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Integrated Tokamak Modeling Taskforce: The Integrated Modeling Project on Equilibrium and Linear MHD Stability.

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The aim of the EFDA Integrated Tokamak Modeling Taskforce (ITM) [http://www.efda-taskforce-itm.org/] is to 'co-ordinate the development of a coherent set of validated simulation tools for the purpose of benchmarking on existing tokamak experiments, with the ultimate aim of providing a comprehensive simulation package for ITER plasmas'. Within the ITM taskforce, 5 physics projects have been defined together with 2 technical projects. Their subjects are equilibrium and linear MHD Stability (IMP#1), non-linear MHD (IMP#2), transport (IMP#3), micro-stability and turbulence (IMP#4) and fast particles and heating (IMP#5). The two technical projects deal with the code platform (CPP) and the data coordination (DCP). The project on the equilibrium and linear MHD stability (IMP#1) was the first physics project to get started. Its objective is to provide the ITM taskforce with a set of validated equilibrium reconstruction codes, high-resolution equilibrium and coordinate system mapping codes and linear MHD stability codes. The codes included in the project are the equilibrium reconstruction codes EFIT, EQUINOX, CEDRES and CLISTE, the high-resolution equilibrium codes CAXE, CHEASE and HELENA, the coordinate transformation package COTRANS, and the linear MHD stability codes KINX, MISHKA and CASTOR. The codes are complemented by an equilibrium toolbox (the JET FLUSH library).

Verification and Validation

The ITM taskforce puts an important emphasis on the verification and validation of the contributed codes. Verification, i.e. assessing the correctness of the numerical implementation of the model and the accuracy of obtained solutions, typically involves synthetic benchmark cases for which the answer is known. Validation, i.e. assessing the ability of a code to accurately model experiments requires the comparison of the code results to experimental observations. Within the IMP#1 project, the subject of the first validation exercise will be on the ideal MHD stability limits in discharges with an internal transport barrier ending in a disruption. This will validate (or not) the whole chain of codes in the IMP#1 project from equilibrium reconstruction including pressure and MSE measurements, the high-resolution equilibrium and the ideal MHD stability codes. One prerequisite for the verification and validation effort is that all codes involved use exactly the same data both for the tokamak geometry, the experimental data and for the data exchanged between codes.

Data Structures

To allow the simulation of discharges in many different machines, the definition of the machine geometry must be separated from the codes. A unique, and ultimately formally approved, machine description for a specific machine will become input to the codes in the simulation framework. The separation of machine geometry from the contributed codes is one of the tasks in the IMP#1 project. This is particularly relevant for equilibrium reconstruction codes which are traditionally closely linked to one specific experiment with the machine geometry often hard-wired in the code. As a result, different versions of, for example, the EFIT code exist, adapted to different experiments. With the separation of code and geometry it becomes possible to use the same unique code version on any machine for which a standardised machine description is available.

The simulation environment will, ultimately, consists of many interconnecting modules. Each code, either as a whole or separated into logical parts, will become a module in this system. To be able to exchange data between these modules, this data needs to be standardised. A software ‘databus’, defining the quantities to be exchanged, needs to be defined. With a unique definition of the interfaces to the different codes, the modules performing the same task can then easily be exchanged.

The DCP and IMP#1 projects have defined a set of data structures to describe the machine geometry of a generic tokamak, building on former CRPP work on the DINA-CH code [Lister]. This includes the position and geometry of the poloidal magnetic field coils, the vessel, limiters etc. Other data structures describe diagnostics like magnetic pick-up coils, MSE and polarimeter. The main data entity to be exchanged between the IMP#1 codes is an equilibrium. A specific data structure has been defined to describe an equilibrium in sufficient detail.

An important detail of the specification is that it is foreseen to exchange, read and write data the data at the level of whole data structuresm, as for example a complete equilibrium structure. An equilibrium entity includes all the equilibrium related quantities such as the global parameters (poloidal beta, internal inductance etc.), the 1d profiles and a 2d map of the poloidal flux. This also includes the data for the flux-surface coordinate systems required by the MHD stability codes. The use of the data-structures defined by the ITM will contribute to data consistency.

The data structures have been defined using the XML language which is a widely used (web) standard to describe and contain data. The data and its description have been separated in three levels. Level 1 is the abstraction layer, this layer contains no data but defines the objects using XML schemas in the form of trees. The XML schemas include the documentation of all the definitions. Level 2 contains the data related to the geometry of the machine. The level 2 data varies only with a change in the machine and does not contain any plasma related parameters. This data is stored in a XML file whose structural content is defined by the XML schemas. Level 3 contains the actual discharge related data, such as the coil currents, measurements, etc. This data is stored in the ITM MDSplus database. The definitions in the XML schemas are used to define the tree structure of the MDSplus database. XSLT (extensible stylesheet language transformations) files have been created to automatically create the documentation and to derive fortran95 datatype and matlab tree structure definitions and the fortran reading and writing data access routines. Using the ITM data access routines, the data can be handled at the level of the complete data structures. Any structure, like an equilibrium or the set of poloidal field coils, can be read or written using one generic routine. Ultimately, writing of data will only be allowed at the level of complete data structures to ensure the consistency of the data. The data structures and the tools are still in the early phase and are actively developed and evolved. At the moment the data structures are in sufficient detail for the practical application within the IMP-1 project but they will have to be extended for their application in the other ITM projects.

Codes

The IMP#1 project has stimulated the development of two new versions of EFIT, EFIT_ITM by W. Zwingmann and EFIT-2006 by L. Appel [Appel]. The EFIT_ITM code is an adaptation of the optimized EFIT described in [Zwingmann] to the ITM requirements of separation of code and geometry, presently written in Matlab. The EFIT_ITM code has been successfully applied to reconstruction of Tore Supra, JET and ITER equilibria. The results from EFIT_ITM are in good agreement with the standard EFIT. One of the tasks within the project is to combine the two efforts into one EFIT version for the ITM taskforce.

The figure illustrates the results of a first example of the use definition of the machine geometry and the ITM data structures using the DINA-CH code and EFIT_ITM. The ITER equilibrium data, generated by the DINA-CH code, is correctly reconstructed by the EFIT_ITM code.

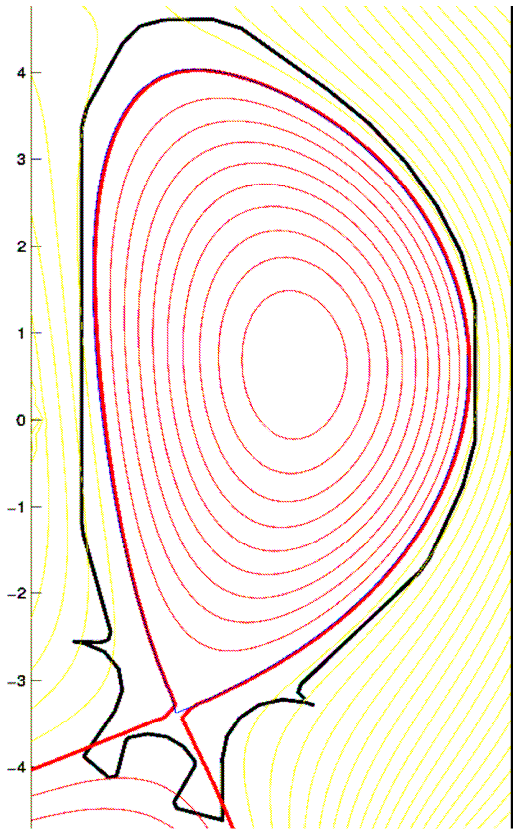
The high-resolution equilibrium codes CHEASE and HELENA have been adapted to read and write the standardised equilibrium data structures from and to the database. The output is an equilibrium data structure at high resolution including a straight field line flux surface coordinate system for the MHD stability codes.

The ideal MHD codes KINX and MISHKA-1 have similarly been adapted to accept an equilibrium data structure with coordinate system as input from the MDSplus database. The standard benchmark using the analytic Soloviev equilibrium has been passed by both codes. Over the years, several versions of the CASTOR and MISHKA MHD stability codes with different physics models and numerical solvers have been developed independently in the associations. As one task in the IMP#1 project, the MISHKA-1, MISHKA-D and CASTOR_FLOW have now been combined into one single code containing the different physics models and the numerical eigenvalue solvers [Strumberger, Konz].

The EFDA ITER reference scenarios, specified in the EQDSK format, have been written the ITM database in the standardised ITM format for the equilibrium. As a first application/benchmark of the IMP#1 codes, the MHD stability of one of the ITER scenarios has been analysed.

Conclusion

The definition of a standard for the description of the machine geometry of a generic tokamak and the definition of the physics objects to be exchanged between codes within the ITM project on the equilibrium and MHD stability has allowed the separation of machine geometry from the codes and facilitates the exchange of data between codes. This is an important first step towards the ITM tokamak simulation environment. The validation of the complete chain of codes within the IMP#1 project from equilibrium reconstruction to MHD stability is being applied to disruptions in discharges with strong internal transport barriers.



EFIT_ITM reconstruction (flux surfaces in red) of an ITER equilibrium generated with the DINA-CH code (boundary in blue) using the ITER machine geometry described in the ITM data structures.

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