The 7th Asia-Pacific Transport Working Group (APTWG) Meeting

K. Ida,[1,2] D. F. Kong,[3] T.Fujita,[4] T. Ido,[1] W.H. Ko,[5] and S.Maeyama[6]

[1] *National Institute for Fusion Science, Toki, Gifu 509-5292, Japan*
[2] *The Graduate University for Advanced Studies, 322-6 Oroshi, Toki, Gifu 509-5292, Japan*
[3] *Institute of Plasma Physics, Chinese Academy of Sciences, 350 Shushanhu Road, Hefei, Anhui 230031, China*
[4] *Dept. of Energy Engineering and Science Graduate School of Engineering, Nagoya University, Furo-cho, Chikusa-ku, Nagoya 464-8603, Japan*
[5] *National Fusion Research Institute, Daejeon, Korea*
[6] *Dep. of Physics, Nagoya University Furo-cho, Chikusa-ku, Nagoya 464-8602 Japan*

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This conference report summarizes the contributions to, and discussions at, the 7th Asia-Pacific Transport Working Group Meeting held at Nagoya University, Japan, during 5-8 June 2017. The topics of the meeting were organized under four main headings: 1) turbulence and Blob at the boundary of magnetic topology, 2) model reduction and experiments for validation, 3) mode competition in turbulence and MHD driven by energetic particle, 4) mechanism determining plasma flows and their impact on transport and MHD. The Young Researchers ' Forum which was held in this meeting is also described in this report.

PACS numbers:

I. INTRODUCTION

The 7th Asia-Pacific Transport Working Group (APTWG) Meeting was held at Nagoya University, Japan, during 5-8 June 2017. This was a series of APTWG meetings started at NIFS Japan in 2011[1] then has been held every year at China, Korean and Japan [2–6]. The goal of the Asia-Pacific Transport Working Group (APTWG) is a predictive understanding of the basic mechanisms responsible for particle, momentum and energy transport in magnetically confined plasmas. The 3D effects on transport, which have been recognized to be an important common topic in toroidal plasmas, were also emphasized in the first APTWG. From the 2nd APTWG, the importance of understudying the mechanisms for particle and heat pinches and the working group of 3D effect on transport was expanded to cover the important topic of MHD- turbulence interaction. Then the working group have been working on turbulence suppression and transport barrier formation, non-diffusive and non-local transport, effect of magnetic topology on MHD activity and transport, and energetic particles and instability for last 6 years (two rotations of venue). The conference conference organizer discussed the major change of topics of working group to stimulate the explore to the new research field rather than to continue the topics in previous meeting.

The 7th APTWG meeting consisted of (a) special plenary sessions, (b) working group sessions, (c) poster sessions, (d) the Young Researchers' Forum, (e) summary sessions. Each working group session consisted of an invited talk, a overview talk and two or three oral talks and a discussion. Poster sessions of 120 min were arranged after the oral sessions of each working group session. Summary talks of each working group were given on the last day.

Special plenary sessions

The purpose of this sessions is to broaden our knowledge to outside the magnetically confined plasma to stimulate our current research. Fluid stratified turbulence in fluids physics was selected as a topics this year. Y. Kimura in Nagoya university gave a special talk on interaction of vortices and waves in stably stratified turbulence.

Working group sessions

This year, the topics of working group was significantly revised from that last six years. The topics of each working group is highly specified to emphasize the explore to the new research field. These working group also include the topics in the previous meeting in the scope in order to keep a continuity of the meeting but with new view point. The following four topical foci have been identified for the working groups :

A. Turbulence and Blob at the boundary of magnetic topology (Edge and SOL)

This working group discusses the turbulence and Blob at the boundary of magnetic topology. Turbulences in the plasma edge, where the magnetic flux surface is closed, and in SOL where the magnetic is open, and their interaction is a main topic in this working group. The characteristics of turbulence and impact to the transport are different in Edge and SOL. The transport barrier physics at the plasma edge and vicinity magnetic island at rational surface is included in this working group.

B. Model reduction and experiments for validation

This working group discusses the model reduction and its validation of structure formation of turbulence such as turbulence spreading, staircase, avalanche, and MHD activities driven by energetic particle. The model for the transport barrier and experiment which can be used for the validation of model are included in this working group.

C. Mode competition in turbulence and MHD driven by energetic particle

This working group discusses the mode competition of turbulence and coupling between turbulence and zonal flow and mode coupling to the MHD. We need expansion of the research field after the finding the turbulence suppression by zonal flow. This working group also covers the coupling to MHD mode driven by energetic particle.The effect of competition of turbulence on transport barrier is included in this working group.

D. Mechanism determining plasma flows and their impact on transport and MHD

It is well known that the poloidal and toroidal flow are not determined independently. However, poloidal and toroidal flow are discussed have been discussed separately. It is important to understand the plasma flow in 3D geometry even in the axisymmetric system, because the both poloidal and toroidal flow would affect the transport barrier and MHD especially plasma edge.

Young Researchers' Forum

The purpose of this forum is to encourage/promote discussions among young researchers. The designated coordinators organize the forum and nominate several representative researchers who lead the forum.

II. TURBULENCE AND BLOB AT THE BOUNDARY OF MAGNETIC TOPOLOGY (EDGE AND SOL)

In this session for the working group, a total of 13 papers were presented (one plenary, one invited, two oral and nine poster) on the subjects of turbulence and blob at the boundary of magnetic topology. Related topics and issues were also discussed. In this section, we briefly summarize the key results of the presented papers and major physics issues discussed during the session.

A. Scrape-off layer physics and their impacts on λ_q

Six papers were presented on the issues of scrape-off layer (SOL) physics and their impacts on the λ_q, i.e. understand the physics of blob filaments and their role in tokamak edge transport.

F.D. Halpern presented their theoretical and experimental understanding of blob dynamics, with an emphasis on their role setting the tokamak scrape-off layer width. In an effort to quantify the radial transport driven by blobs, analytical theories have been developed to determine the blob propagation speed. Blobs are modeled as a plasma monopole associated to a dipolar vortex, which is in turn driven by toroidal curvature and radially propels the filament. The associated blob dynamics and resulting radial transport are largely dependent on parallel current transport closing the circuit along the magnetic field lines, giving rise to several translation regimes related to the filament size and the background plasma parameters. Thus, the predicted filamentary transport levels result from a complicated interaction of 3D effects, including mode filament parallel dynamics and coupling to the Bohm-Chodura sheath at the end of the magnetic field lines. Single-seeded blob dynamics have been simulated using 2D and 3D fluid models, giving much insight on the role of parallel dynamics. Indeed, 2D models can reproduce many of the experimentally observed features, such as the strongly skewed PDFs and the propagation velocities. Perhaps more surprisingly, blobs can propagate faster in 3D than in 2D models due to a reduction in strength of the parallel current response, which has been interpreted as an increased " sheath-drop factor ". Recent advances in computational power now allow flux-driven simulations of tokamak SOL dynamics using realistic sizes and parameters. This enables a direct comparison between the simulations and state-of-the-art diagnostics, with the result that many of the blob structural properties are well reproduced by the simulations, e.g. narrow feature gradient length λ_q is constrained by the correlation length L_{rad}. The simulated plasma profiles display a two-decay length structure associated with a shear layer in the near-SOL, thus suggesting the possibility that blobs formed in the vicinity of the separatrix are responsible for setting the far-SOL decay length.

H. Tanaka investigated the relationship between $m = 0$ and spiraling structures in the three-dimensional space by using a radially and azimuthally segmented electrode and a microwave interferometer. The segmented electrode consisting of 12 pieces was installed in the plasma column. By biasing -100 V, ion saturation current fluctuations were simultaneously measured at a sampling frequency of 500 kHz. In order to capture the enhanced phenomenon near the recombination front, detached and attached divertor conditions were continuously varied by changing the neutral gas pressure, as if the measurement position was swept against the recombination front. They also measured an upstream fluctuation with the interferometer without disturbance in order to determine whether a detected event was axially localized or not. As a result, it was found that the $m = 0$ fluctuation at $f <$ 8 kHz abruptly appeared at the radial center in the transient state. At the same time, the radial profile of the ion saturation current broadened and positive spikes significantly appeared in the periphery. Conditional averaging and proper orthogonal decomposition techniques reveal existences of rotating spiraling structures in the periphery with a few-kilohertz negative $m = 0$ fluctuation at the center region. Further, the envelope analysis indicates that the spiraling plasma ejection correlated with low-frequency $m = 0$ fluctuation of the order of milliseconds. Understanding of the low-frequency fluctuation is necessary to clarify the enhancement mechanism of the cross-field transport.

H. Hasegawa presented a three-dimensional (3D) electrostatic particle-in-cell (PIC) simulation code named "P3BD" (Particle-in-cell 3-dimensional simulation code for Boundary layer plasma Dynamics) to investigate the kinetic effects on blob and hole dynamics [7, 8]. Using the p3bd code, they have shown the self-consistent current system and the temperature structure in a blob [9]. Furthermore, the dynamics between a blob/hole and impurity ions have been analyzed. This analysis has shown that the dipolar profile of impurity ion density in a blob/hole is formed by the polarization drift. Such a density profile propagates with the blob/hole. The simulations in which the initial impurity density has a radial gradient have shown that the effective radial diffusion coefficient for impurity ions by a single blob/hole is comparable to the Bohm diffusion coefficient.

M. Kobayashi presented divertor detachment in LHD with edge stochastic layer. Change of divertor plasma parameters at the detachment transition has been characterized as follows by Langmuir probe measurements. The peak values of divertor particle and power fluxes are reduced by a factor of 5 and 10, respectively, after the detachment transition. Plasma temperature at the divertor plate stays around 5 eV before and after the detachment transition, while the divertor density decreases by a factor of 10. Particle flux broadening towards private flux region during the detachment is also observed. In this magnetic configuration with thick stochastic layer, it is observed that the detached plasma becomes stable with application of $m/n = 1/1$ RMP field, which create magnetic island in the edge stochastic layer. T_e profile becomes flat at the island position, and is kept at ~ 10 eV during detached phase. This temperature range is favorable for emission of carbon impurity, which is divertor materials in LHD. Imaging bolometer and AXUV measurements show enhanced radiation at the X-point of the edge island during detached phase, indicating selective cooling of plasma there. Divertor particle flux is modulated in toroidal direction according to the mode number of RMP field, i.e. $n = 1$. Saddle loop coil measurements show that during attached phase the RMP is tend to be shielded by plasma, while after the detachment transition the plasma tends to enlarge the RMP. These observations are compared with 3D edge transport simulation with EMC3-EIRENE, and validity of the transport model is discussed.

C. Moon presented a coherent large scale low-frequency (~ 2 kHz) fluctuation (CLF) observed in the SOL of ASDEX Upgrade. CLF is enhanced via nonlinear couplings with the background turbulence (10-500 kHz) in the separatrix. The CLF is localized at the safety factor $q \sim 5$, which is determined by using the lithium beam emission spectroscopy and the electron cyclotron emission diagnostics. The CLF propagates in the electron diamagnetic direction, and is characterized by a toroidal mode number of $n = 2$. Furthermore, the CLF has significant coherence with the magnetic signal, the divertor fluctuations, and the envelope of the turbulence, which propagates across the SOL with the radial phase velocity of approximately 100 m/s. The radial structure of the SOL turbulence is locally influenced by the sign of the CLF amplitude through the disparate scale nonlinear interactions. K. Itoh presented a new study that the external source of particles can directly influence the turbulence intensity (i.e., fuelling fuels turbulence). They discuss the process that the strong fluctuations in the SOL plasma penetrate into confined plasma via the fueling of neutral [10]. The intensity of turbulence, which is driven by this process, is calculated. The ratio of this intensity to that of mixing-length estimate is given as

$$\frac{C}{\rho_i \Delta_n k^2} \left| \frac{n_e}{\langle n_e \rangle} \right|_{\mathrm{SOL}} \tag{1}$$

where Δ_n is the penetration length of neutral particles and C is a numerical coefficient of the order unity. Considering that the fluctuation level of SOL is strong, this process can introduce substantially strong turbulence near the edge plasma. This driving mechanism is a candidate that explains experimentally-observed strong turbulence at the edge. Relation between this mechanism and the hydrogen isotope effect of confinement is also discussed.

B. ELM physics and mitigations

Two papers focused on the new experimental observations on ELM physics and mitigations.

D.F. Kong presented the impact of flow shear and collisionality on edge localized mode. The BOUT++ simulations are used to study the linear and nonlinear characteristics of edge localized mode at different collisionality and radial electric field via (pressure profiles are kept the same). By increasing collisionality, nonlinear simulations show that (a) power spectrum becomes broad and flat; (b) the dominant mode changes from $n = 6$ to $n = 35$. Bispectrum analysis shows that nonlinear mode coupling becomes stronger at high collisionality, especially for the high-n modes with $n > 20$, resulting in the lack of dominant filamentary structures and reduced ELM energy loss. The impact of radial electric field E_r on peeling and ballooning modes is different. The increase E_r significantly enhances the linear growth rate of low-n peeling modes, while the linear growth rates of ballooning modes remain almost the same. Bispectrum analysis also indicates that the increase Er can enhance the nonlinear coupling of all modes studied here, and shorten the phase coherence time of the linear growth stage, which is a key nonlinear criterion for the occurrence of ELM crash. Besides the collisionality, our simulations suggest a new way (E_r) to control the ELM size, which is proved by the suppression of ELM at larger $|E_r|$ and high collisionality case on EAST.

J. Q. Dong presented the dynamic features of the trigger for edge-localized-modes (ELMs) on HL-2A tokamak. Detailed analyses of the dynamic evolutions of plasma parameters, including density, temperature, pressure, particle flux, shear flow and their gradients, in pedestal were performed in recent HL-2A H-mode plasma. As a precursor to ELM onset, a pedestal coherent mode (PCM) was observed in the edge transport barrier of H-mode plasmas in inter-ELM phases. The mode interacts with and modulates ambient turbulence and induces inward particle flux and increases of density, pressure and their gradients. It transits into streamers, that stretches in the radial direction near the mid-plane at the low field side, and induces almost instantaneous collapse of plasma energy in the outer region ~ 0.3 of the plasma column and onset of ELMs within a few tens of microseconds without global MHD instabilities. The path of the onset is identified and a clue to the trigger problem of violent events in wider circumstances of high temperature plasmas is discussed.

C. Turbulence induced particle transport

Three papers reported new experimental findings and simulation results on transport barrier formation and particle transport. S. Inagaki presented the results of experimental investigations of axial flow from a linear magnetic device with a strong vacuum pumping system. Cylindrical argon plasma (radius of 6 cm and axial length of 4 m) is generated by 3-6 kW RF (7 MHz) power and radially confined by homogeneous axial magnetic field (0.09T). Typical parameters measured by YAG-Thomson scattering and laser induced fluorescence are $n_{e0} \sim 1.0\times10^{19}$ m^{-3}, $T_{e0} \sim 3$ eV and $T_{i0} \sim 3$eV. By means of Langmuir probe and Mach probe, the spatial structure of axial flow and turbulent fluctuation are measured and excitation of D ’ Angelo mode and strong axial flow shear formation are observed. Axial Reynolds stress evaluated from the axial and radial flow fluctuations clearly indicated that axial flow in the steady-state is determined by a balance between Reynolds force and collisional neutral drag [43]. The axial flow structure and spectral of fluctuations are changed by controlling of axial flow velocity of neutral Ar. Slow mass flow condition of Ar gas (realized by low injection velocity and low pumping velocity) makes the axial flow shear stronger. The neutral gas can contribute both to the drag of axial flow and excitation of instabilities. Effect of neutrals on the axial flow will be determined by competition between such processes. Understanding of interactions between axial flow, turbulence and neutrals will contribute to further study on divertor plasma control.

M. K. Han presented an investigation of the particle transport in transport barriers with a gyro–kinetic quasi-linear turbulent model for ion temperature gradient modes and trapped electron modes with impurity effects included. Detailed analyses of the particle flux dependence on plasma parameters, including the gradients of density and temperature, magnetic shear, safety factor, collision etc., were performed. The numerical simulation results are compared and shown reasonable agreement with the experimental observations. Moreover, for multiple ion temperature gradient modes in transport barriers, particle transport calculated from the gyro-kinetic quasi-linear turbulent model compares with the result based on the quasi-linear mixing length estimations [12]. The results show that steep scale length of ion temperature can enlarge the ion inwardly transport of the ITG mode, but decrease the ion outwardly transport of TEM. When the ion temperature gradient is steep enough, ion transport of the TE-ITG modes changed into outwardly.

K. Miki presented simulation results on the particle transport in case that the density gradient is locally inversed. The locally inversed density profile appears in a hollow density profile when gas-puff or pellets are injected. Using a delfta-f electromagnetic gyro-kinetic simulation code dFEFI [13], they investigate a local dynamics of particle transport in the inversed density region. Other parameters are based on the typical edge ASDEX-Upgrade parameters. A linear mode with peaks at and can be observed. The lower one rotates in the negative (ion diamagnetic) direction and the other rotates in the positive direction. In the nonlinear phase, the lower wave number mode becomes dominant. Here, they observe an inward particle flux. As a candidate of the inward particle flux, they take into account of the ion-mixing-mode [14]. With a high electron collisionality, electron temperature fluctuations associated with the effects of finite electron thermal conductivity can produce a phase shift between the density and electrostatic potential fluctuations. The phase shift causes an inward pinch in the ITG-like mode. We analyze the obtained simulation results are consistent with the conditions for the ion mixing-mode. Note that to satisfy the condition, the inversed density gradient is necessary. Various ion temperature gradients are tested in the inversed density gradient, showing that more ion temperature gradient gives more inward particle fluxes. This can indicate that more ITG growth rates will gives more inward particle flux through a mixing-length theory.

D. Diagnostic development

Finally, there were two presentations focus on the diagnostic development which were used to the turbulence and transport study in EAST and in the linear device PANTA, respectively. T.F. Ming presented a high-speed vacuum ultraviolet (VUV) imaging system being developed on EAST tokamak. It aims to measure the evolution of the spatial structures of the pedestal, by selectively measuring emission of 13.5 nm in wavelength, which mainly comes from C VI (one of the intrinsic impurities in EAST). ELM dynamics can be studied by the combination of VUV imaging and the existing visible imaging system, which mainly monitors the bottom of the pedestal and SOL region on EAST. The key optics consists of an inverse Schwarzschild telescope, a Micro-channel plate (MCP) and a high-speed camera. At present, it is installed to monitor the plasma perpendicularly from the low field side, and the major optical axis is parallel to the major radius. In the 2016 EAST campaign, it has been commissioned and lots of VUV imaging data have been obtained under different discharge conditions, such as ELM event, MHD instabilities, etc. In this work, the hardware of the VUV imaging system, the first results from the VUV imaging data and the VUV imaging of ELMy H mode plasma in the EAST high-betaN discharges will be presented. In addition, the upgrade of the optics is scheduled for the next campaign, which aims to view the plasma tangentially. The proposals of the upgrade will be discussed as well.

B. Y. Zhang presented a comb microwave reflectometer developed for turbulence and transport study in the linear device PANTA. The plasma in the PANTA is produced by the helicon wave (plasma length of 4 m, plasma radius of 0.06m, $n_e \sim 10^{19}$ m^{-3}, $T_e \sim 3$ eV, B = 0.09 - 0.15 T) [43]. To realize multi-point simultaneous measurement of plasma turbulence, a microwave frequency comb reflectometer ranging from 12 - 26 GHz with intervals of 0.5 GHz is developed. Radial profile of electron density and density fluctuation are reconstructed according to the phase delay of reflected wave [15]. Low frequency turbulence is observed with this reflectometer, and radial structure of the turbulence is estimated. Doppler shift of reflected signal is also measured by oblique injection of microwave, and azimuthal rotation of plasma and its fluctuation are obtained. These contribute to further study on plasma transport and turbulence in the SOL region of tokamaks.

III. MODEL REDUCTION AND EXPERIMENTS FOR VALIDATION

This working group dealt with topics related to models for turbulent transport, transport barrier formation and structure formation in turbulence, which cover development of predictive modeling codes in particular with small computational cost (reduced models), the validation of the modeling codes, and experimental results that would contribute to the model development and validation. We had 4 oral presentations and 11 poster presentations. The main points in these presentations and in the discussion session are summarized below.

A. Edge and internal transport barriers

T. Kobayashi presented new analysis of the heavy-ion beam probe data measured on the JFT-2M tokamak. The outward particle flux was evaluated by the amplitudes of density and electrostatic potential fluctuations and the phase difference between them. After emergence of the radial electric field in H-mode, the outward particle flux was significantly reduced predominantly by reducing the density fluctuation amplitude and the phase difference. Amplitude reduction of the potential fluctuation was not as large as that of the density fluctuation. Both the shear and the curvature were found to play an important role to reduce the particle flux. Difference in time scales of changes in the density fluctuation amplitude and the phase difference was also observed. X. Gao presented sustainment of high normalized beta (β_N) plasma with internal transport barrier (ITB) in EAST tokamak in 2016 campaign. The ITB was observed in H mode discharges with tungsten upper divertor, while the ITB was observed in H mode discharges with graphite lower divertor in 2015 campaign [16]. The ITB dynamics is a key issue for the EAST high β_N plasmas. The ITB was formed by NB power ramp-up during H-mode. Quasi-steady state high β_N ($\beta_N = 1.9$ for 56 τ_E) H-mode plasma was achieved and sustained by NBI + LHCD. Both of the edge transport barrier (ETB) and the weak ITB were sustained on electron density, electron temperature and ion temperature profiles. Typical parameters are $T_i(0) \sim T_e(0) \sim 2$ keV and $n_e(0) \sim 5\times10^{19}$ m^{-3}. The quasi steady state safety factor profile with $q(0) \sim 1$ was observed.

H. Du presented transport analysis of steady H-mode plasmas with peaked electron density and electron temperature profiles in EAST tokamak. A class of moderately high internal inductance steady state H-mode discharges with fully non-inductive current drive has been achieved using pure radio-frequency heating. The energy confinement enhancement factor H89 was observed to increase with the internal inductance. This kind of plasmas has peaked electron density and temperature profile in plasma core and q profile flat in the near-axis region with $q(0) >1$. The peaked density profile with pure radio-frequency heating would imply existence of inward particle pinch. Preliminary results from TRANSP give very low electron thermal diffusion coefficient in the plasma core. The electron thermal diffusivity is reduced with reduction of heating power, which implies not strong but weak ITB. The core ECW heating power deposited at ρ = 0.1, which raises up the electron temperature in plasma core to help LHW deposit also near plasma center and therefore enhance core heating. Simulation of a discharge with ECRH shut down during the plasma current flat top supports that the confinement improvement in plasma core is due to higher poloidal field in the plasma core and larger magnetic shear in the outer half of the plasma when the internal inductance is relatively high.

S. Ding presented gyro-kinetic simulations of steady H-mode plasma in EAST tokamak, which was one of the discharges shown in presentation by H. Du. The simulations use GYRO code for linear analysis to identify the most unstable modes and the sub-dominant modes as well, if necessary, in different radial regions. The simulation results confirm that the growth rate of most unstable mode becomes lower in the radii closed to magnetic axis, which has the higher pressure gradient and the lower thermal diffusivity. This is consistent with the experimental observation of the centrally peaked electron temperature profile. Collisionless trapped electron mode (TEM)-like modes are dominant in the near-axis confinement region, like $\rho \sim 0.2, 0.3$. The transition of dominant mode from TEM-like to electron temperature gradient (ETG) mode in the confinement region is identified as the radii increases ($\rho \sim 0.4$). In the no-man's land near pedestal top, the dominant unstable mode is found to be ion temperature gradient (ITG) mode.

B. Structures in turbulence and stochastic field

M. J. Choi presented observations and analysis of electron thermal fluctuations and transport in the ITB and L-mode plasmas on K-STAR tokamak. These two discharges have the same plasma current and the similar NBI power. In the L-mode discharge ECH was applied to suppress tearing mode. Peaked ion and electron temperatures and toroidal rotation profiles were observed in the ITB discharge. The strong electron temperature fluctuation over the broad frequency band ($0 \sim 130$ kHz) was observed in the ECE signal with the increased electron temperature gradient in the L-mode discharge. The intermittent burst in electron temperatures was observed in the ITB discharge. Contribution of these fluctuations to electron thermal transport is not identified yet. The 60 kHz fluctuations were detected in the magnetic field and electron temperature of the ITB discharge before disappearance of ITB. The size of intermittent burst increased with the 60 kHz fluctuations, which is possibly related to the ITB disappearance. W. Lee presented density fluctuation in KSTAR tokamak and related gryokinetic simulations. Stationary L-mode plasmas were analyzed. The fluctuations measured using the microwave imaging reflectometer are found to be broad-band (band width of 100 to 200 kHz) from a cross-coherence analysis between multiple poloidal channels and their local coherence peaks place in the range of ~ 150 to ~ 400 kHz. Poloidal wave-numbers of the unstable modes, deduced from the frequencies and poloidal rotation velocities of the density fluctuations in the laboratory frame, are comparable with those from linear gyro-kinetic simulations with the GYRO code. The values of about 2 - 4 cm^{-1} from both the measurements and simulations suggest that the unstable modes can be ion-gyroscale microinstabilities such as the ITG modes or TEMs. The group velocities estimated from a cross-phase analysis of the fluctuations are all in the ion diamagnetic drift direction and this agrees well with the linear simulation results.

F. Kin presented extraction of nonlinear wave of streamer by convolution method. The streamer was found as an azimuthally localized nonlinear wave, coupled with ambient drift wave fluctuations in the Helicon wave heated plasma in the PANTA device, a linear machine. The nonlinear wave of streamer was extracted from the ion saturation current signals of Langmuir probes by convolution method. A phase of the wave of a specific frequency is used as clock for the conditional averaging. The degree of localization in the azimuthal direction was estimated by defining anharmonicity of the extracted waveform, which implies the difference form the sinusoidal wave. Relation between the anharmonicity and the amplitude of the wave indicated that the localization becomes stronger for larger fluctuation amplitude. The result is also compared with theoretical prediction of streamer waveform [17] and confirmed the theoretical prediction on the amplitude dependence. J.-W. Kim presented evaluation of the magnetic Kubo number (MKN) during the pedestal crash. Nonlinear convection through stochastic magnetic fields is considered as a possible mechanism causing transport of particle, momentum and heat during an edge localized mode crash. The MKN characterizes transport process in the stochastic magnetic field. The MKN was calculated using correlation length estimated from correlation functions of fluctuating magnetic fields in the BOUT++ simulation data. The MKN was typically lower than unity, so modified Rochester-Rosenbluth model may be adequate.

C. Model validation and predictive modeling

M. Nunami presented gyrokinetic simulations by GKV code for multi-species plasmas with hydrogen-dominated and helium-dominated ions in LHD. In LHD experiment, increase in T_i and reduction in ion thermal diffusivity were observed with decrease in the ratio of hydrogen to helium density under almost same heating power. The gyrokinetic simulations with the real-mass kinetic electrons and multi-ion-species show that the linear growth rates of the ion temperature gradient mode are reduced for the helium-dominated plasma compared with the hydrogen-dominated plasma [18]. The mixing length estimatation shows smaller ion thermal diffusivity for the helium-dominated plasma than the hydrogen-dominated one in the hydrogen gyro-Bohm unit, which is consistent to the experimental results. The T_e/T_i effects are dominant for near-marginal temperature gradient region, while the mass and charge effects become large for higher temperature gradient region, for the difference in mixing length diffusivity. A. Ishizawa presented gyrokinetic simulation with GKV code for LHD and Heliotron J plasmas [19]. In the LHD plasma simulation, it is found that (i) including kinetic electron effects is crucial for the model validation, (ii) good agreement of electron and ion heat transport near the edge is obtained for the low temperature phase and then there is no short-fall problem, and (iii) the inward-shifted magnetic axis leads to smaller transport in Gyro-bohm unit because of longer zonal flow relaxation time. In the Heliotron J plasma simulation, the neoclassical optimization through an enhanced toroidal mirror ratio is found to improve the turbulent transport, which is qualitatively consistent with the observation in the experiment.

M. Nakata presented flux-driven global transport simulations based on joint approach with gyro-kinetic and transport solvers. The global heat transport processes and profile formations in ITG-TEM unstable plasmas were investigated by using a newly developed 1D global transport solver coupled with multiple local flux-tube gyrokinetic calculations, TRESS + GKV. The time evolutions of the ion and electron temperature profiles towards a power-balanced steady state were simultaneously solved, where a fixed density profile was assumed. The neoclassical and anomalous heat fluxes were calculated by using the matrix inversion method and the quasilinear approximation based on the simple mixing length rule, respectively. The adaptive source/sink was imposed on the transport solver, which successfully accelerated the temporal convergence to the steady power-balanced state. Examples were shown which realized an ITG-mode stable T_i profile without heating, a stationary T_i profile where heat flux by ITG-mode was balanced with 5 MW heating and stationary T_i and T_e profiles where heat flux by ITG-mode, TEM and equipartition was balanced with 5 MW ion and electron heating. S. Toda presented development of a reduced model with kinetic electrons in helical plasmas. The reduced model for the ion heat diffusivity was proposed [20] using the GKV code with the adiabatic electrons for the transport simulation. In the reduced model, the ion heat diffusivity evaluated with nonlinear gyro-kinetic simulation is approximated by the function of the linear growth rate for the ITG mode and the zonal flow decay time, both of which are evaluated by linear gyro-kinetic analysis with significantly small computational cost compared with the nonlinear simulation. In this presentation, the reduced model for the ion heat diffusivity was constructed by solving the gyro-kinetic equation in terms of the electron in addition to the ion to examine the effect of the kinetic electrons.

E. Narita presented gyro-kinetic modeling of the quasilinear particle flux. In tokamak plasmas, particle transport is governed by turbulence. The turbulent particle flux is usually a nonlinear function of the thermodynamic forces such as the density and the temperature gradients, and the diagonal and the off-diagonal components in the transport matrix are defined in the quasilinear limit. The off-diagonal component sometimes generates the inward particle flux, which is essential for the highly peaked density profile. In the analysis, density and temperature profiles and particle source by NBI in JT-60U H-mode plasmas were employed. The coefficients related to the ratio of the off-diagonal terms to the diagonal term in the particle flux were determined by linear calculations of GKW code, adopting the method of trace particle species [21]. The diagonal term coefficient, the diffusivity, was assumed to be proportional to the mixing length and the proportional coefficient A was determined by using the experimental data. It was found that A increased with the collisionality.

G. M. Staebler presented the "predict first" methodology. Developing a predictive whole device modeling capability, with high accuracy and a quantified statistical confidence, is needed for the future of fusion energy. It requires a long record of experience with predictive modeling. The "predict first initiative" calls for the use of a predict first, run discharge, validate results methodology in order to gain experience, and evolve the tools, towards the goal. Standardized workflows for data processing and theoretical model verification, validation, and uncertainty quantification are rapidly being written using a workflow-based integrated modeling framework OMFIT [22]. An workflow that iterates predictive models of core transport, pedestal pressure and MHD equilibrium to calculate steady state profiles of plasma density, temperatures, and rotation has recently been built [23]. These predicted profiles can be used to predict diagnostic signals like density and temperature fluctuations, MHD instabilities, and fast ion losses. Fast neural networks, trained on the core and pedestal theoretical models, and simplified source and MHD models, can be used in this workflow to make fast predictions of plasma profiles without experimental data. Including scrape-off layer and plasma wall interaction models is the next stage in the evolution towards whole device modeling.

K. Nishioka presented stability and error analysis of a moment extract approach to the toroidal gyro-kinetic simulation with finite collision effect. The moment extract approach, where the drift kinetic equation (DKE) for electrons is divided into the 0th and the 1st order moment equations (fluid equations), and the remnant kinetic equation. This technique enables us to apply a semi-implicit integration to the gyro-kinetic equation straightforwardly. The moment-extract approach was extended for application to the non-uniform magnetic field and finite collisionality. The benchmark test showed that the 2nd order Additive Semi-Implicit Runge-Kutta scheme successfully provided the stable solution of Courant number $C_{\mathrm{w}} \sim 12$, while the 2nd order Adams-Bashforth and Crank-Nicolson scheme yielded unfavourable growth oscillation. In the discussion session led by Y. C. Ghim at the end of the oral presentations, the main subject was how to perform detailed comparison analyses between theory and experiments. The key points in the comments made by attendee include comparison of dynamics, study on nonlinear coupling, measurement of what should be measured, and encouragement for experimentalists to show data that existing theory cannot explain.

IV. MODE COMPETITION IN TURBULENCE AND MHD DRIVEN BY ENERGETIC PARTICLE

After the finding zonal flow in magnetized plasma, it has been recognized that the mode coupling and competition between the zonal flow and turbulence is crucial for transport phenomena. The finding the mode coupling between micro-scale turbulence and mesoscale zonal flow also made us realize the importance of multi-scale interaction among the micro-scale turbulence, the mesoscale zonal flow and other macro-scale modes. The multi-scale interaction and mode competition may be a key to clarify the mechanisms of the unresolved transport phenomena in magnetically confined plasmas, such as shortfall problem in the heat transport, nonlocal transport, isotope effect, and so on. In nuclear fusion plasma, fast ions that are produced as fusion products will also be a source of the macro-scale fluctuations, such as Alfvén eigen-modes. In this session, the multi-scale interaction and mode competition including bulk plasma and energetic particles were discussed. Abrupt phenomena that will be caused by coupling among phenomena with different time scales were also a target of this session.

A. Mode competition

I. Cziegler gave a plenary talk on competition among zonal flow, GAM and turbulence. In this study, the energy distribution among zonal flow, GAM, and turbulence has been estimated by estimating the proposed energy transfer function[24], quantitatively. In Alcator C-Mod tokamak, the competition between zonal flow and GAM has been observed only in I-mode plasmas [25], and GAM/Zonal flow competition and interaction is not necessary for H-mode transition. In addition, H-mode threshold power depends only on the zonal flow component, regardless of the presence of a GAM state before, and the energy transfer rate to zonal flow in the configuration with the grad-B drift direction favorable for H mode is larger than that in the configuration with unfavorable grad-B drift direction. The result suggests that the important role of zonal flow for L-H transition. T. Miura presented the analysis of the competition between ITG turbulence and zonal flow by analyzing entropy production rate based on gyro-kinetic simulation by GKV code. The entropy transfer rate corresponding to the coupling with zonal modes is in good agreement with the shearing rate of zonal flows. The analysis of the entropy production rate confirm that the shearing model works in the simulation.

K. Ida presented the observation of a toroidally, poloidarlly, and radially localized perturbation, so called a tongue, of magnetic field in the LHD [26]. The tongue deformation appears at the non low-order-rational surface (well inner side of $q = 1$ surface), and the plasma displacement due to the deformation increases to 2 cm and expands outwards in 100 μs. After the tongue deformation, the plasma has minor collapse and rotating m/n = 1/1 MHD mode starts, where m and n are poloidal mode number and toroidal mode number, respectively. This rotating mode lasts only 2 ms and stops rotations associated the appearance of stationary $m/n = 1/1$ MHD mode. Thus, there are three phases: stationary $m/n = 1/1$ MHD mode, tongue, and rotating $m/n = 1/1$ MHD mode. The tongue deformation does not always appear. Thus, there is selection rules that determine which phase takes place as a relaxation of the energy source. After the tongue event, distortion of Maxwell-Boltzmann distribution of epithermal ions and exhaust of turbulence eddy are also observed.

Z. Ren presented simulation of high-order harmonics of energetic particle-driven mode(EPM) in $q = 1$ region with weak magnetic shear. The simulation was performed by a particle/MHD hybrid code M3D-K. The linear growth rate of higher harmonics ($m = n >1$) can be higher than the $m/n = 1/1$ component. Unlike a typical fishbone instability, the higher harmonics satisfy multiple resonant conditions in the different resonant locations, while $n = 1$ component has only one resonant condition. Nonlinear analysis shows that the fluid nonlinearity reduces the saturation level of the $m/n = 1$ / 1 component, while it hardly affects high-n components. The flattening region of energetic particle distribution due to high-order harmonics excitation is wider than that due to $n = 1$ component, although the n = 1 component has higher saturation amplitude. Y. Todo presented that zonal flows and sidebands with higher mode numbers are generated in the nonlinear evolution of energetic particle-driven toroidal Alfvén eigenmode (TAE) based on kinetic-magnetohydrodynamic (MHD) hybrid simulations by MEGA code [27]. Take into account the generation of the zonal flow and the sideband, the saturation level of TAE decreases. The simulation of energetic particle-driven GAM (EGAM) was also presented, and an interpretation [28] of abrupt excitation of EGAM observed in LHD [29] was discussed, and it was indicated that the abrupt GAM was excited through kinetic interaction with the energetic particles.

N. Kasuya presented the influence of neutral particles on turbulence. The role of neutral particles in plasma confinement has been recognized to be important especially since discovery of H-mode. This simulation study has been performed for linear device PANTA. A particle code for 2-D profiles of neutral particles and a turbulence code for resistive drift wave turbulence were combined. As the ion-neutral collision frequency (ν_{in}) decreases, instabilities becomes more unstable. In addition, the inhomogeneous profiles enhances the electric potential which is formed though the mode coupling of turbulences. The results mean that larger electric potential is formed by turbulence in higher temperature plasmas, because in higher temperature plasma profiles become hollower. S.-I. Itoh presented a new theoretical model to explain isotope effect on confinement. Recently, in order to explain the hysteresis in gradient-flux relation, it has been pointed out that the plasma heating directly drives turbulence [30]. Thus, owing to heating, the turbulence intensity is enhanced. The enhancement factor is determined by competition between the force to deform the distribution function by the heating and the turbulent diffusivity driven by background turbulence. If the turbulent diffusivity has the gyro-Bohm dependence, the effect of the heating on the turbulence intensity is smaller for the plasmas with heavier hydrogen isotope [31]. Thus, this prediction qualitatively agrees with the isotope effect of confinement observed in experiments.

B. Multiscale interaction

P. H. Diamond gave an overview talk titled "Mode Competition, Saturation Mechanisms, and Spatial Patterns in Multi-Scale Turbulence ". A model based on a primitive system of ion scale electron drift waves driven by ∇T_e, coupled to electron scale ETG turbulence was presented. It describes the spatial and temporal evolution of mean T_e, $E \times B$ flow, ETG energy, and drift wave energy. Thus, the competition of the two turbulence can be investigated self-consistently. The analysis results of the evolution of spatial pattern and the mode competition were presented. As one of examples of spatial structure evolution, a dynamic staircase structures in density profile that moves upward as an escalator were shown [32]. The spatially spreading dynamic staircases lead non-locality of transport. The model also indicates that the energy of ETG condenses to ion scale zonal flow through inverse cascade, and the dynamics leads a Dimits shift like state [33]. By showing the detail analysis, usefulness and necessity of theory and reduced modeling for interpretation of experiment and large-scale simulation on are stressed in this talk.

S. Maeyama presented the analysis of interaction between short-wave-length ETG turbulence and long-wave-length micro-tearing mode (MTM) by multi-scale (full-k) gyro-kinetic simulation. It was demonstrated that ETG turbulence can suppresses MTM through destroying the radially-localized current sheet of MTM [34]. Triad transfer analysis confirms that perturbed entropy of MTM, especially having high - k_x, is transferred to finer modes via the coupling with ETG. This multi-scale interaction will significantly affect electron heat transport. M. Sasaki presented the theoretical study of influence of EGAM with a large spatial structure on micro turbulence. Turbulence wave-packets are trapped by the EGAM, and then radially transferred by the EGAM even across a transport barrier. Thus, the turbulence can propagate ballistically with the phase velocity of the EGAM, and the phenomenon will lead non-locality of turbulence. H. Ren presented simulation study of effects of toroidal rotation on the EGAM [35]. A hybrid kinetic-fluid model and gyro kinetic equations indicate that the toroidal rotation increases the real frequency of the EGAM. Although the toroidal rotation does not affect the critical condition of the EGAM, the growth rate of the EGAM decreases as the toroidal Mach number increases.

C. Wave-particle interaction

T. Zhang presented the observation of Reverse-shear Alfvén eigen-modes (RSAEs) in EAST tokamak. The RSAE was observed in the magnetic field fluctuation by a Mirnov coil, density fluctuation by an interferometer, and the electron temperature fluctuation by ECE. The mode is confirmed to locate at the normalized minor radius of 0.37 - 0.46. Since RSAEs are excited around the location where the safety factor (q) has a local minimum, this observation will give an information on the evolution of reversed magnetic shear which affects the transport of bulk plasma. K. Nagaoka presented the development of wave-particle interaction analyzer (WPIA) and results of control experiment of Alfvén eigen-modes (AEs). In order to investigate detail physical mechanism of wave-particle interaction, the relation between the phase of the wave and the responses of distribution function of fast ions is required. In the new WPIA, the fast ion is detected after energy analysis by fast neutral analyzer (FNA) with fast sampling rate (50 MHz). Then, the response of fast ion and its timing are compared to the phase of the AE signal such as magnetic field fluctuation. The new WPIAs are installed in the LHD, Heliotron-J and TJ-II, and preliminary data have been detected. The latter part of the presentation was devoted to the controlling AEs by modification of fast ion profile using NBI, and it was reported that clear difference in AEs excitation between peaked and hollow fast ion profiles were observed. T. Akiyama presented the development of RF radiation detectors in the LHD as an indicator of fast ion losses or redistribution. Since the system of the diagnostics is simple, it will have a potential to be installed in ITER and even in reactors. In this presentation, it was reported that detected RF signal at around 200 MHz increased intermittently as an energetic particle-driven mode at around 10 kHz bursted. The response in the RF signal suggests the fast ion loss or redistribution during the burst of the low frequency mode.

D. Abrupt phenomena

A.Bierwage presented results of improved simulation with multi phase method, in which two schemes with different time scale are used: interlaced 4ms intervals of fast classical Monte-Carlo simulation and 1ms of slow hybrid simulation [36]. By using this technique, abrupt large event (ALE) observed in JT-60U has been reproduced successfully [37]. T. Ido presented the observation of abrupt excitation of EGAM [29] and low frequency mode newly observed in the LHD. The EGAM is abruptly excited when preceding another EGAM with a chirp-up frequency reaches to twice the GAM frequency. The excitation phenomenon has been interpreted as an excitation of subcritical instability of the EGAM [38, 39]. As another topic, a mode newly observed in high power NBI discharges was reported. The frequency is much lower than the GAM frequency. The toroidal mode number is 0 or 10 which corresponds to the periodicity of the helical coils and the poloidal mode number seems to be 1. Thus, there is no resonant magnetic surface. The mode has not been identified, yet.

V. MECHANISM DETERMINING PLASMA FLOWS AND THEIR IMPACT ON TRANSPORT AND MHD

This working group was devoted to the subjects of mechanism determining plasma flows and their impact on transport and MHD. In this section, we summarize the results of the presented papers and discussions at this working group session. The topics discussed at the meeting include flow transport and mechanism determining plasma flow, and flow fluctuation and structure. The plasma flows and their impact on transport are composed of the dimensionless scaling of intrinsic torque, turbulence induced plasma flow, and ITB formation by toroidal momentum. The plasma flow fluctuation and structures include the flow or potential structure related zonal flow and the flow structure with pellet injection. Experimental results on plasma flows and their impact on transport were reported from DIII-D, KSTAR, LHD, and PANTA.

A. Flow Transport and Mechanism Determining Flow

The flow transport and mechanism determining plasma flow includes the physics of intrinsic torque scaling with dimensionless, investigation of intrinsic rotation, turbulence induced plasma flow, ITB formation by toroidal momentum, and finite orbit width effect on the NTV. The first thing on the flow transport and mechanism determining plasma flow is the influence of plasma rotation on burning performance in tokamak by C. Chrystal, empirical investigation of spontaneous rotation under co- and counter-NBI heated H-mode plasma in KSTAR by W. H. Ko, how turbulence fronts induce plasma spin-up by Y. Kosuga, ITB formation by toroidal momentum injection in flux-driven GK turbulence by K. Imadera, finite orbit width effect on the neoclassical toroidal viscosity in the super banana-plateau regime by S. Matsoka, and gyro-kinetic formulation to derive conservation laws for collisional and turbulent transport of particles, energy, and toroidal momentum by H. Sugama. C. Chrystal summarized the mechanism determining plasma flows in which turbulence by temperature and density profiles generates momentum transport and residual stress, combining with momentum sources to generate momentum profile. Particle and momentum profiles yield toroidal and poloidal rotation profile. Rotation affects MHD and combines with pressure to yield $E \times B$ shear. MHD and $E \times B$ shear affect turbulence, feeding back on rotation through multiple complex pathways. Dimensionless parameter scan experiments provided a path for gaining basic understanding of the underlying complex phenomenon and intrinsic torque and rotation have been investigated with scans of normalized gyro-radius and collisionality. His results showed that the normalized intrinsic torque increases with decreasing normalized gyro-radius and decreases with decreasing collisionality, yielding predictions for ITER of 33 Nm of intrinsic torque [40].

W.H.Ko presented that a clear disparity between the width of the toroidal rotation pedestal and that of the ion temperature pedestal was observed in co-NBI heated plasma [41] while it is not in counter-NBI heated plasma. The core rotation is saturated when stored energy increased in counter-NBI heated plasma while core rotation increased with stored energy in co-NBI heated H-mode plasma. It is related an indirect evidence of the intrinsic rotation with co-direction. Y. Kosuga studied how turbulence fronts induce plasma spin-up. He focuses on the spatial transfer of fluctuation momentum [42] and indicates the radial propagation of turbulence with finite parallel momentum plays an important role in flow generation [43]. His calculation [44] leads to the convective-diffusion form of the spatial flux of fluctuation momentum and the result indicates that fluctuation momentum can spatially propagate at the speed. His calculation applied to fusion induce edge-core coupling of toroidal flows in L-mode. K. Imadera reported that the momentum source can change the mean E_r through the radial force balance, leading to ITB formation in which the ion thermal diffusivity decreases to the neoclassical transport level [45]. Only co-current toroidal rotation can benefit the ITB formation in weak magnetic shear plasma, showing a qualitative agreement with the observations in the JET experiment. The underlying mechanism is identified to originate from a positive feedback loop between E_r shear and resultant momentum flux. Such a mechanism can also benefit the ITB formation around q_{min} surface in reversed magnetic shear plasma.

S. Matsoka presented two global kinetic simulations which are the global drift-kinetic code, FORTEC-3D and the global full-f gyrokinetic Eulerian code, GT5D [46]. He showed that the neoclassical toroidal viscosity (NTV) which is induced by the non-resonant and non-axisymmetric perturbations is much smaller than that predicted by the standard superbanana-plateau theory and depends on the collisionality. The absence of the resonance in the global kinetic simulations leads to the smaller NTV of the global kinetic simulations than the superbanana-plateau theory. The finite banana width of the trapped particles also generates the finite $k_{||}$ mode structure along the bounce motion, leading to the phase mixing in the trapped region of the velocity space. Fine scale structures caused by the phase mixing in the velocity space results in the smaller NTV in lower collisionality. H. Sugama presented the new gyro-kinetic formulation including collisional effects into the Lagrangian variational principle to derive governing equations of background and turbulent electromagnetic fields and gyro-center distribution functions for toroidally rotating plasmas. The governing equations of particles, energy, and toroidal momentum derived here include, in a unified way, classical, neoclassical, and turbulent transport fluxes which agree with those derived separately from the conventional recursive formulations [47].

B. Flow Structures

Flow fluctuation and structure contain the effects of parallel flow on zonal flow, electric potential structure via zonal flow coupling to RMP (Resonant Magnetic Perturbations), and flow structure associated with the pellet injection The flow fluctuation and structures included how parallel dynamics affects the generation of zonal flow by S. Yi, residual zonal flows with finite radial wavenumber revisited, and effects of initial parallel flow and electromagnetic potentials in tokamaks by O. Yamagishi, helical electric potential modulation via zonal-flow coupling to RMP by M. Leconte, and observation of solitary and mono-cycle shaped flow structure associated with the TESPEL injection by T. Tokzawa. S. Yi presented the results of gyro-kinetic simulations and of analysis of poloidal momentum transport in the framework of the potential vorticity (PV) mixing theory [48]. The results provided that parallel flow fluctuation indeed contribute to zonal flow generation in ion temperature gradient turbulence. Radial profiles of zonal flow show clear differences when the equilibrium parallel flow shear is applied. The difference in the zonal flow structures is well described by that of PV flux. The contribution of the parallel flow fluctuation on the PV flux is smaller than the other perpendicular mechanisms in absolute amplitude. But, the perpendicular contributions, the $E \times B$ diffusion and the thermoelectric pinch are largely cancelled each other. So, the compression of the parallel flow fluctuation shows a substantial contribution to the total PV flux evolution.

O. Yamagishi presented that finite radial wavenumber dependence of the residual zonal flows in tokamaks are revisited by means of the collisionless gyrokinetic simulations [49]. By including the initial parallel flow in addition to diamagnetic flow as a first order perpendicular flow in the usual Rosenbluth-Hinton test, effects of initial parallel flow on the residual flows and toroidal momentum conservation are investigated. In addition to the conventional electrostatic and electromagnetic potential in the Rosenbluth-Hinton test, the time to reach to the stationary zonal flow becomes longer. Thus this electromagnetic effect may weaken the suppression effect of turbulence moderately. Helical electric potential modulation via zonal-flow coupling to RMP is presented by M. Leconte. To address the implication of the helical modulation on RMP-induced transport, a system of 1D equation for zonal flows and helical potential with RMPs was derived based on the theory of RMP-induced zonal flow damping [50]. The RMPs trigger the form of a transport bifurcation by allowing energy-transfer out of turbulence-driven zonal flows into zonal flows -driven helical potential. The new saturated state by RMPs has weaker zonal flows and a 3D topology with a helical modulation of the electrostatic potential. T. Tokzawa presented topics related to flow structure which is observation of solitary and mono-cycle shaped flow structure associated with the small pellet injection. It can be measured the spatio-temporal behavior of flow and turbulence structure from a multi-channel Doppler Reflectometer system [51] in LHD with deuterium. Preliminary results showed that the edge flow structure is oscillated in the condition near the density threshold of transition and turbulence intensity is related with the flow but it is changed during the oscillatory phase. Solitary and mono-cycle shaped flow structure is appeared by the small pellet (TESPEL [52]) injection in which the local potential change travels towards the core with two time scale and the sign of flow velocity in the edge region changes abruptly.

Y. Nagashima studied impact of end-plate biasing on plasma fluctuations in PANTA (Plasma Assembly for Nonlinear Turbulence Analysis) which is a cylindrical linear plasma device. Electric biasing is one of the well-known experiments for observation and analysis of plasma turbulence control. The change in fluctuation properties is observed between with and without the biasing and the turbulence Reynolds stress is measured with Reynolds stress probe [53]. The results showed that the change of the floating potential is very fast within order of micro-second just after the trigger while the change of the turbulence Reynolds stress is relatively slow, order of a hundred 100 micro-second just after the trigger. The spatial variation of the response time of the turbulence Reynolds stress from the triggering was found [54]. Plasma flow is governed by the conservation of momentum, and its vector nature makes momentum transport more complicated than particle or energy transport. The need to account for toroidal and poloidal rotation is a complication that becomes increasingly important as shown in C. Crystal's presentation which tried to solve the mechanism determining plasma flows. There are an open question and future direction in the topics of how turbulence fronts induce plasma flow. Mechanism determining plasma flows is linked to spatial dynamics of momentum transport and turbulence. The on-going detailed studies in mechanism determining plasma flows and their impact on transport and MHD should be investigated.

VI. YOUNG RESEARCHERS' FORUM

The Young Researcher Forum (YRF) is dedicated to students and researchers at early stages of their careers, and aims to encourage discussion and promote further collaboration among young researchers in the Asia-Pacific region. The YRF has started from the 3rd APTWG meeting held in 2013. This year's YRF, led by S. Maeyama, T. Zhang, and M.-J. Choi, consisted of a lecture session and students' presentation session. The lecture session was on gyro-kinetic turbulence simulations given by two lecturers. First, K. Imadera explained the basic concept of gyro-kinetics and showed recent progress by global full-f gyro-kinetic simulations. Second, M. Nunami introduced a local delta-f model and discussed its usefulness for experimental analysis. These well-organized two lecture talks clarified the difference and limitation of their simulation models, and suggested future directions of gyro-kinetic turbulence simulation studies.

In the latter session, there were five talks by students. J.-W. Kim analyzed BOUT++ simulation data and showed that magnetic Kubo number had strong correlation to stochasticity of the magnetic field before a pedestal collapse. Z.-Z. Ren carried out linear analyses of DIII-D discharges by using M3D-K code and reported that the frequency of the fishbone instability was consistent with experimental observation. F. Kin extracted a nonlinear solitary waveform from an experimental signal in PANTA and showed a dependence of anharmonicity on fluctuation amplitude consistent with a theoretical prediction. Y.-W. Cho's gyro-fluid simulations revealed that the position of the localized heat source was a key for ITB formation in reversed shear plasma, which qualitatively agreed with JT-60U experiments. M.-K. Han showed not only conventional (even parity) but also unconventional (odd parity) ITG modes were able to be unstable in high density gradient region and had non-negligible contribution for quasilinear transport estimate.

As attempts to help understanding and vitalize discussion, a copy of YRF presentation view graphs were handed out at the conference sight, and the session was at any time open for questions. Because of the active discussion, the session felt shortage of time. Although the number of talks in YRF tends to increase year by year [2013 (6 students' and 2 lecture talks), 2014 (4 students' and 1 lecture talks), 2015 (3 invited and 6 students' talks), 2016 (1 lecture and 5 students' talks), 2017 (2 lecture and 5 students' talks)], one of the YRF leaders (S.M.) suggests that a small number of selected talks will enable us to have more interactive and deeper discussion in future YRF. In addition, a summary and discussion session, which seems to be disappeared since 2015, will be indispensable to collect opinions and to find a way for future collaborations among young researchers.

VII. SUMMARY

A. Critical issues and relationships among four topics at this meeting

The critical issues of this meeting were to explore the topics which has not been discussed and provide a new view point on the turbulence transport and MHD instability. The relation between the turbulence and blob, that have been studied separately, was discussed in this meeting. The understanding of the underlining physics of the edge turbulence and blob gives new insight to the scrape-off layer (SOL) physics and better prediction for the SOL width. There are intensive research activities for the model validation especially in the gyro-kinetic simulation in the core plasmas. However, the model validation of the blob and edge turbulence simulation was not discussed. The model validation on MHD simulation was discussed in the working group of mode competition in turbulence and MHD driven by energetic particle. Although the mode competition in turbulence, especially interaction between turbulence and zonal flow, was discussed, there is no theoretical work on the mode competition of MHD instability observed experimentally. The toroidal and poloidal flow can not be determined independently because of the non-compression condition of the flow in toroidal system. The importance of the interaction between the toroidal and poloidal flow was presented in this meeting. The deep understanding of the flow structure determined by the driving, damping, and interaction between the two flows, is also essential in the edge turbulence and blob physics, mode validation, and mode competition. The four topics discussed in this meeting have strong interactions in physics mechanism.

B. Conclusion and future plans

In total, there were 24 oral sessions and 60 posters from five countries. In order to promote new ideas and a free discussion, there are no published proceedings, although there is information on most of the oral and poster presentations on the web-site. The 7th APTWG international conference provided a place for the fruitful discussion in the new topics on (1) connection of turbulence between inside and outside the last closed flux surface (2) model validation of turbulence and MHD, (3) turbulence and MHD mode competition and (4) coupling between the toroidal and poloildal flow. The new experimental results offer new insights. Several oral speakers demonstrated the new trend of the research, especially on edge turbulence and blob as a boundary physics, mode competition of turbulence and MHD instability and edge plasma flow as flow dynamics in toroidal geometry. The APTWG meeting includes a young researcher forum, dedicated for students and researchers at early stages of their careers. This year, there were presentations by students who did not have a chance to present their work in the oral sessions. Informal discussion with a senior researcher was also arranged. Every year, we gave a poster prize to a student who presents excellent research achievements regarding plasma transport. In this conference, Dr. Emi Narita (QST) wins the young research award for her poster entitled "Gyrokinetic modeling of the quasilinear particle flux". The next meeting will be held in China in 2018. In addition, G. M. Staebler introduced the current status of US-EU transport task force (TTF) meeting to provide the information in the consideration for a possible international joint meeting of APTWG and US-EU TTF in 2020.

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