Integrated Transport Analysis Suite for LHD Plasmas

**TASK3D-α**

M. Yokoyama

for integrated transport code group, NSRP
with close collaboration with LHD Experiment group

Special thanks:
(NBI modules) M. Osakabe, S. Murakami (Kyoto U.)
(dynamic transport module) K. Ida, J. Lee
(application) K. Nagaoka, H. Takahashi, K. Ida et al.,
(International collaboration) N. Pablant, M. Zarnstorff
• “3D” blocks (modules for “3D” physics)
• Piling Up -> making shape (integration)
• bright colors (friendly and productive collaboration)
TASK3D development strategy

Systematic understandings
Accurate discussion

Model Validation

Given conditions
Transport models, Sources,

TASK3D-a
(Analysis of LHD experiment)

common modules

Experimental condition
Profiles, Sources,

TASK3D-p
(Predictive analysis) with Kyoto Univ.

• Extension of high-performance plasmas in LHD
• FFHR-d1 design,

http://www.nifs.ac.jp/fuseng/index.html
**TSMAP**, real-time coordinate mapping ($r_{\text{eff}}$)

C. Suzuki, PPCF 55(2013)014016

TSMAP LHD #106655

$B_r = -2.850T$, $R_{\text{ox}} = 3.600m$, $B_q = 100\%$, $\gamma = 1.254$

Exp. Date: 20110819, Cycle: 15
Registered: '08/19/2011 14:41

$a_{\text{ee}} = 0.637$ m
mphi$\text{edge} = -3.264$ Wb
Lasers: 1 (OFF) 3 (OFF) 5 (OFF) 7 (OFF)

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$t = 3.07s$

$T_e, n_e$ (real coordinates) $\rightarrow$ $T_e$ ($r_{\text{eff}}$), $n_e$ ($r_{\text{eff}}$) via vmec-db

Typically $< 3$ min (shot int.)
Release of the 1st Version of Experimental Analysis Suite

**TASK3D-a01**

(2012.9)

- Automated Analyses on Experimental Energy Balance
- Significant progress on
  - Detailed *time-series analyses* in an individual shot
  - Analyses in *many shots*


  - progress of international collaboration
Calculation procedure of TASK3D-a01

LHD Data interface
- Pressure/Current specified with TSMAP
  - **TSMAP**
    - Te(reff)
    - ne(reff)
- **CXSMAP**
  - Ti(reff)

3D equilibrium
- All the timings @ strong Thomson laser
  - **VMEC**
    - wout (VMEC)
      - geometry
    - Boozer
      - newboz.dat

Heating (NBI)
- X each port-through power
  - **fit3d**
    - conv_fit3d
      - nb*pwr_temporal

Energy and Momentum Balance
- **dytrans6**
- **dytrans7**
  - **dytrans**
    - **TR_snap**
      - tsmap
        - cxsmap6, ermap6
        - cxsmap7, ermap7

Module
- **fit3d_1MW**
  - #1-#5, per 1MW
    - Multiply with each port-through power when used
- **fit3d_sd**
  - Slowing down accounted on energy and momentum

“eg” file (Kaiseki Data Server)
• **Gateway established**: `tsmap-task3d.lhd.nifs.ac.jp`
  ✓ open to collaborators
  ✓ no need to download the suite nor set-up the environment in your own computer

• **Standard usage**:
  ✓ simply “**go, #shot**”
  ✓ not depend on who to run the suite

• **Output**: `eg` file format (on **LHD Data Server**)
  ✓ accessible from collaborators
  ✓ validity check can be enhanced with a lot of “eyes and senses”

• **Flexible structure**
  ✓ easy update of modules, improvement
  ✓ impact of module replacement can be easily checked
Computational time of **TASK3D-a01**

- \( t = 3.24 \text{s} \sim 5.44 \text{s} \)
- 23 timing selected
- 1 timing \( \sim 10-15 \text{ min.} \) (mostly fit3d module)

\[ B = -2.750 \text{T}, \quad I_{\text{ud}} : \]

\[ \begin{array}{c}
\text{LHD} 109696 \\
gas : \text{Ar H}
\end{array} \]
Usefulness of **TASK3D-a01**

Number of analysis-cases can be significantly enhanced → Systematic understandings, accurate discussion

(ex.) when does the confinement improvement occur

![Graph showing data points and time intervals]  
- R = 4.156 m  
- t = 2.20 s  
- r/a = 0.63  
- ITB foot  
- t = 2.35 s  
- t = 2.13 s  
- t = 2.06 s  
- t = 2.00 s

### Graphical Data

- **Wp max** = 1200, **t** = 2.081 s
- **<\beta_{diss}>** = 1.01%
- **I** = 1.860 m
- **R** = 3669 mm
- **f** = 1.870 s

### Analysis Cases
- K.Ida et al., ISHW, PPCF
- H.Takahashi et al., IAEA-FEC
- A.Dinklage et al., IAEA-FEC
- K.Nagaoka et al., APS etc.....
Towards **systematic understanding** of energy confinement

- $\chi_e$, CERC, Ida PRL2003
- $\chi_i$, high-Ti, K. Nagaoka NF2011
- $\chi_e$, ECH, H. Yamada, PFR2008
- $Q_e$, $Q_i$, Medium-density Te~Ti ~ a few keV, A. Dinklage, NF 2013 (CWGM outcome)

**Analysis performed Topics-basis so far;**

Comprehensive understanding through **TASK3D-a**

→ Increased predictability towards reactor-relevant regime
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Summary

- **TASK3D** has been programmatically developed as “extension” of TASK to LHD Plasmas

- Analysis Suite, **TASK3D-a01**, has been released to conduct automated energy balance analyses of NBI-heated LHD plasmas

- There have been already a number of contributions to LHD papers by providing “nucleus” results

- International collaboration with TASK3D has also been initiated (eg., N.Pablant, oral talk in ISHW-RFP WS)
Extension of TASK3D-a → a02, a03, ...

Neoclassical transport

(2013) Neoclassical Energy/Particle Flux

Edge Physics

- Heating
  - ECH (LHD Gauss)
  - ICH (TASK/WM)

GNET-TD

AURORA (neutrals)

EMC3/EIRENE (database?)

Any codes utilizing "wout"

n_c(reff) Zeff

LHD Data interface

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CXSMAP
  - Ti(reff)

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All the timings @strong Thomson laser

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geometry

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X each port-through power

fit3d

conv_fit3d
dltrans6 dltrans7
dytrans

Energy and Momentum Balance

dytrans6 dytrans7

dytrans

TR_snap

tmap

cxmap6, ermap6

cxmap7, ermap7

Neoclassical transport
<table>
<thead>
<tr>
<th>Function</th>
<th>Code</th>
<th>Functions, Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>3D Equilibrium</td>
<td>VMEC</td>
<td>It calculates MHD equilibrium (fixed boundary). The VMEC equilibrium database for TSMAP has been prepared with VMEC2000_8.0. The equilibrium solution used for each time slice is re-calculated by utilizing parameters of so-called “best-fit” TSMAP.</td>
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<tr>
<td></td>
<td>BOOZER</td>
<td>It performs the mapping from VMEC coordinated to Boozer coordinates.</td>
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</table>
| Heating              | fit3d | It was developed (“reduced” version of GNET) to evaluate radial profiles of NBI absorbed power, beam pressure, beam source and induced momentum. The calculation consists of three parts:  
  • HFREYA: calculations of the birth profile (from the generation of the beam particles in the beam source to ionization in the plasma)  
  • MCNBI: birth-ions are followed (shorter than the energy slowing-down time, but longer than the orbit effects such as prompt loss can be reflected)  
  • Steady-state solution of Fokker-Plank equation is obtained analytically without orbit effects taken into account |
|                      | Conv_fit3d| It has been developed to evaluate the NBI absorbed power and induced momentum by taking the beam slowing down (SD) effect into account, based on fit3d (SS) results.                                                  |
| Energy balance       | TRsnap| It has been modified based on TASK/TR to evaluate steady-state energy balance. NB.) currently (in task3d-a01),  
  • Pin,e is evaluated just for NBI. ECH and ICH have not been available. Other losses (=negative contribution) like radiation loss have not been included.  
  • energy-transfer considered.                                                                                     |
| Energy and Momentum balance | dytrans | It evaluates “dynamic transport”, in which energy flows due to the temporal variation of plasma profiles are also taken into account.                                                                                     |