Start-up runaway generation with neutral and low Z impurity reduced screening effects at the KSTAR Ohmic plasmas

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While runaway electron physics is a branch of tokamak research recently focusing on investigating, suppressing and mitigating it in the disruption phase, start-up runaways have been little interest after an early tokamak start-up study established. However, a recent ITER plasma initiation revision [1] indicated that ITER plasmas have a chance to produce the runaway electrons because of a low P plasma initiation condition constrained by a burn-through limit. ITER plasmas must avoid a runaways-dominant plasmas initiation, where runaway electrons carry most of plasma current, to prevent a harmful effect on the device by the energetic electrons. In fact, JET start-up runaway study reported that there is a case where the runaway current dominated the thermal current, which prohibited the thermal population from burning [2]. The runaway dominancy seems to arise from electrons density and electric field dynamics at an early stage.

Understanding of their formation and energy limit is necessary in order to predict how much they do the harm on the device. In this work, we only tackle the modelling of their formation process. We conducted a numerical analysis on a formation of runaway electrons at KSTAR Ohmic breakdown start up employing the gyro-averaged Fokker Planck solver [3] and the DYON [4].

An evaluation of a reduced screening effect on electron-ion elastic and electron-electron inelastic collision has been typically concentrating on high Z impurity because the high Z impurities like Ne and Ar were used for runaway mitigation [5-7]. However, a species is different at plasma initiation, i.g. C for KSTAR and Be for ITER, and thus low Z impurity's effect on deflection and slowing-down frequency should be revisited. We extended an investigation to relevant low-Z elements.

Before equilibrium reliably reconstructed, the plasma position cannot be located and thus pushing it inward is adopted to a position control strategy. In this process, impurities from the wall can penetrate into the plasma, which should affect electron density, electric field and impurity contents. The DYON code can capture this picture setting the sputtering coefficient as a function of time.

The well-known runaway generation mechanisms are the Dreicer mechanism, the avalanche mechanism and the hot-tail mechanism. The last one omitted in 0d modelling but the others cannot describe a time transient effect. Moreover, the formulas for 0d modelling were developed assuming fully-ionized plasmas and thus they are not applicable at an early stage of tokamak start-up. On the other hands, the gyro-averaged Fokker Planck solver can be applicable to weakly ionized plasmas and consider all mechanisms with neutral and impurity only if the maxwellian background assumption is valid. With the DYON and the gyro-averaged Fokker Planck solver, we modelled the formation of start-up runaways at KSTAR Ohmic plasma. We compared the Dreicer flow rate and the runaway current between the analytic expectation and the numerical computation.

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