EIGHTEENTH FUSION ENERGY CONFERENCE

SESSION TH3

Friday, 6 October 2000, at 2:20 p.m.

Chair: A. BONDESON (Sweden)

SESSION TH3: MHD, Ideal and Resistive (provided by L. LAO, USA)

Paper IAEA-CN77/TH3/1 (presented by F. Porcelli)

DISCUSSION

M.G. HAINES: There is another collisionless reconnection process based on the triggering of microscopic turbulence by the high electron drift velocity in the reconnection layer, published by J. Aparicio et al., Phys. Plasma 5, 3180 (1998). The micro-turbulence can be ion-acoustic turbulence in the unusual regime when $T_e < T_I$ and the critical drift velocity is about equal to the electron thermal speed. This mechanism has a distinct trigger and it can be shown that electron inertia effects and electron viscosity effects are only small corrections. Have you considered localized micro-turbulence in the reconnection layer?

F. PORCELLI: No, micro-turbulence is not accounted for in our model. We have shown that the growth of a magnetic island in the collisionless regime is accompanied by “phase mixing” in space, i.e. the formation of small spatial scale-lengths, while the plasma flow and parallel current are mainly distributed over the ion (sound) Larmor radius (ρ_s) scale length. Like in the problem of non-linear Landau damping or the bump-on-tail instability, the time scale of the non-linear process is independent of the physical processes that may eventually limit the small scale structures. Thus, I believe that the process we have described provides the relevant rate for fast collisionless reconnection, irrespective of the possible occurrence of micro-turbulence if affecting sub-Larmor-radius scale lengths.

Y.I. KOLESNICHENKO: What are the diamagnetic effects on neo-classical tearing modes and for what plasma β they are of importance?

F. PORCELLI: The “diamagnetic” effects we have considered are related to the equilibrium density gradients and are represented by the parallel electron pressure gradient term in the generalized Ohm’s law. These effects are relevant as soon as the electron drift wave frequency exceeds the standard tearing growth rate. This normally requires very low value of β that are realized in practically all present-day tokamak experiments.

B. COPPI: This is a follow up to the comment of M. Haynes. The curse of collisionless reconnection theory is the smallness of the layer $d_e = c / \omega_{pe}$ that inevitably plays the key role in its dynamics. A way out as we proposed in the 70’s (Astrophysical Journal) is to consider a 3-D situation where micro-instability, driven by the perpendicular field, is excited and produces an anomalous resistivity. Thus, the reconnection layer can acquire a width and correspond to growth rate that can be adequate to explain relevant experimental observations (e.g. solar flares).

F. PORCELLI: In general, I agree with this comment, however with two qualifications. First, the width of the reconnection layer for the parameter we have considered is actually the ion (sound) Larmor radius, ρ_s, which is normally larger than d_e in present-day tokamak experiments (e.g. $\rho_s \sim 0.5$ for typical JET plasmas). Secondly, for strongly magnetized tokamak plasmas, I do not see any problem with the formation of narrow current sheets in the vicinity of mode-rational surfaces. For instance, in the case of a macroscopic internal kink mode, the $q = 1$ surface has to withstand a magnetic pressure of several atmospheres due to the displacement of the central plasma core. Hence, the plasma near $q = 1$ is strongly squeezed and narrow current sheets with a width a fraction of a centimeter must indeed form. The 2-D model we have considered provides this width and a non-linear reconnection rate in good agreement with that observed experimentally (e.g. the sawtooth crash time). If 3-D processes provide wider current channels and faster rates, then of course they are more relevant than the model we have considered. However, nobody has yet been able to show that this is indeed the case for relevant tokamak plasma parameters.

Paper IAEA-CN77/TH3/3 (presented by T. Matsumoto)

DISCUSSION

R. GOLDSTON: The ideal kink can be very sensitive to the precise pressure profile. How confident are you that the JT-60U cases are truly stable to the ideal kink? Also, it seems that your mechanism is not driven by β. So this brings up the question as to how reversed shear configurations are developed at low β , which we know they are?

T. MATSUMOTO: As you mentioned, the beta limit is sensitive to the precise pressure profile. The collapses around the beta limit shown by us might be unstable to the ideal mode. However, the fast collapses are observed at beta values lower than half of the limit ($\beta_N < 1$). By the experimental results in JT-60U, we show the existence of the fast collapses which are induced not by the ideal mode but by the kinetic (collisionless) mode. Of course, the beta effect is a problem to be clarified. However, we use low beta models to analyze the kinetic double tearing mode. The beta effect is not studied at present.

M.C. ZARNSTORFF: Have you compared your calculated (tearing) eigen function with experimental measurements? On TFTR, the measurements showed the fast collapse were preceded by modes with ideal MHD eigen functions.

T. MATSUMOTO: I have not compared the eigen functions. I will try it. Thank you for your comment.

TH3/D

Paper IAEA-CN77/TH3/4 (presented by D.F. Escande)

DISCUSSION

M.G. HAINES: The visco-resistive model can lead to the characteristic scale length being comparable with the ion Larmor radius; besides FLR, the Hall term can be important. Furthermore the mean free path can be too long for a local viscosity coefficient to be valid. Have you considered this?

D.F. ESCANDE: It is true that additional physics effects proposed in the questions should be taken into account in a further stage of the theory. However, single helicity states of the RFP present no small spatial or temporal scales. In particular, reconnection layers may be absent. This justifies the use of visco-resistive MHD for simulating the RFP magnetics, a practice which has proved for years to be extremely successful as far as comparison to experiments is concerned.

B. COPPI: The measured temperature in the bright spots that are formed is about 400 eV, according to a recent paper by the RFX group. This means that the simple one-fluid theory is no longer applicable as we know from past work for plasmas confined in different configurations. In particular finite ion diamagnetic and electron drift frequency, finite gyro-radius effects become important and should change the analysis in a significant way.

D.F. ESCANDE: See response to Haines above.

TH3/D

Paper IAEA-CN77/TH3/5 (presented by H.R. Wilson)

DISCUSSION

F. PORCELLI: If the polarization current is indeed destabilizing, then not only we do not have a theory for the seed island, but also theoretical predictions of saturated neo-classical island width become shaky.

H.R. WILSON: The polarization current can be stabilizing, destabilizing or absent depending on the island propagation frequency ω, as we have shown. This needs to be determined either experimentally or theoretically. Furthermore, I agree that it is unlikely that the polarization current is destabilizing for NTMs, as experimentally they are not prevalent in collisional plasmas, i.e. $\nu_I / \varepsilon\omega > 1$, $\nu_{*I} < 1$. As far as the saturated island size is concerned, the polarization current associated with isolated islands is only important for small island widths; thus it would have little effect on the saturated island size.

T.C. LUCE: Does your coupled RWM-NTM model predict tearing instability in all cases where β is greater than the no-wall ideal β limit?

H.R. WILSON: The model we have presented for the NTM-RWM coupling is a rather simple model in which we neglect plasma rotation and associated torque balance. If the RWM remains locked to the wall, but the plasma rotation can be maintained, it is possible that the magnetic perturbation would not penetrate and the NTM not triggered; this could be addressed by a more complete theory. In addition, it is possible that some additional mechanism, not considered here, could saturate the RWM at a lower amplitude than the threshold required to trigger the NTM.

Paper IAEA-CN77/TH3/6 (presented by A.D. Turnbull)

DISCUSSION

V. PARAIL: Different instabilities have been used by different people to explain ELMs: ballooning, kink, peeling. How universal is your conclusion that this is peeling mode which triggers ELM?

A.D. TURNBULL: I am really only discussing the type I ELMs. These, we believe are intermediate n ideal edge kink modes. One could call them peeling modes.

H. ZOHM: How do you explain the difference between type I and type II ELMs in the frame work of your model?

A.D. TURNBULL: The type II ELMs seen in the past on DIII-D are not included in this model. We have not considered them. I avoid using the terms type I or type II, since these terms are used differently for different tokamak groups.

P. SMEULDERS: In JET we measured the external kink that we believe was driven by the edge currents. What is in your case the driving force of the ELM, pressure gradient or edge current?

A.D. TURNBULL: The ELMs here are different, I believe, from the low n external kinks seen in JET. The driving force for the ELMs is the pressure gradient and the associated bootstrap current density.