, B. Chatthong\textsuperscript{2}, T. Onjun. R. Picha\textsuperscript{3}, J. Promping\textsuperscript{3}

\textsuperscript{1}Faculty of Engineering, Thaksin University, Phatthalung, Thailand,
\textsuperscript{2}Department of Physics, Faculty of Science, Prince of Songkla University, Songkla, Thailand
\textsuperscript{3}Thailand Institute of Nuclear Technology, Bangkok
I. Introduction: Kingdom of Thailand

- Thailand is a country on Southeast Asia’s Indochina peninsula
- Previously called “Siam”
- Member of “ASEAN”
- Capital: Bangkok
- Currency: Thai baht
I. Introduction: Land of Smiles

Rich of Nature and Culture
Where are we in Thailand?

Thailand Institute of Nuclear Technology

Thaksin University
• Motivation
• Literature Review
• Description of Code and Module
  • MMM 95 anomalous transport model
  • Mixed B/gB anomalous transport model
  • Pellet injection Module
• Simulation Results
• Micro-instability Analysis
• Conclusions
Motivation

• Pellet fueling is crucial issue in ITER
• The effect of micro instability with pellet in a large tokamak is interesting.
• Pellet injection discharge 53212 is available in ITPA data base
• The study of plasma transport can be done with simulation code and can compare with experiment data
• It is interesting to see what happen in the instability and ITB during pellet injection
Simulations of JET pellet fuelled ITB plasmas
L. Garzotti et al 2006 Nucl. Fusion 46 73

To investigate the pellet–barrier interaction two particular pellets from two different discharges:

shot 57941 with 7 shallower pellets (mass $1–2\cdot10^{21}$ atom and injection speed $80 \text{ ms}^{-1}$) injected between 4 and 6.6 s from the vertical HFS track

shot 55861 with 5 HFS pellets (mass $1–2 \cdot 10^{21}$ atom and injection speed $160 \text{ ms}^{-1}$) injected between 4.9 and 6.9 s.

shot 57941 the pellet penetration depth was about 15 cm ($r/a = 0.85$ at the injection location)

shot 55861 it was 30–40 cm ($r/a = 0.65$ at the injection location).
Simulations of JET pellet fuelled ITB plasmas

Typical waveforms for the pellet fuelling of high density ITBs experiments described in the paper (shot 55861). The three phases are visible: LHCD prelude (1.5–3 s), ohmic gap (3–4 s) and main heating phase (4–9 s). L. Garzotti et al 2006 Nucl. Fusion 46 73
Simulations of JET pellet fuelled ITB plasmas

JETTO simulation for JET pulse 57941 (the pellet is injected at \( t = 5.2 \) s and does not destroy the ITB). The solid lines are the pre-pellet profiles (\( t = 5.19 \) s), whereas the dashed lines are the post-pellet profiles (\( t = 5.24 \) s). The plot shows: (a) particle diffusion coefficient, (b) plasma toroidal rotation velocity, (c) density gradient and (d) shear. The profiles before and after pellet injection remain similar. The suppression of \( D \) according to the \( s - \omega_{E\times B}/\gamma_{ITG} \) criterion indicates that the ITB is not destroyed.

L. Garzotti et al 2006 Nucl. Fusion 46 73
JETTO simulation for JET pulse 55861 (the pellet is injected at $t = 4.935\ s$ and destroys the ITB). The solid lines are the pre-pellet profiles ($t = 4.92\ s$), whereas the dashed lines are the post-pellet profiles ($t = 5.06\ s$). The plot shows (a) particle diffusion coefficient, (b) plasma toroidal rotation velocity, (c) density gradient and (d) shear. $D$ is reduced according to the criterion before pellet injection but not after, indicating that the pellet destroys the ITB.
Gyrokinetic simulations of transport in pellet fuelled discharges at JET

GENE results as a function of radius. Density profiles for the two cases are also shown.

D. Tegnered, H. Nordman, P. Strand, L. Garzotti, I. Lupelli, C. M. Roach, M. Valoviˇc and JET ContributorsTo be presented at the EPS conference 2016(this can be found on the JET pinboard under contribution to conferences, EPS)
Gyrokinetic simulations of transport in pellet fuelled discharges at JET

- Linearly the microinstability spectrum is dominated by the ITG mode for $k_y \rho_s < 0.6$ and $\rho < 0.9$. ITG remains unstable with reduced growth rates in the positive $dn/dr$ region.
- The nonlinear analysis is concentrated on the initial $t = 0.0042s$ and the in between $0.034s$ time point. The corresponding density profiles are shown together with the nonlinear heat and particle fluxes and the linear growth rates. In the positive $dn/dr$ region the particle flux is inwards and the (outward) heat flux is reduced just after the pellet ablation, but later when the pellet ablation peak has disappeared the particle flux changes sign and becomes outwards. The results are compared and contrasted with the analysis of pellet fuelled H-mode MAST\cite[L Garzotti et al 2014 Plasma Phys. Control. Fusion 56 035004]{Garzotti} plasmas and extrapolated to reactor relevant plasmas.
Description of Models

MMM95[1]

\[ \chi_{\text{eweiland}} + \chi_{\text{eRB}} + \chi_{\text{eKB}} \]

\[ \chi_{\text{iweiland}} + \chi_{\text{ieRB}} + \chi_{\text{iKB}} \]

Mixed B/gB[2]

\[ \chi^B \equiv \rho_s c_s q^2 \frac{a(dp_e/dr)}{\Delta T_e} \]

\[ \chi^{gB} \equiv \frac{P_s^2 c_s (dT^e_e/dr)}{T_e} \]


Description of Model

• Pellet injection[1]

\[ \frac{dt}{dt} = 5.2 \times 10^{16} n_e^{0.333} T_e^{1.64} r_p^{1.333} M_i^{-0.333} \]

• Relocation Module [2]

\[ \Delta_{drift} = c_1 v_p^{c_2} r_p^{c_3} n_e^{c_4} T_e^{c_5} \left( \theta - c_6 + c_7 \right)^{c_8} \]
\[ \times (1 - \Lambda)^{c_9} a_0^{c_10} R_0^{c_11} B_t^{c_12} k^{c_13} \]


The time evolution of line average electron density is compared for experimental data and the simulations using either MMM95 (left) and Mixed Bohm/gyro-Bohm (right).
Simulation Results

The electron temperature and density profiles during the pellet operation is plotted for the experimental data and the simulations using MMM95 (left) and Mixed Bohm/gyro-Bohm (right).
The Ware pinch velocity profiles during the pellet operation is plotted for the simulations using MMM95 (left) and Mixed Bohm/gyro-Bohm (right).
Simulation Results

The profiles for total electron thermal diffusivity during the pellet operation are plotted for the simulations using MMM95.

does not destroy the ITB
The components of electron thermal diffusivity profiles during the pellet injection obtained from the simulation using MMM95 transport model are shown for the radius from $\rho = 0$ to $\rho = 1.0$. Those components are the drift wave (ITG&TE) (top panel), the drift-resistive ballooning (RB) modes (middle panel), and kinetic ballooning (KB) modes (bottom panel).
Simulation Results

The time evolution of electron density, electron temperature are shown during pellet ablation.
Simulation Results

The profiles of the growth rate due to ITG and TEM during the pellet fueling operation are shown for the radius from $\rho = 0$ to $\rho = 1.0$.

It can also be seen that ITG modes, which dominate before pellet injection, are increased by the increased temperature gradient $\eta_i = (\nabla T_i/T_i) (\nabla n_i/\nabla n_{TEM})$ modes are stabilized by increased collisionality during pellet injection.
Conclusions

• Transport during pellet injection this is dominated by RB modes due to the increase of collisionality and resistivity near the plasma edge.

• The results show that the micro instability properties of the post-pellet profiles are highly sensitive to rapid and large excursions in the gradients, and collisionality, induced by the pellet injection.

• In particular, at a location, corresponding to the part of the pellet deposition profile, ITG modes are destabilized by an increase of temperature gradient, TEM modes are stabilized by increased collisionality.

• It was found that the shallower pellet does not destroy the internal transport barrier, which locating mostly between \( r/a = 0.8 \) and 0.9. Moreover in the plasma center region \( (0.4 < r/a < 0.6) \) the effective electron thermal diffusivities during the ablation time not change and decreased after pellet ablation, it mean a shallower pellet can improve the internal transport barrier.
Thank you