

Study on ICRH and FWCD for KSTAR Baseline Operation Period

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1. Introduction

KSTAR project will undergoes three big operational phases after construction. Those are (i) base line operation period, (ii) long pulse operation period and (iii) advanced operation period. In the base line operation period, KSTAR will be operated on short pulse mode less than 20 second and presently existing operation modes that have been developed by modern tokamaks will be reproduced including advanced tokamak operation mode. In this paper, ICRF heating and FWCD characteristics especially for the physical parameters of H-mode and reverse shear mode in baseline operation period will be studied. To accomplish the works as proposed above we adopt the full wave code of TORIC[1] as of main research tool for this preliminary study.

The initial KSTAR ion cyclotron system will consist of one port-mounted antenna that will have four current straps. Each strap delivers 1.5 MW RF power to plasma. The geometrical parameters of antenna and the major tokamak parameters are listed in table 1.

Table 1. The reference KSTAR parameters

Major Radius R_0	1.8 m
Minor Radius a	0.5 m
Toroidal Field B_0	3.5 T
Elongation κ	2.0
Triangularity δ	0.8
Antenna Radius	54.5 cm
Antenna Length	65 cm
Width of Current Strap	9 cm
Faraday Shield Radius	52 cm

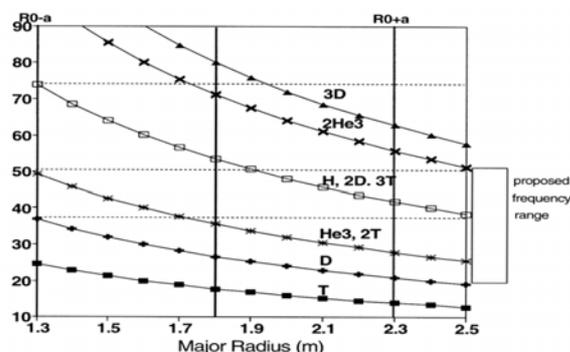


Fig. 1. Variation of the cyclotron resonance frequencies of ions across minor radius.

With these parameters we implement the TORIC simulation to investigate the effects of pressure profile and safety factor profile on heating and current drive for the H-mode and reverse shear mode(RS-mode). The TORIC code adopts a simple analytic magnetic coordinate system for convenient calculation of coefficients of fields and MHD quantities. The plasma pressure and the toroidal plasma current effects are not consistently incorporated into the MHD equilibrium of TORIC so we can change the each profile independently. We used typical plasma parameters of the H-mode and simulated RS-mode

in this study. The effects of the pressure profiles and the q-profile of the both modes on heating and current drive are studied.

2. Heating and current drive scenarios and plasma parameters of H-mode and RS-mode.

Figure 1 shows the variation of cyclotron resonance frequency of various ion species across minor radius and the frequency range of the RF system for the reference 3.5 T toroidal magnetic field. Three main heating and current drive scenarios are proposed[2]:

- 1) H minority heating in D majority plasma. The frequency of 51 MHz is adequate for H minority heating or second harmonic heating of D.
- 2) On-axis current drive in D majority plasma with H minority. The frequency of 38 MHz can be possibly used for its purpose.
- 3) Off-axis current drive in D majority plasma with He³ minority. The frequency between 30 and 40 MHz may be possible for ion-ion hybrid resonance mode conversion heating and current drive.

In this paper we consider the first coming two scenarios and the plasma parameters of H-mode and RS-mode. Especially RS-mode parameters are taken from a result of the ASTRA plasma transport simulation[3]. Figure 2 and fig. 3 show plasma density and temperature profiles of the H-mode and RS-mode with respectively. The q -profiles of the H-mode and the reverse shear mode are shown in Fig. 4 which are reproduced by the TORIC code using by the fitted plasma current profiles.

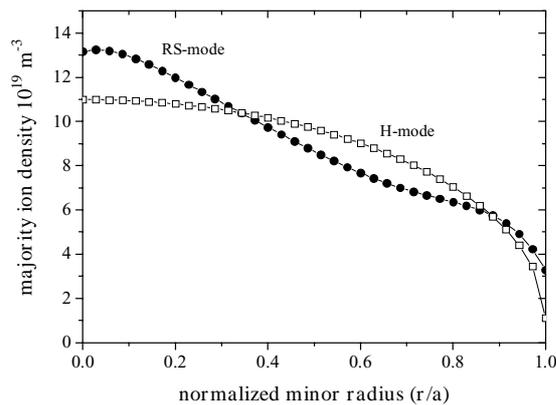


Fig. 2. Majoriety density profiles of H and RS-mode

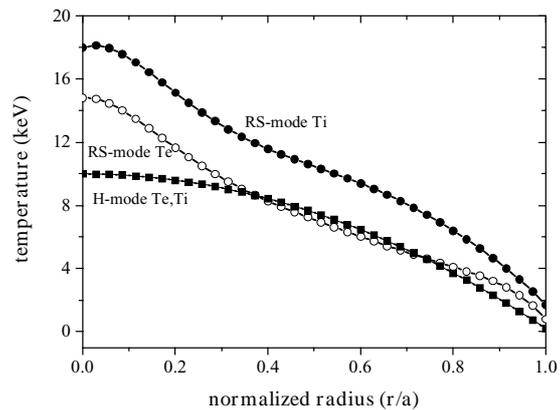


Fig. 3. Electron and ion temperature profiles of H-mode and RS-mode.

3. Simulation results

We implement the TORIC simulation under the previously mentioned plasma parameters of operation modes. A FLR, poloidal magnetic field, and toroidal broadening of ion cyclotron resonance effects are taken into account. In both H-mode and RS-mode,

the minority ion density is assumed 5 % of the electron density and 2 MA toroidal plasma current is also assumed.

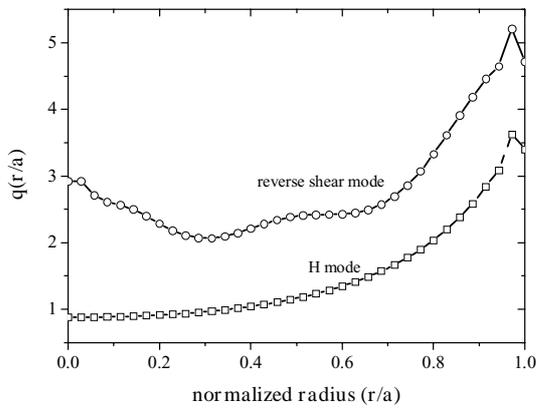


Fig. 4. q profiles of H and RS-mode

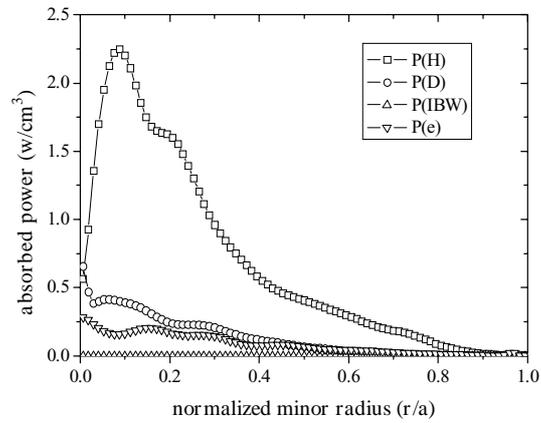


Fig. 5. Power absorption profiles of minority heating scenario for H-mode

3-1. Minority heating scenario

The toroidal wave number $n_\phi = 36$ which corresponds to the π phasing of each current straps was considered for minority heating scheme. Figure 5 to 8 show the power absorption profiles of majority, minority, IBW, and electrons for each operation modes. Figures clearly indicate that the characteristic RS-mode heating profiles are mainly due to the pressure profile. The q profile also affects the heating characters but it is not significant.

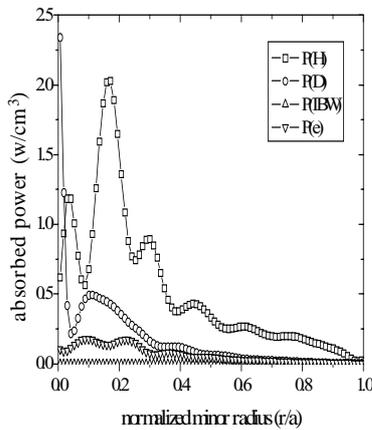


Fig. 6. Power absorption profiles of RS-mode.

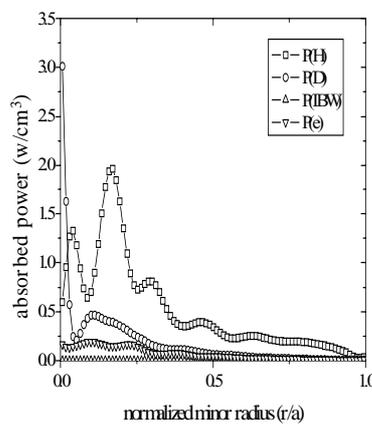


Fig. 7. Power absorption profiles for H-mode q profile and RS-mode pressure profile.

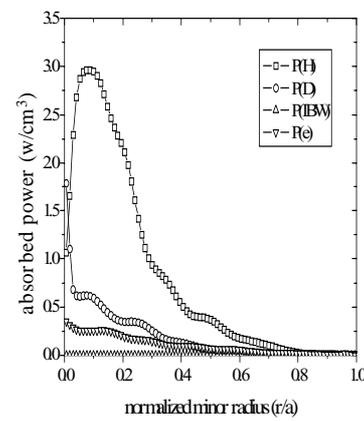


Fig. 8. Power absorption profiles for H-mode pressure and RS-mode q profile.

3-2. On-axis current drive scenario

For the on-axis current drive, $n_\phi = 18$ which corresponds to the $\pi/2$ phasing of each current straps was used for effective current drive. Figure 9 shows driven current profiles for H-mode and RS-mode. In both cases, the currents are driven mainly on axis but in

RS-mode, considerable off axis current is also driven near the ITB region. We can find the almost same tendency of driven current as in the heating scenario i.e. FWCD characteristic is also deeply affected by the plasma density and temperature rather than q profile.

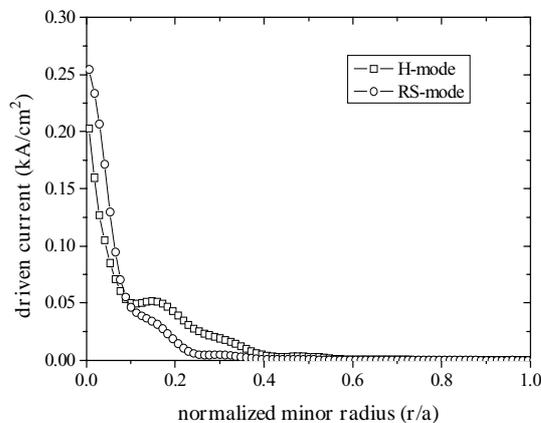


Fig. 9. Driven current profile for H-mode and RS-mode

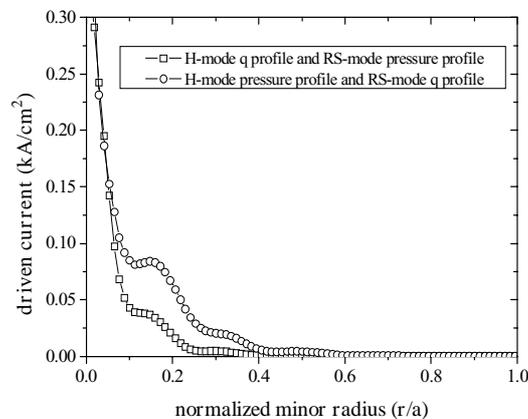


Fig. 10. Driven current profile for mixed mode.

4. Conclusions

For two different operation scenarios of the minority ion heating and on axis current drive, we calculated the heating and driven current profiles for H-mode and reverse shear mode. The most distinct characteristics of the reverse shear mode are appearance of internal transport barrier and the reverse sheared safety profile. To clarify which factor is mostly important in forming its heating characteristics we altered the pressure profile and safety factor profile independently as input of TORIC code although it is inconsistent with MHD equilibrium. The results say that at least in view points of heating and current drive, density and temperature profiles are more critical.

References

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