Summary
H-mode/Pedestal/Edge

R.J. Groebner and R.A. Moyer

US TTF Meeting, Salt Lake City

Apr 29- May 2, 2004

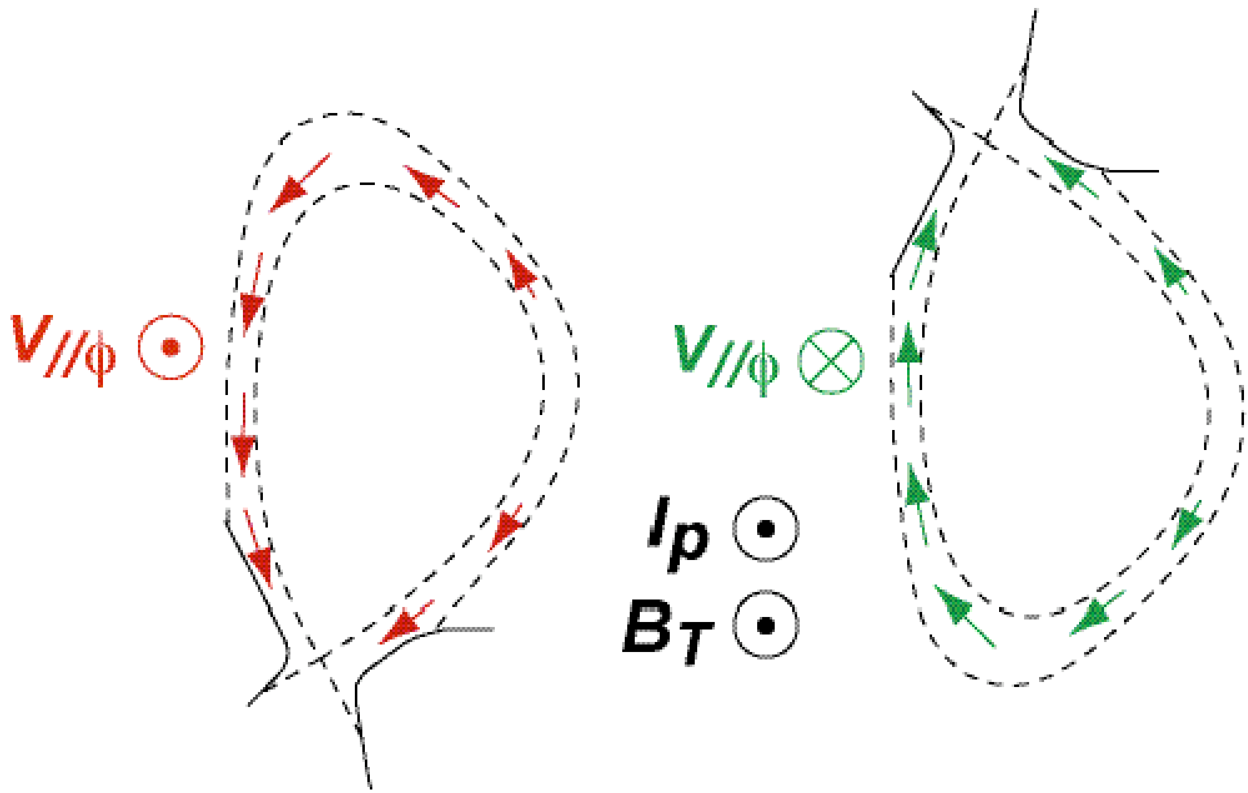
H-mode Threshold (1)

During the last few years, a major issue for the H-mode transition has been the dependence of the H-mode threshold on the plasma configuration, particularly the grad-B drift effect. Another area of interest has been comparing experimental conditions at the transition to a theoretical transition criterion due to Guzdar. Presentations were made on both of these topics.

- **SOL flows may provide an explanation for the up-down asymmetry in the L-H threshold (M. Greenwald)**
  - **Probes show that the SOL pressure at the low field side (LFS) is much higher than at the high field side (HFS) of C-mod (evidently due to ballooning dependence of transport)**
  - **This pressure differential drives flows around plasma periphery in the SOL**
  - **An x-point cuts off the flow from LFS to HFS; thus, USN and LSN plasmas will have different flows**
  - **These flow may add to other flows and help to change P_th in USN vs LSN**

High pressure at LFS determines direction of parallel SOL flows

⊥ transport-driven parallel SOL flows:



Data from M. Greenwald, C-Mod

H-mode Threshold (2)

- **Careful studies of edge profiles before H-mode transition were made in C-mod to study Grad-B drift effect (A. Hubbard)**
  - **In L-mode, at fixed power, there is little difference in the profiles**
  - **Theorize that there must be a difference in mean flows for USN and LSN, consistent with results from Greenwald's talk**
  - **Guzdar's theoretical parameter is within a factor of 2 of the experiment, with favorable Grad-B condition being low and unfavorable Grad-B drift condition being high relative to the theoretical prediction**

Pedestal Structure (1)

A general picture is emerging that to understand the pedestal structure (prior to an ELM) we must understand the heat and particle fuelling, particle transport and ion and electron thermal transport. Modeling codes are needed to address the interactions of these ingredients and a variety of different codes are being used or are in development. Some of these were discussed here.

- **A review of studies of fuelling in DIII-D with edge measurements of neutrals and modeling with coupled edge transport and Monte Carlo neutrals was discussed (R. Groebner)**
  - **The work was performed by R. Colchin and L. Owen of ORNL**
  - **D-alpha measurements have been used to determine neutral densities inside LCFS in divertor and at midplane**
  - **Coupled B2.5/Eirene modeling is able to match these and other measurements with dominant fuelling calculated to be at divertor**
- **Coupled transport equations with a fuelling model are being used to model pedestal (W. Stacey)**
  - **Analytic theoretical used for thermal transport: ion neoclassical, ITG, ETG and TEM**
  - **Particle transport is obtained from momentum balance equation with only neoclassical transport assumed - gyroviscosity is an important contributor**
  - **Initial test of model provides reasonable agreement with a set of DIII-D pedestal profiles**

Pedestal Structure (2)

- A Monte Carlo orbit following code has been used to study neoclassical effects in the pedestal (C-S. Chang)
  - Model includes a Monte Carlo neutrals model to provide a fuelling source, a heat source at inner edge of simulation domain and an adjustable diffusion coefficient to model anomalous particle transport
  - Model produces steep edge gradients in density and ion temperature, also produces negative E_r at separatrix
  - Scaling of width of density step is being studied as function of plasma parameters
    - Finds little dependence of Δ_n on n_e^{ped} or B_p
    - Finds n_{ewid} going as $1/B_t$ and as $(T_i)^{1/2}$
    - B_p dependence disappears due to orbit-squeezing

ELMS (1)

The peeling/ballooning model for predicting onset of ELM instability has wide acceptance. There is a desire to complete the story with measurements of current density, being pursued on DIII-D. Much of the attention of worldwide community is devoted to measuring rapid evolution of plasma parameters after the ELM occurs. Interest is in predicting how much energy an ELM removes from the plasma. Several talks discussed that.

- **Comprehensive overview talk shows that there is a rather consistent picture of ELM physics emerging from worldwide database (A. Loarte)**
  - **Peeling/ballooning model provides a picture of ELM onset**
    - **One mystery is the lack of explosive growth in ELM precursors, as observed on some machines**
  - **At an ELM crash, there is a flow of fast electrons to divertor plate followed by a flow of energy at the ion transit time**
  - **Some energy goes to vessel components other the divertor; this effect decreases as ELMs become more convective**
  - **The amount of energy released by an ELM is not proportional to the volume of plasma affected by the ELM. Calls into question the idea that width of eigenfunctions helps set ELM size**
  - **Energy loss from ELMs becomes smaller as ΔT decreases, I.e., ELMs become more convective and less conductive**

ELMS (2)

- Edge stochastic magnetic field has been used to suppress ELMs in DIII-D (R. Moyer)
  - Stochastic field was weak and carefully localized to pedestal region
  - Accomplished without a change of stored energy or radiation; toroidal rotation did decrease markedly
  - ELMs were replaced by a rapid, irregular oscillation, which broadens profile slightly; not clear what the oscillation is or if it is related to ELMs in some way
- Relaxation properties of ELMs were studied in JET (L. Popova)
  - Concludes that relaxation time of ELMs is slightly faster than pedestal relaxation time (definitions not clear)
  - This may be evidence for convection being important in ELMs
- A probe has been used to characterize ELM-induced transport in SOL of DIII-D (J. Boedo)
  - ELMs are poloidally localized on low field side and produce bursts of hot plasma traveling radially in SOL
  - Initial speed ~450 m/s, slowing to ~150 m/s at wall
  - Temperature decay length much shorter than density decay length

ELMS (3)

- **Role of edge MHD instabilities in regulating edge transport has been studied in an RFP (P. Martin)**
  - **Most of gradient in n and T is near the plasma edge around resonance of m=0 modes (toroidal field reversal surface)**
  - **If m=0 islands do not overlap too much, they may produce some insulation for particle confinement**
  - **When overlap becomes too severe, they have a large burst of instability which worsens confinement; see fast pulse moving outward on SXR**
  - **We can speculate that this might be a point of contact with tokamaks: Can the same theory be used to predict onset of these modes? Is the overlap of several modes at all related to non-linear evolution of ELM?**

Edge Transport (1)

Recently, there has been much study of transport in scrape-off layers of many devices with different magnetic configurations. They all tend to show intermittent features with large radial transport (blobs), which can account for a significant amount of SOL transport. Due to the universality of observations, studies of this edge transport provides a good point of contact between devices of different configurations. Several talks were presented on this issue.

- **The origin of intermittency in a linear device (PISCES) has been studied (G. Antar)**
  - **There is an oscillation just inside the LCFS of PISCES**
  - **Careful work shows that intermittent events in SOL are correlated with this oscillation**
  - **Thus, the oscillation may be the origin of the intermittent events (Blobs)**
- **High speed movies of edge transport have been obtained in several conditions on NSTX and C-Mod (S. Zweben)**
  - **All show the standard story - intermittency and blobs occur**
  - **Edge becomes significantly quieter in H-mode, although intermittency still occurs**
  - **MHD events produce large intermittent structures**

Edge Transport (2)

- Intermittency has been studied by examining BOUT simulations (D. Russell)
  - Developed wavelet analysis to pick out blobs from BOUT 3D turbulence simulations
  - Find that curvature drift induces electric dipole in blob; blob is driven radially due to ExB drift
  - Discussed possibility that blobs are disconnected from divertor sheath, thereby altering the blob dynamics
- A 3D model for blobs with X-point physics has been developed (D. D'Ippolito, presented by D. Russell)
  - 3D model has been developed because the 2D model has some differences with the BOUT 3D simulations
  - Blobs may be electrically disconnected from the sheath due to effects near the X-point; this allows blobs to maintain integrity and leads to more rapid radial transport
    - This provides improved agreement with BOUT

Basic Turbulence Studies - experiment

A key issue for understanding the H-mode pedestal structure is to obtain an understanding of transport in the pedestal and in the scrape-off layer. Some of this transport may be due to turbulence (particularly in the SOL). Thus, basic turbulence studies are of great interest because they will help form the basis for this understanding. Several papers were presented in this area.

- **Poloidal asymmetry in edge turbulence is being studied in ET (A. White, D. Pace)**
  - **Diagnostics being improved**
  - **Density fluctuations at HFS and LFS are similar; correlation length a little smaller at HFS**
- **Non-linear development of turbulence being studied in TORPEX (F. Poli)**
  - **Looking at coherent modes turning into turbulence**
  - **Modes are identified as being due to drift waves**
- **Evidence for turbulence generating shear flows in CSDX cylindrical plasma (G. Tynan)**
  - **Transition from coherent modes to turbulence is studied by increasing magnetic field**
  - **A mean potential profile is observed, with turbulence suppression at shear layer**
  - **Non-linear energy transfer must be invoked to explain the profile**
  - **Results are well explained by** Hasegawa A and Wakatani M 1987 Phys. Rev. Lett. 59 1581–4

Basic Turbulence Studies - Analysis Techniques

Analysis of turbulence data is a complicated undertaking but is crucial for obtaining a deeper understanding of turbulence dynamics. Several papers proposed advanced analysis techniques of turbulence.

- **A method of determining velocity of turbulent eddies is being applied to two-dimensional BES data (G. McKee**
  - **Goal is to determine fluctuating eddy velocity for use in determining turbulence particle flux and other quantities**
  - **An analysis algorithm from fluid dynamics has been adopted**
  - **First results look promising; average radial velocity found to be outwards**
- **A time delay method to determine velocity fluctuations is being examined (C. Holland)**
  - **An analytic basis for the method exists**
  - **Method being studied on known signals to build understanding**
- **A new method for bi-spectral analysis has been proposed (D. Baver)**
  - **A new class of bi-spectral algorithms was presented**
  - **These greatly reduce the number of degrees of freedom, as compared to previous techniques**
  - **Promise to provide greatly improved analysis with much smaller data sets**