Combined DINA-CH and CRONOS Simulations of ITER

S.H. Kim, J-F. Artaud[2], V. Basiuk[2], R.R. Khayrutdinov[3], V. Dokuka[3], J.B. Lister, V.E. Lukash[4]

Centre de Recherches en Physique des Plasmas,
Association EURATOM-Confédération Suisse, EPFL, 1015 Lausanne, Switzerland
[2]CEA-Cadarache, France
[3]TRINITI, Moscow Region, Russia
[4]RRC Kurchatov, Moscow, Russia

1. Introduction

Simulating the Free Boundary evolution of an ITER plasma requires a Free Boundary evolution code cooperating with a PF-coil current controller model and an advanced core transport model coupled with auxiliary heating and current drive modules. For this, DINA-CH [1] and CRONOS [2] codes have been combined on the SIMULINK environment in MATLAB. Before this effort to combine two independent codes, the transport modelling in CRONOS had not been linked with a Free Boundary evolution code, but only functioned with a prescribed evolving boundary code. On the other hand, the DINA-CH simulations of ITER previously used relatively simple modelling of core transport and all the effort was dedicated to modelling specifically Free Boundary issues, mainly plasma equilibrium control and disruptions. CRONOS is an integrated modelling code for the simulations of tokamak plasma. It consists of four main parts, Fixed Boundary equilibrium, heating and current drive, transport coefficient model and transport calculation. DINA-CH is a SIMULINK model equipped with the DINA code [3] for the calculation of Free Boundary equilibria and the evolution in response to PF-coil current variations. In the model, it cooperates with a PF-coil current controller which controls the plasma shape and position by using gap measurements between

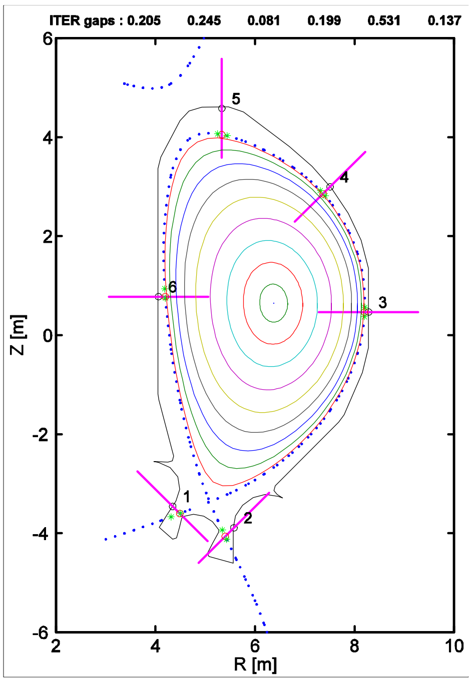

Figure 1. ITER H-mode simulation, 6 gaps between plasma and vacuum

ITER plasma and vacuum vessel as shown in Figure 1. These two tools are now combined to develop an integrated platform for ITER simulation. The intention is to provide a tool with the flexibility of operating in both previous conditions as well as combined. The first steps in this direction were recently completed to demonstrate the feasibility. This paper will present and explain the approaches taken to combine these two models and will illustrate the graphical programming environment in which this work is being performed and the first combined ITER simulation result.

This work is a forerunner of the new EU Integrated Tokamak Modelling Task Force and provides useful insight into the problems which will be encountered during this longer term project.

2. Coupling method

The PF-coil current controller in DINA-CH model has been updated for this coupling work. The narrow operation window depending on plasma current was removed by re-normalization of the controller inputs. Now, it works with an arbitrary plasma current in steady state and allows slow plasma current variation during simulations providing the capacity of ramp-up and ramp-down phases. DINA-CH outputs for CRONOS inputs are mainly the plasma boundary from a Free Boundary calculation and plasma parameters and profiles. Up to now, CRONOS has to recalculate its equilibrium using the inputs to provide its geometric information. However, the best way to get rid of discrepancies between two equilibria seems to be to directly use the equilibrium information from DINA-CH when all required inputs are provided. CRONOS uses the recalculated equilibrium information and heating and current sources and computes transport with transport coefficients provided by various transport models. The current diffusion during the CRONOS transport calculation is turned off since DINA-CH provides it in a more accurate way based on plasma movement

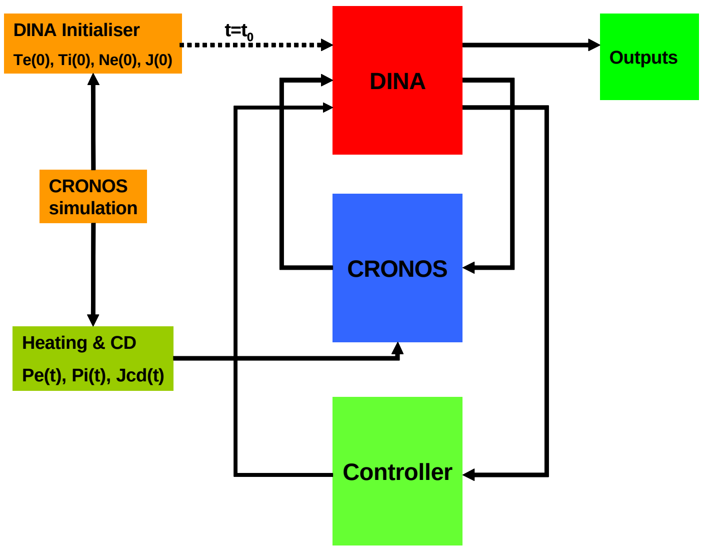

Figure 2. Diagram of the combined DINA-CH and CRONOS

and PF-coil current response. After CRONOS calculation, its outputs go back into DINA-CH. The main inputs are the plasma density and temperature profiles and the current sources. In this first version of a coupled simulation, the particle and heat transport are computed by CRONOS, whereas the current diffusion and plasma evolution are provided by DINA-CH and the PF-coil current controller.

The difficulties found and studied during this first coupling work should also be mentioned for the preparation of the next steps planned to generate a more consistent simulation. The main difficulty was the requirement by CRONOS to reconstruct the DINA-CH equilibrium. Small differences in the two equilibria created problems due to this exchange being necessary for each simulation step. This discrepancy causes unphysical results, especially when time dependent variables are calculated and they are used for the calculation of transport coefficients. Therefore, it is essential to have only the one equilibrium which can be used for both codes. Another finding during this work is that there is one time step delay of data exchange from DINA-CH to CRONOS. Both of them use previous time step results as their inputs. This problem seems to be related to the SIMULINK environment and is under study.

3. The first ITER simulation

ITER H-mode plasma with 15MA plasma current has been simulated in this work. For the simulation, an initial equilibrium is taken from an existing CRONOS simulation. After calculation by the DINA Initialiser which is specially made to provide initial equilibrium information for DINA-CH as well as initial PF-coil currents, the coupled DINA-CH and CRONOS model starts the simulation of the ITER plasma. In the initial phase of the simulation, there were some fluctuations in temperature profiles because the initial equilibrium is not perfect for both codes. This fluctuation could be removed, if more frequent heating and current source calculations are used during the initial phase of the simulation. After this fluctuation, the plasma has been kept stable and the PF-coil controller has functioned well, maintaining the gaps between the plasma and vacuum vessel.

However, this simulation takes a very long time compared with DINA-CH only or CRONOS only simulations though some causes which cause slow calculation in CRONOS were detected and resolved. One of the reasons is again the discrepancy in the equilibria which result in a lot of calculations for convergence. It also use large amount of memory for a long simulation.

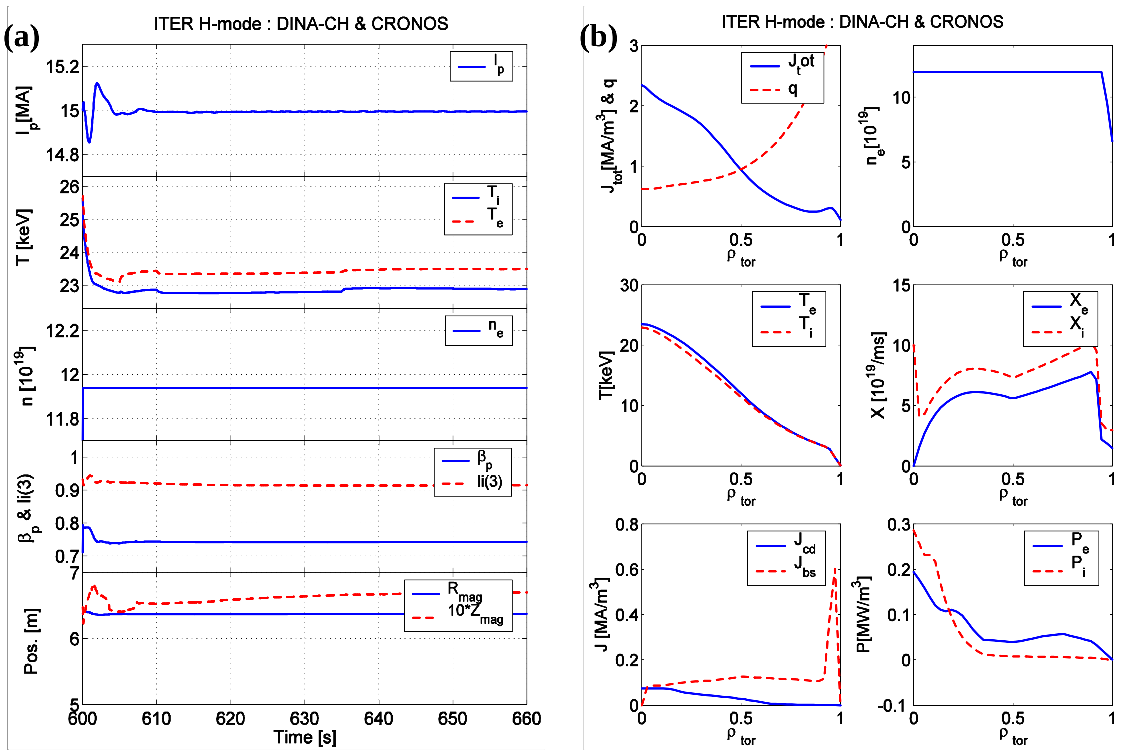

Figure 3. ITER H-mode simulation. (a) Time traces and (b) profiles at 660sec.

4. Conclusions and future work

The possibility of ITER simulation by using a combined simulation package has tested. As the first step of this work, ITER H-mode scenario was tested, since the simulation of the ITER Hybrid scenario still needs more work in each code as well as in the combined model. Two difficulties mentioned above and other hidden problems could make it to take long task to get a more complete simulation package. As an alternative for the full coupling of two codes, it is also possible to make the simulation package more compact by taking the necessary and strongest parts of the two codes and revising the overall strategy.

This work was partly supported by the Fonds National Suisse de la Recherche Scientifique.

References

[1] J-Y. Favez *et al.*, *Plasma Phys. Control. Fusion* **44** (2002) 171-193

[2] V. Basiuk *et al.*, *Nucl. Fusion* **43** (2003) 822-830

[3] R.R. Khayrutdinov *et al.*, *J. Comp. Phys.* **109** 193-201