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Introduction

Accurate modelling of cross-field turbulent transport in tokamak's edge plasma remains a challenge, many key experimental features such as edge transport barriers formation being still hard to simulate, especially for ITER size tokamaks. Being able to predict the SOL width or the power load imbalance between inner and outer divertor legs even for today's JET size tokamaks is still an open issue. First principle modelling of edge plasma turbulence is thus today a very active topic in the fusion community.

The edge plasma code SOLEDGE3X [H. Bufferand et al., Nucl. Fusion 61 (2021), 116052] aims at simulating plasma transport and plasma turbulence in the edge plasma based on a fluid description. In this poster, we present first SOLEDGE3X simulation results of the so-called TCV-X21 case [D.S. Oliveira et al., Nucl. Fusion 62 (2022), 096001], a series of diverted ohmic L-mode discharges on TCV designed as a dataset for edge turbulence codes validation. The simulation

Simulation setting

First attempt for full-scale TCV simulation with neutrals.

Simulation parameters:	Power	n _{sep}	\boldsymbol{B}_{t}	I _p	
	120 <i>kW</i>	$7 \cdot 10^{18} m^{-3}$	0.95 T	165 <i>kA</i>	

- Recycling coefficient set to 90% (quite low to speedup convergence given $\tau \sim \frac{1}{1-R}$)
- Fluid neutrals model based on [Horsten et al., Nucl. Fusion 57 (2017)]
- Plasma density set at separatrix by feedback on gas puff (localized at the outboard mid-plane)

Grid resolution: $N_{\psi} \sim 200$, $N_{\theta} \sim 1400$, $N_{\varphi} \sim 64$ [quarter torus]

CPU time: 800kCPUh on 3072 CPUs, not yet (at all) at quasi steady state.

includes plasma recycling and impact of neutrals on edge plasma turbulence.

The SOLEDGE3X code

SOLEDGE3X solves Braginskii/Zhdanov equations for a multi-species plasma in 2D or 3D geometry. fSOLEDGE3X is coupled to several neutral models : fluid neutrals of kinetic neutrals via coupling with EIRENE.

Recall on the model (simplified):

- Mass balance: $\partial_t n + \vec{\nabla} \cdot (n\vec{v}) = S_n$
- Parallel momentum balance $\partial_t(mnv_{\parallel}) + \vec{\nabla} \cdot (mnv_{\parallel}\vec{v}) = -\nabla_{\parallel}p + ZneE_{\parallel} + \vec{b} \cdot (\vec{\nabla} \cdot \overline{\Pi}) + R_{\parallel} + S_v$
- Perpendicular momentum balance (drifts zeroth order) : $\vec{v}_{\perp} = \frac{\vec{E} \times \vec{B}}{B^2} + \frac{\vec{B} \times \vec{\nabla} p}{qnB^2}$
- Energy balance: $\partial_t \mathcal{E} + \vec{\nabla} \cdot \left(\mathcal{E}\vec{v} + pv_{\parallel}\vec{b} + \bar{\vec{\Pi}} \cdot \vec{v} + \vec{q}\right) = (ZneE_{\parallel} + R_{\parallel})v_{\parallel} + S_{\mathcal{E}}$
- Current balance (vorticity equation): $\vec{\nabla} \cdot (\vec{j}_{pola} + \vec{j}^* + j_{\parallel}\vec{b}) = 0$

Ongoing implementation of electromagnetic effects (see R. Düll poster)





Turbulence in high recycling plasma



Numerical Aspects

The code is based on a 2D/3D finite volumes numerical scheme. One uses structured grid aligned on magnetic flux surfaces + domain decomposition to treat X-points. A mask function χ is used to define the wall location. Boundary conditions are imposed at the interface $\chi=1 | \chi=0$.

The parallelization is hybrid MPI/OpenMP + ongoing porting to GPU architectures. More details on www.soledge3x.com.



Fig 1. SOLEDGE3X mesh

Example of mesh for a WEST case (double X-point) showing domain decomposition and wall mask function

The TCV-X21 case

In order to benchmark European turbulence codes (at that time GBS, GRILLIX and TOKAM3X), a dedicated set of discharged where performed on TCV. The magnetic field was chosen quite low to increases $\rho^* = \rho_L/a$ and be less demanding in term of grid resolution. The discharges were low power Ohmic L-mode plasmas.

Fig 5. Snapshot of toroidal fluctuations

From left to right: density, electron temperature, ion temperature and electric potential

Preliminary observation: Edge plasma turbulence characterized by temperature fluctuations in the confined region and density fluctuations in the Scrape-off layer. Properties of turbulence still to be investigated at quasi-steady-state based on statistics.



Fig 6. Spatio-temporal evolution of plasma at the outboard mid-plane

From left to right: density, density and electron temperature fluctuation level and electric potential

Avalanches clearly observed on electron temperature fluctuations. Zonal flows and staircases to be

Fig 2. TCV shot #51333 for X21 series Magnetic equilibrium and wall geometry



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investigated. Influence of the "core" boundary condition to be assessed since grid do no extend to the

magnetic axis. Confined plasma region still being fueled by the edge (reverse density profile)



Fig 7. Time averaged radial profiles at the outboard mid-plane

From left to right: density, temperatures, electric potential and levels of fluctuations

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