S11-1

Development on Disruption Research with the goal of DEMO Reactor Control Explanation of Aim as Introduction
原型炉制御に向けたディスラプション研究の展開
趣旨説明　はじめに

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The aim of the symposium: 'Development on disruption research with the goal of DEMO reactor control' is briefly explained as an introduction. In the symposium, the current status and issues on disruption research are overviewed in the experimental viewpoint. Subsequently, the issues that should be resolved on DEMO reactor design are discussed. Following them, the domestic activity on theory and simulation research aimed for the disruption control will be explained. The progress of simulation research on the runaway electrons and the integrated transport simulation of disruption control are presented. Finally, the urgent issues on the disruption research will be discussed and the related collaborations will be proposed in the general discussion.

1. Introduction

The development of physical and technical basis for the mitigation of disruption loads such as electromagnetic and thermal ones has been the most important challenges in ITER [1,2]. For this aim, the predictive simulation of plasma operation avoiding disruptions by integrated modeling, which consists of tokamak equilibrium evolution, linear and nonlinear stability analysis, and impurity transport, has become an important topic. In particular, for reactor-relevant regimes of multi-MA plasma current, runaway electrons produced after a rapid thermal quench are expected to cause a significant damage on the PFCs (Plasma Facing Component) and might give a limitation of their lifetime. Therefore, the avoidance and mitigation of runaway electrons has now been considered as one of urgent tasks in ITPA TG. Nevertheless, a transient and complex behavior of tokamak disruptions inhibits building up a solid basis for runaway mitigation in ITER even though the runaway generation mechanism itself is described basically in a classical way of Coulomb and knock-on collisions, which appears in the textbook of plasma physics.

In the domestic activity of plasma theory and simulation research on burning plasmas physics, BPSI (Burning Plasma Simulation Initiative) is the most active collaboration framework [3,4]. On the basis of collaborations between universities, NIFS, JAEA, etc., BPSI aims at the prediction of burning plasma behavior and the development of burn control method. Under this collaboration, physics modeling framework as well as software and hardware has been developed. Furthermore, IFERC-CSC (International Fusion Energy Research Center, Computer Simulation Center) offers computer resource for fusion simulation research [5]. The objectives of CSC are to provide a supercomputer (named as HELIOS) and to exploit high performance and large-scale simulations to analyze experimental data on fusion plasmas, to prepare scenarios for ITER operation, to predict the performance of the ITER, and to contribute to the DEMO design physics under the BA (Broader Approach) activities [6]. Using these frameworks, disruption research on burning plasma is now going on [7]. In the symposium, recent progress on disruption research is reported.

The symposium will consist of 5 talks and general discussion. The aim of the symposium is briefly explained as an introduction. Then, the current status and issues on disruption research are overviewed in the view of present experiments. Subsequently, the issues that should be resolved on DEMO reactor design are discussed. Following that, theory and simulation researches on disruption physics will be explained, which involves the progress of simulation research on the runaway electrons and the integrated transport simulations for the disruption control. In the last part of the symposium, the urgent issues on disruption research are discussed, and the related collaborations will be proposed.

2. Disruption Physics

The disruption process is composed of several related phenomena, such as (1) the thermal quench due to MHD instability, (2) runaway electron birth due to induced loop voltage and (3) the termination

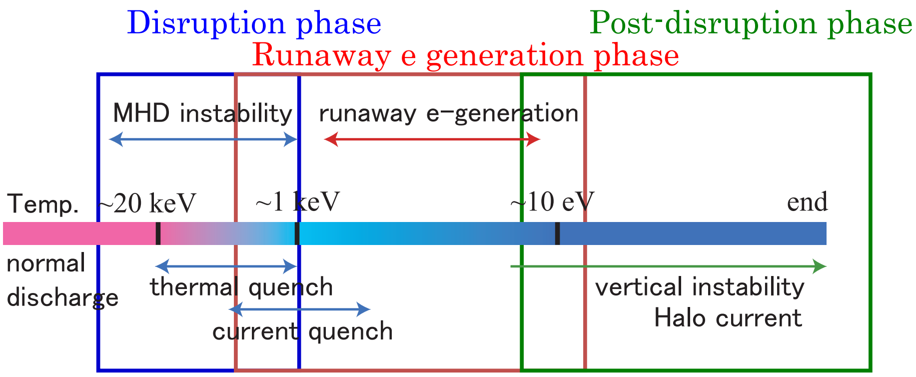

Fig.1 Schematic view of whole life of a major disruption.

of runaway plasma due to the positional instability. Figure 1 shows the schematic view of the whole life of disruption. Subsequent events during the whole time of major disruptions might be categorized into (1) disruption phase, (2) runaway electron generation phase, and (3) post-disruption phase. During a rapid thermal quench, the temperature drops from ~ 20 keV to ~ 10 eV, being dominated by the balance between ohmic heating and impurity radiation, and such a wide range of the temperature variation must be included in the simulation. Additionally, the time scale of disruption events covers from Alfvénic time (~ 1 μs), transport time (~ the order of tens of ms), and the time constant for external circuit (~ seconds). It indicates that the disruption is multi-scale and multi-physics phenomena in their intrinsic properties and the integrated simulation is indispensable to explore their physics.

The multi-scale phenomena involved in the runaway electron physics is illustrated in Fig. 2, which is characterized by the interplay between MHD modes, runaway electrons, and induced loop voltage. At the first point, MHD modes induce a thermal quench, lead to the induced loop voltage to maintain the plasma current, and finally yield the significant populations of runaways. In addition to such a classical picture of the runaway generation, nonlinear behavior caused by the induced loop voltage and runaway electrons through the avalanche process is recently clarified in the "marginal stability model" [8]. Also, once the runaway electrons are generated, they dominate the plasma current profile and closely connect to the linear stability properties. The excitation of MHD modes during the runaway generation phase has intensely been studied in JT-60U and other tokamaks. Furthermore, in recent studies, the "actuator" such as massive gas injection has also played a major role for the collisional dissipation of runaway electron beams, which is now considered to be the most promising scheme in ITER. As a whole, the systems are thus become highly nonlinear and are characterized by its transient and open-system nature. To complete the picture of major disruptions, it is also crucial to evaluate the wall damages by the vertical displacement event (VDE) and by Halo current [9].

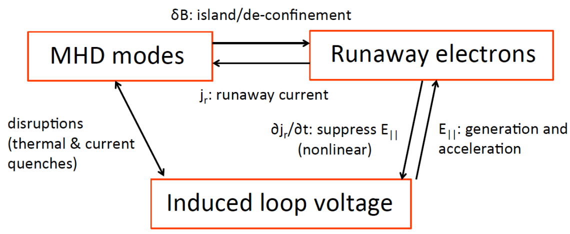

Fig. 2 Concept of integrated simulation for disruption phase and runaway electron generation phase

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