§13. Development and Improvement of SONIC Code for Divertor Study

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i) Introduction

A purpose of this research in this year is to examine the development element which extend the integrated divertor code SONIC[1] toward 3 dimensional modelling for full-scale analysis of divertor experiment of LHD. The divertor code system SONIC consists of the 2D fluid code (SOLDOR), the neutral Monte-Carlo code (NEUT2D), and the impurity Monte-Carlo code (IMPMC). Extending the IMPMC, we intend to develop a new 3D impurity modelling within 2 or 3 years and investigate the impurity generation mechanism and transport in LHD device by using this code.

The transport of plasma and impurity in the SOL region in tokamaks are usually treated in two dimensions. However, the magnetic field perturbation experiments have been carried out to reduce high heat load onto the divertor plates. In such cases, the transport in the SOL should be treated in three dimensions, as well as in LHD device. The planned simulation code for 3D impurity transport has a lot of similarities to Monte-Carlo schemes in the code EMC3[2] introduced at NIFS, where the fluid equations are solved by Monte-Carlo techniques in 3D real space.

ii) Concept of LEAP

It is of significance to incorporate effectively the 3D structure of magnetic field line in LHD equilibrium into the 2D impurity transport in advance. Because such code facilitates development of complex 3D code and comprehension of complicated impurity transport in three dimensions. Two-dimensional model concept which contains equivalently 3D transport properties in peripheral region of LHD is called “LHD Equivalent Axis-symmetric Plasma modelling”, for brevity, “LEAP”. In tokamaks the separatrix and the X-point are defined distinctly, while LHD has no clear separatrix and no clear X-point. Instead there exist ergodic layer where the connection length changes from 10 m to 1000 m (FIG. 1 SOL area). The modelling to change the connection length both spatially and temporally in this ergodic region is presented in order to incorporate 3D transport effects of impurities into the IMPMC.

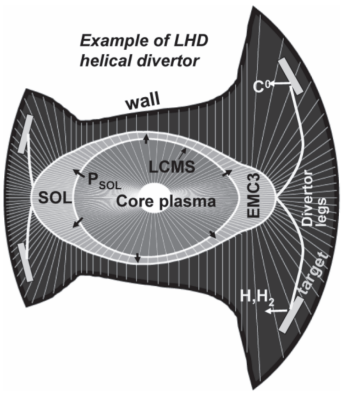

Fig.1 The equilibrium configuration of LHD

In this LEAP modelling, we determine approximately a 2D equilibrium with characteristic of the width of the stochastic region and the connection length from the X-point to the strike point by using the current filament approximate method. And then, the steady plasma parameter such as density, temperature, and poloidal velocity are calculated with UEDGE or SOLDOR/NEUT2D. Under the background plasma parameters obtained, the impurity transport is studied with the extended IMPMC which include the effect of stochastic region. This is the procedure of the LEAP simulation. The impurity contamination process from the stochastic region into the core is investigated.

iii) Executing multiple independent codes on parallel computer

In the SONIC code package, the Monte-Carlo codes, i.e. NEUT2D and IMPMC have been optimized by using Message Passing Interface (MPI) on the massive parallel computer, SGI ALTIX 3900. The SONIC simulations have been performed by a single large load module. The load module which contains SOLDOR, NEUT2D and IMPMC are executed on all PEs (process element), as shown in Fig. 2(a). Including all common variables, a load module becomes very huge when the transports of several impurities are simulated. In addition, extension of the code package becomes hard task because the codes are closely connected. Takayama demonstrated that multiple independent load modules could be executed concertedly on parallel computer. Figure 2(b) illustrates an example of the simulation where Carbon, Helium and Argon are treated as impurities. The data are exchanged between codes with MPI. This method makes it possible to evade interference between codes. As a result, we can develop each code independently. Using this method, we make a start on coupling of the SONIC package to a Tokamak transport code system (TOPICS or TASK) which simulates the transport in the main plasma.

(a) conventional method:
mpirun –np 96 lod_all

(b) new method:
mpirun -np 1 lod_SOLDOR: -np 31 lod_NEUT2D:
-np 32 lod_IMPMC_C: -np 32 lod_IMPMC_He:
-np lod_IMPMC_Ar

Fig.2 How to execute SONIC code. (a) conventional method. (b) new method to execute multiple independent load modules. The number after “-np” indicates the number of PE used for a load module of lod_xxx.

1) Kawashima, H., et al., Plasma Fusion Res.**1** 031 (2006) 1
2) Kobayashi, M., et al., Contrib. Plasma Phys. **48** (2008) 255