COREDIV modeling of the DEMO tokamak scenarios

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MOTIVATION
- A limited number of baseline DEMO design concepts with various degrees of extrapolation from today's known underlying physics and engineering bases is currently being explored.
- One of the most crucial and challenging issues of the fusion power plant is the development of reactor scenarios which satisfy simultaneously the requirement of sufficiently high power amplification with the needs for sustainable power exhaust.
- In DEMO reactor, the radiative exhaust of energy by sputtered and by externally seeded impurities is considered as possible way of spreading energy over large wall area.
- Radiating scenarios have been already successfully developed for present day tokamaks, like ASDEX and for JET ITER-like-Wall (ILW) configuration, however it has to be checked if similar approach is applicable for burning plasma, self-heated by graphite and with tungsten as the wall material.

TOOL
- Numerical tool (COREDIV code) to investigate integrated DEMO scenarios has been developed.
- Long experience in coupled core-edge modelling.

TARGET
- Understanding the reduction of divertor power load due to radiation of sputtered and externally seeded impurities.
- Understanding of the W production and transport.

Transport Model

Energy balance equation with transport modeled to reproduce q_e defined by ELMy H-mode scalings [12]:

\[ \frac{1}{2} \frac{\partial T_e}{\partial r} = \frac{1}{P_{\text{pol}} + P_{\text{lin}} + P_{\text{d}} - P_{\text{ramp}} - P_{\text{rad}} - Q} \]

Transport coefficients with prescribed profiles [8]:

Main ion densities:

\[ n_i = C_i 2^{s_F} (r/F) \]

Impurity ions:

\[ n_d = D_{d,r} (r/F)^{1/2} \]

Boundary conditions: \( n_i, n_z, T_e, T_i \) – from SOL model

P_{inp} = \text{calculated from core model}

SOL PLASMA

W plate and Ar seeding

Influence on the peaking factor on the plasma parameters for DEMO 1

Simulations results for DEMO1 for different radial diffusion in SOL:

- \( c = 0.5 \)
- \( P_{\text{aux}} = 50 \text{ MW}, \psi > 9.33 \times 10^9 \text{ m}^{-1} \)

Conclusions

- COREDIV has been successfully applied to simulate DEMO scenarios.
- The obtained global parameters using COREDIV are closed to proposed by PROCESS but depend strongly on seeded impurities concentration and velocity pinch.
- Increase of seeded impurity influx leads to the reduction of fusion power and Q-factor due to plasma dilution.
- Total radiation almost independent on \( G_{\text{puff}} \), dominated by core radiation (> 90%).
- SOL radiation remains small (< 10%).
- To achieve high recycling or semi-detached conditions in the divertor.

Restrictions on the seeding density level for the core and SOL

For a given input particle and energy fluxes and fixed separatrix density there is a limit on achievable seeding impurity influx due to edge density limit

Conclusions

- Good core performance with a good balance between high confinement and low radiation.
- Total radiation almost independent on \( G_{\text{puff}} \) dominated by core radiation (> 90%)
- Increase of seeded impurity influx leads to the reduction of fusion power and Q-factor due to plasma dilution.
- High recycling or semi-detached conditions in the divertor.

Basic features of the solution for the core part of the model follows from the 3D energy balance in the core.

Influence on the pinch velocity

With the increase of Ar influx:
- Increase of \( x_{\text{Pinch}} \) and corresponding decrease of \( Q \), factor due to dilution effect of argon and helium.
- Total plasma radiation depends very weakly on Ar influx.
- Majority of the radiation losses coming from the plasma core (> 90%).
- Significant W radiation (above 50%) in CORE.
- SOL radiation remains small (< 10%).

- To achieve high recycling or semi-detached conditions in the divertor.

Simulations results for DEMO1 for different levels of Ar seeding for \( C_v = 0.5 \)

- Increase of seeded impurity influx leads to the reduction of fusion power and Q-factor due to plasma dilution.
- High recycling or semi-detached conditions in the divertor.

Basic features of the solution for the core part of the model follows from the 3D energy balance in the core.

Simulations results for DEMO1 for different radial diffusion in SOL:

- \( c = 0.5 \)
- \( P_{\text{aux}} = 50 \text{ MW}, \psi > 9.33 \times 10^9 \text{ m}^{-1} \)

- Increase of the radial diffusion:
  - Decrease of \( Q \) and \( x_{\text{Pinch}} \)
  - Strong decrease of W concentration and W radiation in the CORE.

Only core model: \( C_v, C_{\text{imp}} > 0 \) increased impurity concentration leads to termination of the solution.

For a given input particle and energy fluxes and fixed separatrix density there is a limit on achievable seeding impurity influx due to edge density limit.