2006 핵융합 기초 #2 (Harms, Principles of Fusion Energy)

4.6 Compute the maximum fusion power density of a magnetically confined d-h fusion plasma ($N_d = N_h$, $T_d = T_h = T_e$, no impurities) as limited by an assumed upper value of attainable field strength , B = 15 Tesla, dependent on the plasma temperature. Superimpose the result for β_{max} = 2 % in Fig. 4.3.

8.3 Develop Lawson Criteria for a d-d plasma (include both branches of the d-d reaction), and plot $N\tau$ vs T. Assume a fusion power to electrical conversion efficiency of 30%.

8.4 Develop Ignition Criteria for a d-t, d-h and d-d plasma, and plot $N\tau$ vs T for each. Assume alpha-particle heating of the d-t plasma, alpha-particle and proton heating of the d-h plasma, and triton, proton and h heating of the d-d plasma

8.5 Derive-analogously to Eq. (8.28)-a more realistic MCF reactor criterion accounting also for cyclotron radiation losses Display graphically its temperature dependence, $N_e\tau_{E*}$ (T) for the two cases

(a) d-t: $N_d = N_t = N_e/2$, $T_i \approx T_e$, $\psi/N_e = 10^{-23}$ m^3, B = 5 T, η_{in} = 0.5 and η_{out} = 0.35;

(b) d-t: $N_d = N_t = N_i/2$, $T_i \approx T_e$, $\psi/N_e = 10^{-22}$ m^3, B = 10 T, η_{in} = 0.5 and η_{out} = 0.7;

Note: for the derivation of the criterion, use fractions of the ion density such that $N_j = \kappa_j N_i$ with j denoting the considered ion species. You should finally obtain.

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$$(N_e\tau_{E*})_{ab} > \frac{\frac{3}{2}\left(\frac{T_i}{\sum\kappa_j Z_j}+T_e\right)}{\frac{\eta_{in}\eta_{out}}{1-\eta_{in}\eta_{out}}\left[\frac{\kappa_a\kappa_b}{\sum\kappa_j Z_j}\frac{<\sigma v>_{ab}}{(1+\delta_{ab})}Q_{ab}-\frac{\sum\kappa_j Z_j^2}{\sum\kappa_j Z_j}A_{br}\sqrt{T_e}-A_{cyc}B^2\frac{\psi}{N_e}T_e\right]}$$

for j = a, b, impurities. Compare the plots from (a) and (b) with those that result if cyclotron radiation losses are neglected.

8.6 Discuss the physical differences between (i) the Lawson reactor criterion, (ii) the ignition criterion and (iii) the break-even condition. What fraction of the entire plasma loss power can be made up for by α-particle heating in steady state operation, when Q_p = 5 ?