**Report on 2014 WPCD deliverable WP14-D05: benchmarking of EC codes on identified test cases**

**Lorenzo Figini and the WPCD-HCD team**

This report summarizes the advances obtained in 2014 for the benchmarking activity performed among the Electron Cyclotron (EC) codes present in the WPCD framework. Purpose of this activity is to verify all the EC codes involved in WPCD, which are used to compute electron Heating and Current Drive (H&CD) in the HCD workflow, before their exploitation in the European Transport Solver ETS.

## Involved codes

The EC ray- or beam-tracing codes presently involved are the following:

* C3PO/LUKE (contact person: Y. Peysson/J. Decker)
* GRAY (contact person: D. Farina/L. Figini)
* TORAY-FOM (contact person: E. Westerhof)
* TORBEAM (contact person: E. Poli)
* TRAVIS (contact person: N. Marushchenko)

All the codes have a corresponding actor to run them in a Kepler environment, and they all use the same set of input/output CPOs: coreprof, equilibrium and antennas as input, waves as output.

## Update of data structure to 4.10b

At the beginning of 2014 the WPCD data structure has been updated to the 4.10b version, which, as far as EC codes are concerned, involved significant changes mainly in the distribution CPOs used by Fokker-Planck codes like LUKE and RELAX. Still, all the codes required to be upgraded, recompiled, and tested with the new version of the UAL.

## Extended set of test cases

A few variants have been created in 2013 of the original ITER baseline H-mode scenario (user filo, machine test, shot 2, run 501) used for the benchmark performed in 2012:

* A set with low EC power (1 W instead of 1 MW) and one out of three EC beams powered at each time slice, to verify any quasi-linear regime by comparing the results obtained by the LUKE code with the other (linear) codes (user filo, machine test, shot 2, runs 551, 601)
* A second set of cases with gradually decreasing edge density, to observe how the codes handle the finite step found at the edge of the density profile (user filo, machine test, shot 2, runs 701, 801)

Further details on these ITER test cases can be found at the following webpages:

<http://portal.efda-itm.eu/twiki/bin/view/Main/IMP5_ValidationVerification_EC>

<http://portal.efda-itm.eu/twiki/bin/view/Main/CodeCamp2013_Lisbon_Figini_Lorenzo>

After a few bugs have been found and fixed in the computation of refraction at the plasma edge and in the evaluation of the absorption coefficient for propagation at large toroidal angles (i.e. small angle between the wave vector and the magnetic field), the results issued by the codes were all solidly consistent, as shown at the links above.

The absence any relevant quasi-linear effect in current drive efficiency for the regime of the test case has been confirmed in 2014 with new runs for the C3PO/LUKE code:

|  |  |  |
| --- | --- | --- |
|  | **P = 1 MW** | **P = 1 W** |
| **Launcher** | **Icd/P (kA/MW)** | **Icd/P (kA/MW)** |
| **EL25** | 40.322 | 40.245 |
| **EL40** | 18.088 | 18.079 |
| **UL** | 7.1119 | 7.0616 |

New test cases have been created in 2014, which represent a set of scenarios covering a wide range of machine sizes and very different plasma parameters (Asdex-U, ITER, DEMO), in order to test the codes under different physics regimes:

* user filo, machine aug, shot 30263, runs 1-4
* user filo, machine demo1, shot 666, run 12
* user filo, machine iter, shot 6, run 1

For this purpose, a few tools to fill coreprof and equilibrium data from ASCII files has been developed (e.g. <http://portal.efda-itm.eu/twiki/bin/view/Main/IMP5#How_do_generate_an_equilibrium_C>). The shots have been prepared for multiple versions of the data structure (4.09a, 4.10a, 4.10b) to allow code verification when upgrading from one version to the next.

A database of EC antennas configurations has also been compiled, to use in the HCD workflow as well as in verification/benchmarking workflows: <http://www.efda-itm.eu/ITM/html/imp5_ECAntennaDatabase.html>.

The new test cases allow a more detailed verification of the codes, including sign consistency in reading the input data and in writing the output CPOs, and both O- and X-mode absorption. The AUG shot has variants for all the sign combinations of toroidal magnetic field, plasma current and toroidal injection angle ,

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Run** | **time (s)** | **Sign(Bphi)** | **Sign(Ipla)** | **Sign()** |
| **1** | 0 | - | + | + |
|  | 1 | - | + | - |
| **2** | 0 | + | + | + |
|  | 1 | + | + | - |
| **3** | 0 | - | - | + |
|  | 1 | - | - | - |
| **4** | 0 | + | - | + |
|  | 1 | + | - | - |

while the ITER shot 6 represents a half field scenario where X-mode injection is necessary for optimal absorption at the second harmonic resonance.

The codes GRAY and TRAVIS have been successfully verified on the 4.10b version of the AUG case variants, by executing the HCD workflow with their respective Kepler actor, apart from minor differences found in the plasma volume/cross section computation. The results are stored in user filo, machine aug, shot 30263, runs 1101-1104 (GRAY) and runs 2104-2104 (TRAVIS). For the other codes, the testing of the 4.10b version is still ongoing.

## Kepler test workflow standardization

Some work has been done to make the verification workflow as reproducible as possible, exploiting some of the upgrades done to the HCD workflow:

* an ID flag is used to tag the output waves CPO, with IDs unique to each code.
* the production and release of the Kepler actors has been automated, forcing to use an unmodified copy of the repository for the codes under SVN control
* when final, the resulting data are set as read-only to avoid unintentional modifications

The final verification of the codes is performed using the HCD workflow itself as test bed. A detailed documentation of the content of each shot and run is under production, and the final results will be copied in the public database.