Application of high performance computing for fusion research

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The study of the alternative energy source is one of the absolutely imperative research topics in the world as our present energy sources such as fossil fuels are limited. This work is dedicated to the nuclear fusion physics research in close collaboration with existing experimental fusion devices and the ITER organization (www.iter.org) which is an huge international nuclear fusion R&D project. The goal of the ITER project is to demonstrate a clean and safe energy production by nuclear fusion which is the reaction that powers the sun. One of the ideas of the nuclear fusion on the earth is that the very high temperature ionized particles, forming a plasma can be controlled by a magnetic field, called magnetically confined plasma. This is essential, because no material can be sustained against such high temperature reached in a fusion reactor. Tokamak is a device which uses a powerful magnetic field to confine a hot plasma in the shape of a torus. It is a demanding task to achieve a sufficiently good confinement in a tokamak for a 'burning plasma' due to various kinds of plasma instabilities.

One of the critical unsolved problems is MHD (MagnetoHydroDynamics) instabilities in the fusion plasmas. The MHD instabilities at the plasma boundary damages the plasma facing component of the fusion reactor. One of techniques to control the MHD instabilities is injection of pellets (small deuterium ice bodies). The physics of the interaction between pellet ablation and MHD dynamics is very complex, and uncertainties still remain regarding the theoretical physics as well as the numerical modelling point of view. The simulation of the plasma physics, which includes wide range of spatio-temporal scales, especially, the non-linear interaction of plasma particles and magnetic fields requires significantly large computing resources within highly sophisticated numerical scheme. Numerical modelling of MHD instabilities and the control by pellet injection for existing fusion experiment machines has been carried out with the non-linear MHD code JOREK (www.jorek.eu) using the high performance computing via PRACE project. JOREK is one of the recognized codes in the fusion community as it allows to determine the consequences caused by the MHD instabilities in fusion plasmas. The numerical experiment of the pellet injection studies contributes the design and the optimization of the pellet injector and the injection conditions in the fusion devices.
In the PRACEdays21, our recently published work which shows good agreement in qualitative and quantitative comparison between JOREK simulation and experimental observation will be presented [S. Futatani et al 2020 Nucl. Fusion 60 026003].

In parallel to the numerical modellings of fusion plasmas in tokamaks which have been carried out in the previous PRACE projects, the simulations of stellarator which is alternative fusion device to tokamak, have been carried out. Stellarator exploits strangely-shaped magnets that is hard to build but potentially easier to operate, so it is considered as an alternative promising future fusion device. Non-linear MHD simulations of stellarator plasma have been carried out with Japanese-made simulation code, MIPS. In the PRACEdays21, the MHD simulation results of stellarator plasma obtained by MIPS code which has been published in these years will be presented [Shimpei Futatani and Yasuhiro Suzuki 2019 Plasma Phys. Control. Fusion 61 095014].