IFERC Newsletter

IFERC-N-2012-18~21 (*No. 7, 31 October, 2012*)

International Fusion Energy Research Centre, Rokkasho, Aomori 039-3212, Japan

CSC Activity

Lighthouse project: Comprehensive global gyrokinetic simulations for ASDEX-Upgrade and JET discharges

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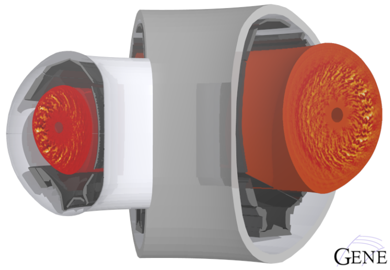
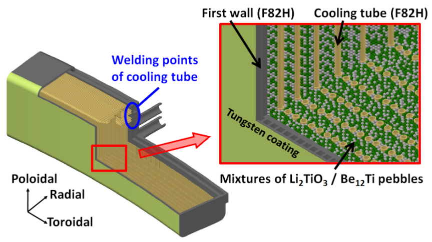


DEMO Design Activity

Mixed breeder concept for DEMO blanket



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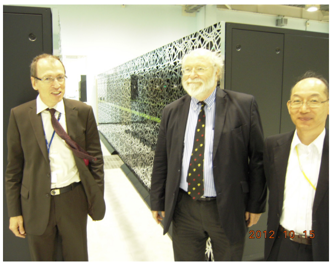

Meetings

11th Meeting of the IFERC Project Committee

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International Fusion Energy Research Centre, Rokkasho, Aomori 039-3212, Japan

CSC Activity

Lighthouse project: Comprehensive global gyrokinetic simulations for ASDEX-Upgrade and JET discharges

Besides issues related to technology and material science, the way to efficient fusion power plants is still hampered by physics problems like a more thorough understanding of the turbulence-induced heat and particle transport from the core of the plasma to its edge. Here, continued experimental as well as theoretical efforts will be necessary in order to gain insight into possible turbulence reduction mechanisms which are supposed to help get the energy confinement times as large as required for a self-sustained burning plasma. The theoretical framework of choice for plasma turbulence investigations is gyrokinetic theory. The latter is a scale-reduced kinetic description in a five-dimensional position-velocity space. Here, a set of gyrokinetic Vlasov equations (one for each relevant particle species) is solved self-consistently with a rewritten version of the Maxwell equations. One example of an efficient and comprehensive implementation of these gyrokinetic equations is the GENE code (see http://gene.rzg.mpg.de). Among other things, GENE provides the option to choose between two modes of operation – a flux-tube (radially local) version considering just a small domain about a given field line and a full-torus (radially global) version covering most of the device. The latter description is more appropriate in cases where profile variations over radial turbulent correlation lengths cannot be considered small or where meso-scale effects yield transport scalings different from gyro-Bohm. Most dedicated studies in this context had been based on simplified problems (e.g., adiabatic electrons, circular flux surfaces, etc.) - partially due to code restrictions but also due to the significant computational effort being required. Here, the new resources offered by IFERC on the Helios supercomputer in combination with recent software extensions allow for a degree of realism hardly reached in the past. In the framework of the lighthouse project, these capabilities have been applied to the simulation of ASDEX-Upgrade and JET L-mode discharges involving realistic MHD equilibria, finite-β (electromagnetic) effects, collisions, and an interface to the experimental profile data in order to perform both global and local computations for these machines (see Fig. 1 for a visualization of the turbulence data for both machines).

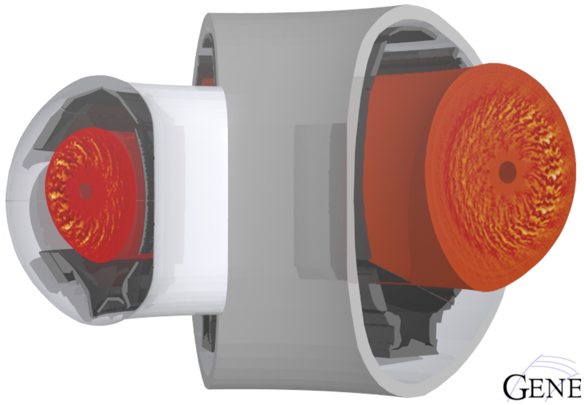

Fig. 1: Ion temperature fluctuations in global gyrokinetic simulations with the GENE code. Vessel parts of ASDEX-Upgrade (left) and JET (right) are shown as well.

The underlying questions are of prime importance for ab initio transport modelling of machines like ITER and DEMO: Is the existing collection of primarily local code results valid for the present medium to future large size fusion devices? Can gyro-Bohm scaling thus be taken as a basis for modelling efforts for ITER and beyond? The results gained in the present lighthouse project support this conjecture as local and global code transport levels agree reasonably well for the cases under investigations, see Fig. 2. However, further studies involving, e.g., H-mode discharges, transport barrier regimes, etc., are required for a more universal and meaningful conclusion. The computational resources provided by IFERC will certainly play an important role in this context.

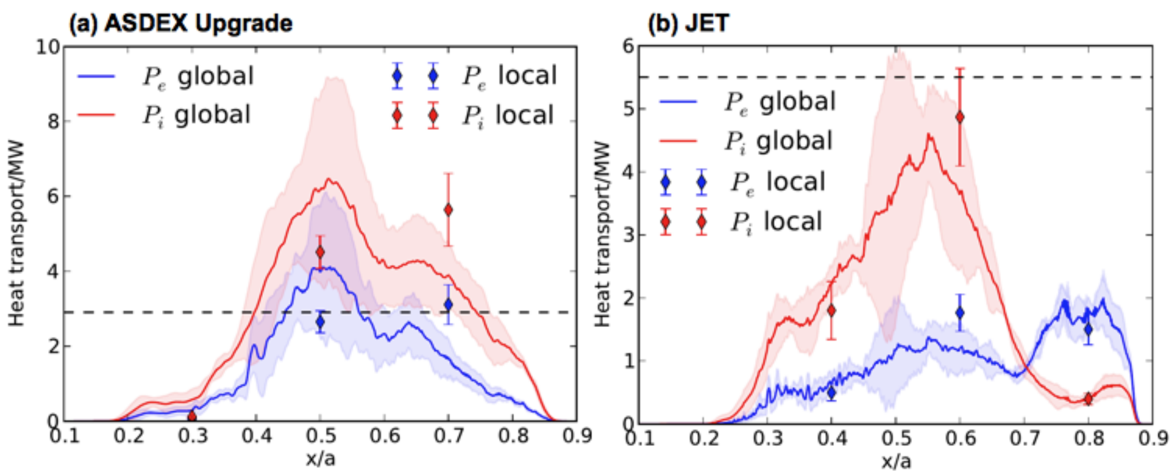

Fig. 2: Global and local gyrokinetic simulation results with the GENE code for two different discharges/machines. One finds a reasonable agreement with the actual experimental total power deposition (dashed line) and between the global (solid line with shaded regions indicating the error bars) and local code (points with error bars) heat fluxes. Note that the heating is applied around x/a~0.2-0.3 thus explaining the low transport before and around this position.

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DEMO Design Activity

Mixed breeder concept for DEMO blanket

Considering DEMO specific requirements, JA home team places emphasis on a blanket concept with durability under severe irradiation, facility of fabrication for mass production, and optimized operation temperature of blanket materials. A blanket concept is proposed which meets these requirements, and is characterized by minimized welding lines near the front, a simplified blanket interior consisting of cooling tubes and a mixed pebble bed composed of tritium breeder and neutron multiplier materials, and approximately the same outlet temperature of coolant for all blanket modules. In addition, overall Tritium Breeding Ratio (TBR) should be higher than 1.05 to ensure self-sufficient production of tritium to sustain operation and provide the initial tritium for next fusion reactor.

A simplification of the blanket structure is proposed for a mixed breeder blanket as shown in Fig. 1. In the mixed breeder concept, the blanket is filled with the mixture of Li_2TiO_3 pebbles for the tritium breeding and $Be_{12}Ti$ pebbles for the neutron multiplication. When $Be_{12}Ti$ is used as the multiplier, the partition between the multiplier and the lithium ceramic can be removed, because $Be_{12}Ti$ is chemically stable. A remarkable feature of the proposed blanket is the simple structure in that structural materials in the blanket are cooling tubes and support for them only. Here, the structure material is reduced-activation martensitic steel (F82H). Moreover, this design has a possibility of increasing TBR due to a relative increase the fraction of breeding materials by decreasing structural materials.

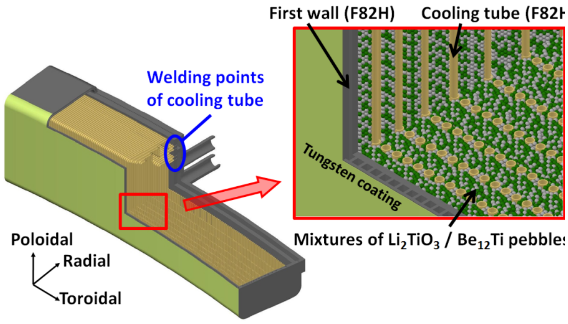


Fig. 1: Interior design of the mixed breeder blanket.

In the case of a DEMO reactor with a fusion output of 3 GW, the Neutron Wall Load (NWL) varies between 1.6 and 3.6 MW/m^2 in the poloidal direction as shown in Fig. 2. If we supply the same quantity of water to the blanket modules with different NWL, the outlet temperature from every module is different, which is inefficient in terms of heat utilization. In order to resolve the problem, the number of cooling tubes or the spacing between the neighboring cooling tubes should be determined to adjust the outlet temperature from each blanket module. Here, the sizes and arrangement of the cooling tubes for the proposed blanket are changed in accordance with the NWL. In the 1-D calculations of the neutronic and thermal analysis for the blanket, the ANIHEAT code with the nuclear library FENDL-2.0 is used. The calculation conditions are as follows: ^{6}Li enrichment of 90%,

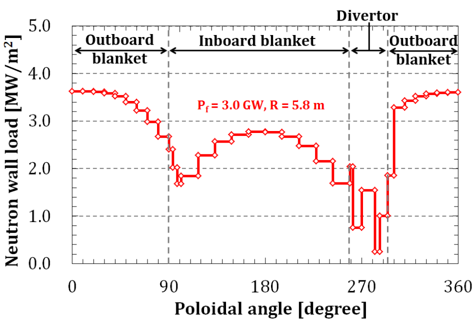


Fig. 2: Poloidal distribution of neutron wall load for fusion DEMO reactor

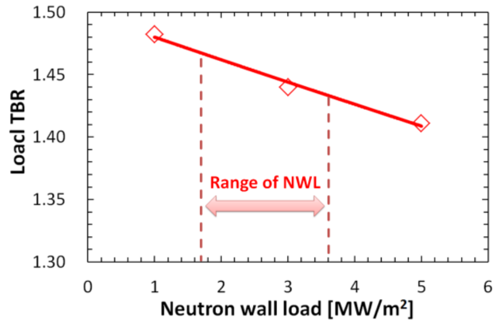


Fig. 3: Dependence of local TBR on neutron wall load

packing fractions of 65% and 80 %, and blanket thickness of 0.6 m. Moreover, the upper coolant velocity is limited to 5 m/s and the outlet temperature is less than 330 ºC. The heat load from plasma such as impurity radiation is assumed to be 0.5 MW/m^2 on all blanket surfaces. The neutronics is calculated on local TBR and nuclear heating in the blanket. The thickness of each layer is determined to satisfy the operation temperature of materials (Li_2TiO_3 & $Be_{12}Ti$ ≦ 900 ℃ and F82H ≦ 550 ℃). As a result, Fig. 3 shows the dependence of local TBR on NWL. It is found that this design also contributes to increasing TBR due to a relative increase of the breeding material fraction for blanket modules with low NWL.

A neutronics analysis ensures the blanket concept meets a self-sufficient supply of tritium when the blanket thickness is about 0.6 m, where the overall TBR is calculated by considering the poloidal distribution of NWL. The overall TBR is attained to be 1.09 and 1.15, where the packing factors are 65 % and 80 %, respectively. Neutronics calculations indicate that the blanket satisfies a self-sufficient production of tritium with a factor of 65 %. It is found that the proposed blanket with simplified mechanical design has margins in terms of TBR. Therefore, a mixed breeder blanket is found to be the preferred option for DEMO reactor.

IFERC-N-2012-20 (*No.7, 31 October, 2012*)

Visit

Professor Roger Cashmore (UKAEA) visits Rokkasho BA site

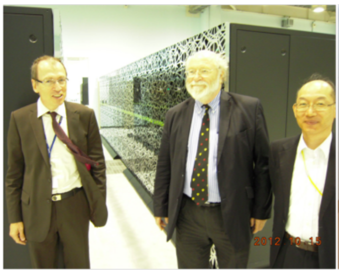
On 15 October 2012, Professor Roger Cashmore, Chairman of United Kingdom Atomic Energy Authority, visited the Rokkasho BA site to see the progress of IFERC and IFMIF projects implemented in Rokkasho.

In his agenda, Professor Roger Cashmore was firstly given a general presentation/discussion by Takeo Nishitani, Deputy Director of JAEA Fusion Research and Development Directorate, on the status and main topics in IFERC and IFMIF activities. Then, IFERC Project Team members, Jacques Noé, the CSC Leader, Kunihiko Okano, the DDA Leader and Kimio Hayashi in charge of DEMO R&D presented the progress of each sub-project.

Under the recent operation of DEMO R&D Building as a radioisotope (RI) handling facility and the CSC supercomputer, and the start of joint work between EU and Japan on DEMO design, IFERC project shifts recently from a preparatory phase to an actual research phase. The Light House Projects in the CSC were performed in order to show how magnetically confined fusion simulations could exploit a new research fields and frontier research. Many researchers in EU countries including UK as well as those in Japan are now using the supercomputer in various fusion research fields. After a number of engineering/ physics preparatory assessments, safety research activities on the DEMO design have been launched in collaboration between EU and Japan. The DEMO R&D facility at the Rokkasho BA site is a quite unique facility in Japan and also worldwide, where tritium, beta/gamma radioactive materials, and beryllium can simultaneously be used. EU/JA collaborations for utilizing the unique features of the R&D facility are ongoing and in preparation.

Professor Roger Cashmore toured the Rokkasho facilities, namely, the CSC & REC Building, the DEMO R&D Building and the IFMIF/EVEDA Accelerator Building, and expressed his gratitude for being shown the intensive activities at Rokkasho in the collaboration between EU and Japan.

We, the IFERC Project Team members, are really honored by Prof. Cashmore's visit to Rokkasho, and are very happy of his interest in our BA activities as well as in the facilities in Rokkasho.



IFERC-N-2012-21 (*No.7, 31 October, 2012*)

Meetings

11th Meeting of the IFERC Project Committee

The 11th Meeting of the IFERC Project Committee (PC-11) was held on 2-3 October 2012 at Rokkasho BA Site with 27 participants, including 6 PC members, the Project Leader, 7 experts from the Project Team and 13 experts from EU and JA Implementing Agencies (with remote participation from Barcelona, Garching, Saclay and Culham). In addition, Mr. Shuichi SAKAMOTO, Director of International Nuclear and Fusion Energy Affairs Division, Research and Development Bureau, MEXT, attended the meeting and gave an opening speech stressing the importance of the BA activities.

The PC took note of the actions after the last PC-10 and recent status of sub-projects including the CSC activity, the Safety Research of Fusion Plants, the Peer Review Final Report for DEMO R&D and the Preparatory Working Group of REC etc, and recommended for approval by the Steering Committee the Work Programme 2013, the Overall Plan of REC and the update of the Project Plan.

The next IFERC Project Committee meeting will be held in Kyoto on 21-22 March 2013, combined with a review of the CSC lighthouse and 1st cycle projects.