§1. Reactor Size Optimization of LHD-Type Reactor FFHR2m

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The design parameters of the LHD-type helical reactor FFHR2 are modified to those of FFHR2m, as shown in Table 1 [1]. Figure 1 shows the 3D view of the FFHR2m1. The coil pitch parameter γ, which is defined by $(m/l)(a_c/R_c)$, is 1.15 in FFHR2m1 to expand the blanket space and to reduce electromagnetic force, while γ is 1.25 in FFHR2m2 with the inner shift of the plasma center as same as the standard condition in the present LHD. In both cases the major radius R is increased and the toroidal field B_0 is decreased within B_{max} of 13T. Then the blanket space is as wide as 1.2m, resulting in sufficient TBR and nuclear shielding for SC magnets. At the same time the wide maintenance ports are possible due to simplification of coil-supporting structures as shown in Fig.1 under the averaged stress level below 200MPa.

Figure 2 shows the major radius R dependences of capital cost on reactor construction, helical-coil (HC) supporting mass weight, COE (cost of electricity) and the magnetic field B_0 at the plasma center, which are normalized at the FFHR2 design (R = 10m) under the constraints of an ISS95 enhancement near 1.6 achieved in LHD, the maximum magnetic field B_{max} (13-15T) with the current density J (25-33 A/mm^2) and the neutron wall loading Γ (1.3-1.5MW/m^2) limited by the long-life STB blanket concept [1]. With increasing R (namely FFHR2, FFHR2m1 and FFHR2m2), B_0 can be reduced and COE decreases because of the increase of fusion output as listed in Table 1. On the other hand, the capital cost increases more slowly, because the mass of HC supporting structure increases only in proportion to $R^{0.4}$ due to the decrease of B_0 [2]. Therefore, a reactor size around 15m of R is the present candidate for FFHR designs within those conditions. R&D on SC magnet systems of large scale, high field and high current-density are new challenging targets based on the LHD.

Table 1. Design parameters of helical reactor

Design parameters			LHD	FFHR2	FFHR2m1	FFHR2m2
Polarity	l		2	2	2	2
Field periods	m		10	10	10	10
Coil pitch parameter	γ		1.25	1.15	1.15	1.25
Coil major Radius	R_c	m	3.9	10	14.0	17.3
Coil minor radius	a_c	m	0.98	2.3	3.22	4.33
Plasma major radius	R_p	m	3.75	10	14.0	16.0
Plasma radius	a_p	m	0.61	1.2	1.73	2.80
Blanket space	Δ	m	0.12	0.7	1.2	1.1
Magnetic field	B_0	T	4	10	6.18	4.43
Max. field on coils	B_{max}	T	9.2	15	13.3	13.0
Coil current density	j	MA/m^2	53	25	26.6	32.8
Weight of HC support		ton	400	2880	3020	3210
Magnetic energy		GJ	1.64	147	154	142
Fusion power	P_F	GW		1	1.9	3
Neutron wall load	Γ_n	MW/m^2		1.5	1.5	1.3
External heating power	P_{ext}	MW		70	80	100
α heating efficiency	η_α			0.7	0.9	0.9
Density lim.improvement				1	1.5	1.5
H factor of ISS95				2.40	1.92	1.76
Effective ion charge	Z_{eff}			1.40	1.34	1.35
Electron density	$n_e(0)$	10^19 m^{-3}		27.4	26.7	19.0
Temperature	$T_i(0)$	keV		21	15.8	16.1
Plasma beta	<β>	%		1.6	3.0	4.1
Plasma conduction loss	P_L	MW			290	463
Diverter heat load	Γ_{div}	MW/m^2			1.6	2.3
Total capital cost		G$		5.1	5.8	6.6
COE		Yen/kWh		21	13	9.5

Reference:
1) A.Sagara et al., Nuclear Fusion 45 (2005) 258-263.
2) S.Imagawa et al., Plasma Science and Technology, 7 (2005) 2626-2628.

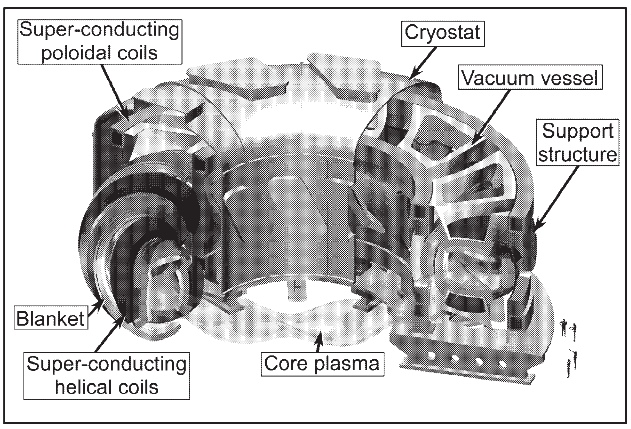

Fig.1. The 3D illustration of the FFHR2m1.

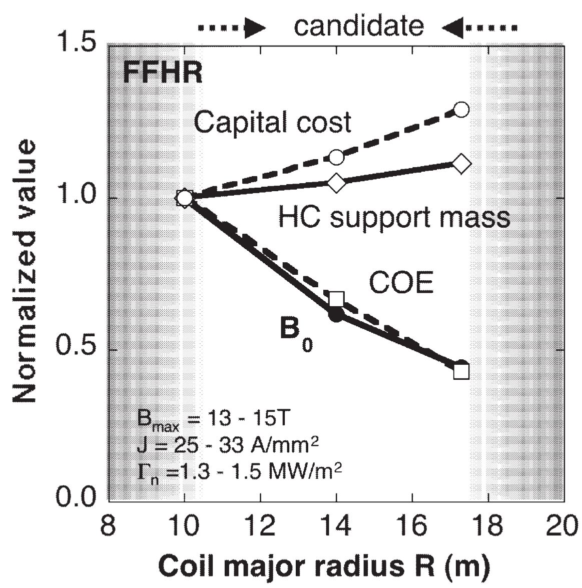

Fig.2 R dependences of the reactor capital cost, helical-coil supporting mass, cost of electricity and magnetic field B_0 at the plasma center, which are normalized at the FFHR2 design (R = 10m).