§1. Design Integration toward Optimization of LHD-type Fusion Reactor FFHR

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The recent activities have been devoted toward optimization of FFHR2m1 as a base design to clarify key issues, mainly focusing on blanket space, neutronics performance, large superconducting magnet system, and plasma operation. The design parameters of FFHR2 are listed in Table 1, which newly includes the recent results of cost evaluation based on the ITER (2003) design.

Three candidates to secure the blanket space are proposed with the aim of reactor size optimization without deteriorating α-heating efficiency. As shown in Fig.1, it is expected that there is an optimum size around R_c of 15 m by taking into account the cost of electricity (COE), the total capital cost, and engineering feasibility on large scaled magnets.

In this way the key engineering aspects are investigated; from 3D blanket designs, it is demonstrated that the peaking factor of the neutron wall loading is 1.2 to 1.3 and a blanket covering ratio of over 90% is effectively possible by a new proposal of Discrete Pumping with Semi-closed Shield (DPSS) concept as shown in Fig.2. This DPSS is very important not only to increase the total TBR over 1.2 but also to reduce the radiation effects on magnets. Helical blanket shaping along the divertor field lines is the next big issue. For large superconducting magnet systems under the maximum nuclear heating of 200W/m^3, cable-in conduit conductor (CICC) and alternative conductor designs are proposed with a robust design of cryogenic support posts.

For access to ignited plasmas, new methods are proposed, in which a long rise-up time over 300 s reduces the heating power to 30 MW and a new proportional integration derivative (PID) control of the fueling can handle the thermally unstable plasma at high density operation.

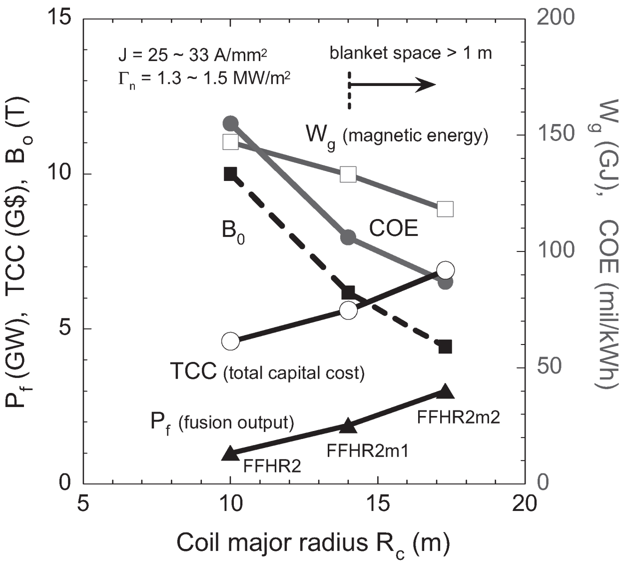

Fig.1. R_c dependences of the fusion output P_f, the total capital cost (TCC), magnetic field B_0 at the plasma center, cost of electricity (COE) and magnetic energy W_g under almost same conditions on neutron wall loading G and current density J of helical coils.

Table 1. Design parameters of helical reactor FFHR

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	1.24	1.73	2.80
Plasma volume	Vp	m^3	30	303	827	2471
Blanket space	Δ	m	0.12	0.7	1.1	1.15
Magnetic field	B_0	T	4	10	6.18	4.43
Max. field on coils	B_{max}	T	9.2	14.8	13.3	13.0
Coil current density	j	MA/m^2	53	25	26.6	32.8
Magnetic energy		GJ	1.64	147	133	118
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	$\langle\beta\rangle$	%		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$(2003)		4.6	5.6	6.9
COE		mill/kWh		155	106	87

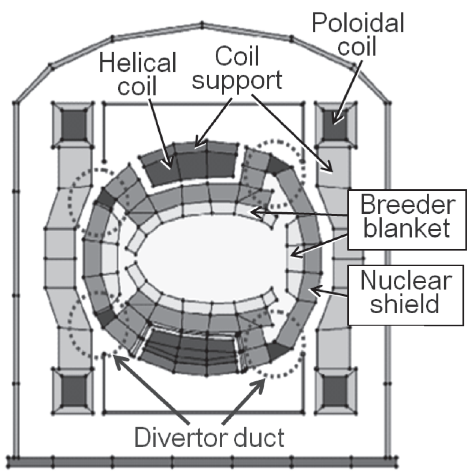

Fig.2 Discrete Pumping with Semi-closed Shield (DPSS) concept, where the helical divertor duct is almost closed being partly opened at only the discrete pumping ports.