Z. ABOU-ASSALEH

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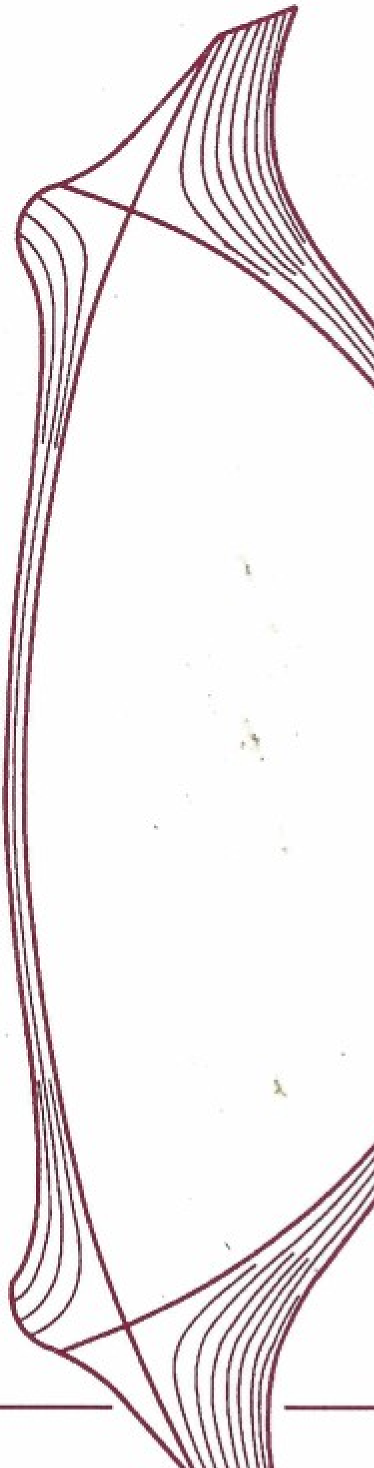
KFA



3rd International Workshop on

Plasma Edge Theory in Fusion Devices

Bad Honnef
Physikzentrum
22 - 24 June 1992

Abstracts

Review of Papers at the 3rd International Workshop on Plasma Edge Theory
Bad Honnef, Federal Republic of Germany. 92
Zouhier Abou-Assaleh, Ph.D., Culham Laboratory, Abingdon, Oxfordshire, UK. AEA Fusion

INRS

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Zouhier ABOU-ASSALEH
INRS - énergie et Matériaux
AEA-Fusion, Culham

- 3rd International workshop on plasma Edge Theory Bad Honnef. 1992.
- Edge activities at LLNL and UCLA
- Review of Paper on " New Boundary conditions By Yu. L. Igitkhanov et al Presented at Bad Honnef 1992
- Fokker-Planck Modelling of edge Plasma Near the Neutralizer plate in a Tokamak By: Z. ABOU-ASSALEH et al. presented at Bad Honnef 1992.

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Forschungszentrum Jülich GmbH
Institute for Plasma Physics

3rd International Workshop on
Plasma Edge Theory in Fusion Devices

Abstracts of the Papers Presented
Physikzentrum Bad Honnef, Germany
22 - 24 June 1992

The Workshop was jointly organized by the Forschungszentrum Jülich and the Arbeitsgemeinschaft Plasmaphysik of the Universities of Bochum, Düsseldorf, Essen and KFA Jülich.

June 1992

2D

- R. Zanino : Finite element modelling of the
  Garching - Torino scrape-off layer
- A. Taroni : The multifluid codes EDGE1D and
  JET EDGE2D : Models and results
- K. Parbhakar & J. Lewendowski : properties of a biased
  INRS divertor scrape-off layer
  plasma (1D)
- T. D. Ragnlien, et al : A fully implicit, 2-D fluid
  LLNL transport code for
  simulating tokamak edge
  plasma.

B2

- W. D. D'haeseler, H. D. Pacher, G. W. Pacher
  NET
  B2 with an analytical recycling model for ITER/NE
- M. W. Wuttke et al.: Validation of the B2-EIRENE
  Julich code by comparison with TEXTOR experiments
- H. Kastelewicz et al.,: Parameter study of the diverto
  Garching conditions in ASDEX-up-grade

  B2, Analytical recycling, EIRENE (neutra
- R. Schneider et al.: extensions of B2 for the
  Garching simulation of ASDEX-upgrade scrape-off layer plasma

  - Deuterium plasma & Helium ions as impurity
  - Neutral atoms and molecules:
    Monte-carlo code EIRENE
  - B2 plasma profiles → calculates the source terms
  - B2-EIRENE more realistic recycling model than the stand-alone B2-code.

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Kinetic

- Krasheninnikov et al.
  - Kinetic modeling of the transport processes in the tokamak edge plasma. (Preliminary results).
  - Electron Heat conduction and suprathermal particles

- R. Chodura (Garching)
  - Kinetic effects in the scrape-off layer
    Non-Maxwellian : 1- sources: from the bulk plasma
    Reionized recycled neutral
    2- Parallel transport
    3- Sheath

- Z. ABOU-ASSALEH et al,

  Fokker-Planck Modelling of Edge plasma Near the Neutralizer plate in a tokamak..
  * electron kinetic / ion fluid

UCLA

R.W. Conn } PISCES — ($D_\perp$, $D_\parallel$)
F. Najmabadi } 1D & 2D Modelling
Y. HIROOKA
B. Merriman → UCLA next-generation code

LLNL

T. D. Rognlien
M. E. Rensink
G. D. Porter
⋮

2D code : LEDGE

Fully implicit
2D fluid

Applications: DIII-D

Boundary Conditions

- K. Günther : Boundary conditions for the momentu
  Berlin and energy flux of ions at the
  plasma - sheath interface.

- Yu. L. Igitkhanov et al.
  Kurchatov Institute, Moscow

  - Effective Boundary conditions at the plasma - surface ~~interaction~~ interface.
  - The influence of Different Boundary conditions on the Divertor plasma parameters.

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Effective Boundary conditions at the Plasma-surface interface.

Yu. L. Igitkhanov, A.M. Runov

Presented at the 3rd International workshop on plasma Edge Theory in Fusion Devices, Bad Honnef, Germany 1992.

- Fluid can be used if the nonlocal effects are included into the transport coefficients and the appropriate boundary conditions are present.

- The existing boundary conditions do not permit to include the contribution of suprathermal particles due to their local nature.

- New Boundary conditions for fluid models of SOL and divertor plasma:

New Boundary conditions

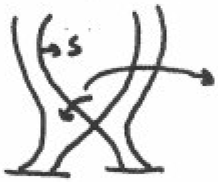
- starting from BGK Kinetic equation
- This boundary conditions permit to extent the applicability of fluid equations to the moderate collisionality regimes typical for the divertor plasma.
- The BGK approximation gives an apportunity to express the boundary fluxes as functions of fluid profiles instead of local values
- Used $T_i = 0$:
  The Boundary conditions effects By
  - whole ion distribution function
  - Hot tail of the electron distribution function.

Kinetic Model

1D along $\overrightarrow{B}$

e-e collisions presented by the BKG approximation

e-n collisions



$f_M(n_s, T_s) = \varphi_s$

$$v_x \frac{\partial F}{\partial x} = \nu_m (n \varphi_m - F) + 0.5\, n\, \nu_n\, \delta(|v_x| - v_0)\, \delta(v_y)\, \delta(v_z)$$
$$- \nu_n F + \nu_s n_s \varphi_s\, \vartheta(-|x| + a) - F \nu_s$$

$1/\nu_m$ is the Maxwellization time

F is the electron distribution function

φ_s is the Maxwellian

φ_m is the local shifted Maxwellian

ν_n is the frequency of ionisation

$\nu_s = N \langle \sigma v \rangle$, $N(x) = N_w \exp(-|x|/\lambda - L/\lambda)$

Boundary conditions at the entrance of the Debye sheath:

- Mirror reflection for the particles with energy below a potential barrier
- φ_d the sheath drop is found from the local parameters of φ_m, n, T, and V

New variables

$$\xi = \frac{x}{L}, \quad u = \frac{v_x}{v_s}, \quad \tilde{T} = \frac{T}{T_s}, \quad \tilde{V} = \frac{V}{V_s}$$

The solution of the Kinetic equation:

$$f^{+}(u,\xi) = \exp\left[-\int_{-1}^{\xi}\frac{d\xi'}{u}\right]\int_{-1}^{\xi}\frac{R(\xi')}{u}\exp\left[+\int_{-1}^{\xi'}\frac{d\xi''}{u\tau}\right]d\xi'$$
$$+\,C(u)\exp\left[-\int_{-1}^{\xi}\frac{d\xi'}{u\tau}\right]$$

where

$$1/\tau = \nu_m + \nu_n + \nu_s$$

$$R(\xi') = \frac{n}{\sqrt{\pi T}}\,\nu_m \exp\left[-(u - V^2)/T\right] + \nu_s\frac{\vartheta(-|\xi| + a_-)}{\sqrt{\pi}}\exp(-u^2$$
$$+\,0.5\, n\,\nu_n\, \delta(|u| - u_0)$$

[redacted] $+$: half space of positive velocities

$C(u)$: mirror reflection from the wall.

Fluid Model

Set of fluid equations: particles, energy, and momentum with sink and source terms

Boundary conditions:

at $\xi = 0$ (symmetry plane): $j\big|_0 = 0$, $\frac{\partial T}{\partial \xi}\big|_0 = 0$

at $\xi = 1$ (plate): The particle, momentum and heat flux values are obtained by integration of $f^+(u, \xi)$

Profiles obtained by iteration

Boundary conditions at the plate with the profiles of hydrodynamic quantities T, v, n and to include kinetic effects into the fluid approach.

Improvement of the transport coefficients by including the nonlocal effects

Heat flux

$$\left(\nu + \frac{8}{3}\frac{\partial u}{\partial \xi}\right) q = \alpha \nu_m q_{SH} + \frac{5}{3} u P \frac{\partial u}{\partial \xi} - (RU - Q)$$

where: $\nu = \nu_m + \nu_s + \nu_n$

u is the fluid velocity

$P = nT$

R and Q are the integrals over f_e with the weight of v^2 and $v^2 v_x$

q_{SH} is the classical expression

Viscosity

$$\pi = -\frac{4}{3\nu_m} nT\, 0.73 \left[\frac{\partial v}{\partial \xi} + \frac{2}{5}\frac{1}{nT}\frac{\partial q}{\partial \xi}\right]$$

q is the thermal conduction flux.

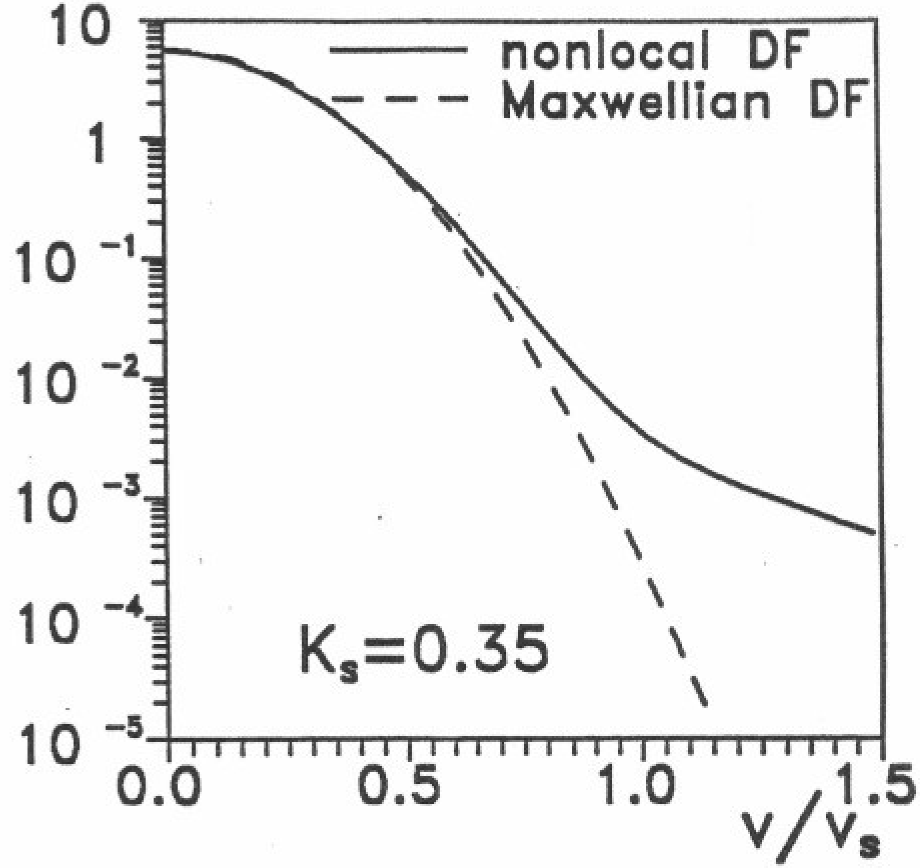


Fig.1 The comparison of the boundary distribution functions, corresponding to the nonlocal boundary conditions with the Maxwellian one

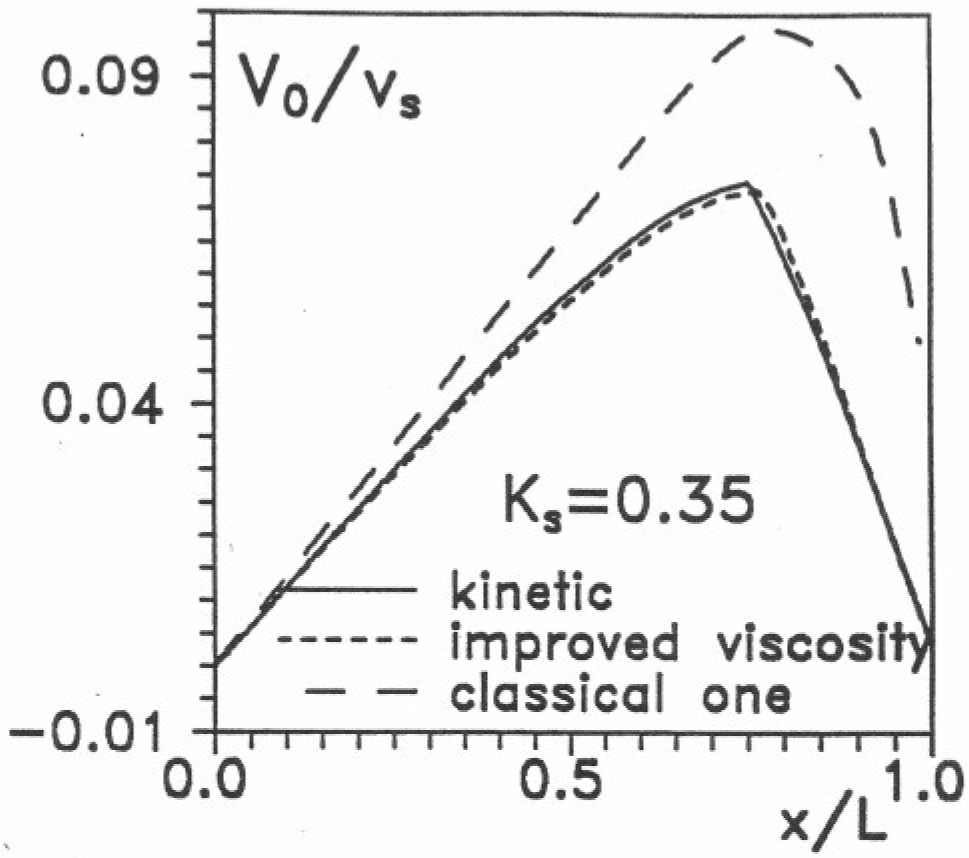


Fig.2 The velocity profiles corresponding to the classical viscosity, the improved one and the result of kinetic treatment

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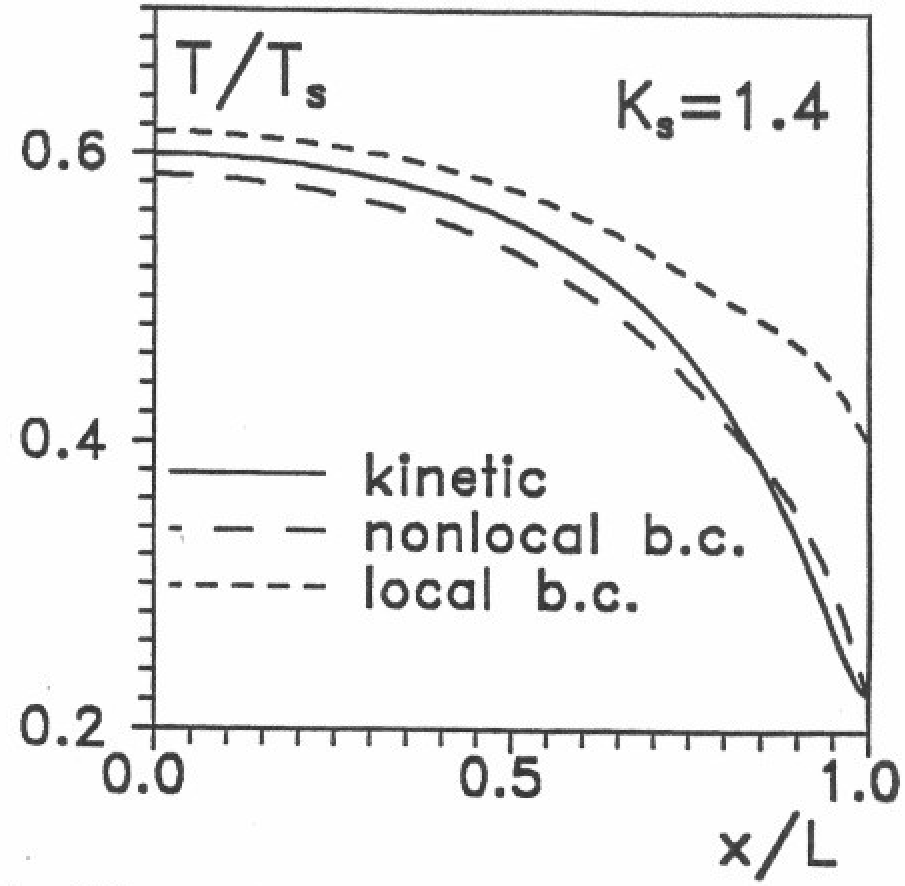

Fig.3 The temperature profiles for three cases: kinetic, local and nonlocal boundary conditions

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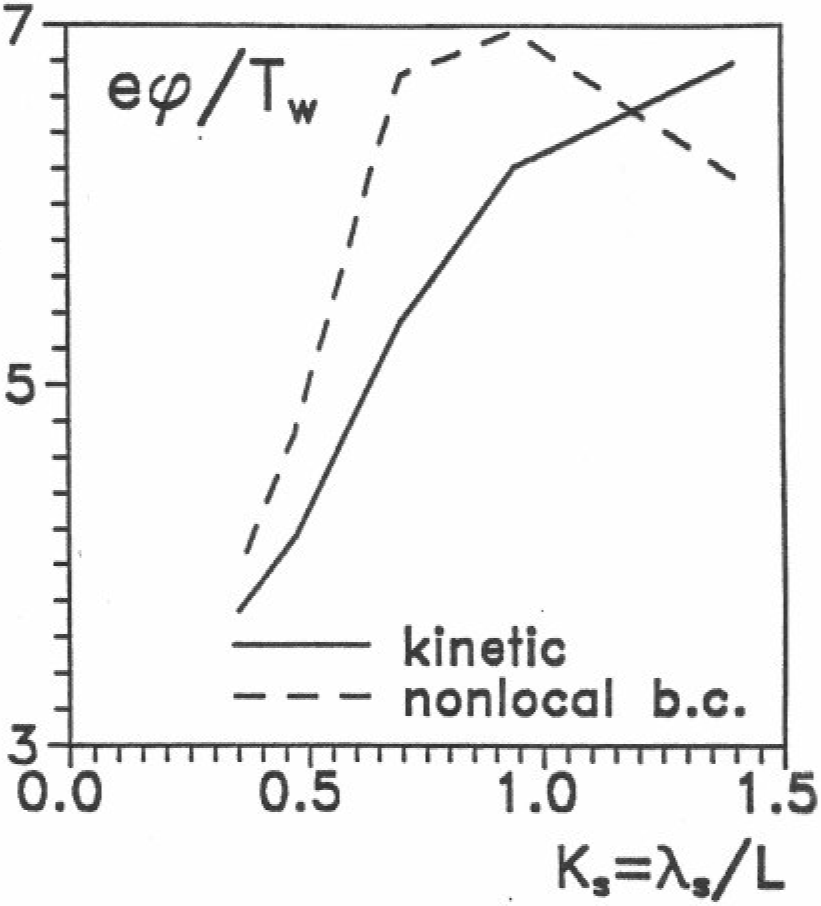

Fig.4 The sheath potential drop vs $K_s=\lambda_s/L$, where λ is electron mean free path and L is the length of magnetic field line

Conclusions.

1.The effective boundary conditions for the fluid set of equation at the plasma surfase interfase, which include the kinetic effects, are suggested.

2.The BGK approximation gives an opportunity to express the boundary fluxes as functionals of fluide profiles insted of local values.

3.The comparison with the kinetic solution shows that the propoused boundary conditions give such an accuracy of plasma parameters at the plate which is provided by the proximity of fluide profiles to the kinetic ones, i.e. the contribution of suprathermal particles in the transport coefficients is taken into account.

4.The conventional viscosity therm does not allow one to obtain the velocity profiles close to the kinetic ones. It has been shown that the usage of a viscous therm from the 13 - moment Grad approximation, taking account of a heat flux contribution, is more adequate to represent the regimes of moderate collisionality.

5.The flux - limited classical electron heat conduction does not bring to satisfactory resultes. The expression for a thermal heat flux in terms of higher moments of distribution function, could be recommeded for the fluid codes.

$$\begin{Bmatrix} j \\ \Pi \\ q \end{Bmatrix} = \int G(\nabla n, T, V)\, dw$$