§1. A LHD-type Compact Reactor FFHR-2

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The Force-Free like Helical Reactor, FFHR, is a demo relevant D-T fusion reactor, which has been designed on the basis of R&D results established in construction of the Large Helical Device LHD. Our present activity is at the first stage in Phase 1 for the concept definition.

This work focuses on design issues for reducing the size of LHD-type helical reactors [1]. It has already been pointed out that the distance from the plasma to the helical coils, δL, is the most important parameter since it determines the reactor size. In fact the thickness of tritium breeder blankets with nuclear shielding for superconducting magnets should be larger than 1m. However, δL decreases due to the increase of the SC coils thickness with increasing the toroidal magnetic field strength B_0, eventually limiting the reactor major radius, R, to about 15m or larger. Therefore, when we design a compact helical reactor having a high magnetic field, it is necessary to introduce innovative concepts on both of coils configurations and nuclear blanket systems.

The force-free concept applied in a $\ell=3$ system FFHR-1[2] is advantageous and applied again in this LHD-type ($\ell=2$, m=10, $\alpha=+0.1$) compact system FFHR-2 as shown in Table 1, where the reactor size of FFHR-2 is 2.5 times of LHD but a half of FFHR-1. By reducing the helical pitch parameter, $\gamma=(m/\ell)(ac/R)$, from 1.25 of LHD to 1.15, the clearance δL increases about 20 times of LHD. At this time, since the averaged minor radius hoop force on helical coils <f> normalized by $B_0 I_H$ is reduced to 73% of LHD, the high toroidal field B_0 of 10T is possible to use with innovative SC materials such as Nb_3Al or $(NbTi)_3Sn$. The POPCON ignition analysis using the LHD scaling with the LH transition scenario based on W7-AS results shows the low $<\beta>$ of 1.8% is enough with the confinement enhancement factor of 2.5.

In FFHR designs, molten-salt Flibe has been selected as a self-cooling tritium breeder from the main reason of safety: low tritium solubility, low reactivity with air and water, low pressure operation, and low MHD resistance which is compatible with our high magnetic field designs [2, 3].

A localized blanket (LB) concept is newly proposed as illustrated in Fig.1. In the coil-to-plasma space, there is installed the nuclear shielding of 50cm including the vacuum chamber of 20cm in thickness. At only the outer side the tritium breeder blanket of 30cm is placed. In the divertor region, there is located the breeder blanket, because this region has no limit for radial build and an efficiently thick blanket works as a strong absorber of neutrons. Since the tritium breeding is mainly due to the reaction of Li-6 with well thermalized neutrons, TBR is almost proportional to the breeder thickness. Replaceability of the breeder blankets is also well improved together with divertor targets which are designed to be cooled with Flibe. The He gas, which is used to sweep out permeated tritium in doubled tubes of the Flibe loop, is also used for cooling the nuclear shielding.

Reference

[1] A.Sagara et al., Proc. 17th IAEA Fusion Energy Conf., Yokohama, 1998, IAEA-CN-69 / FTP / 03(R).
[2] A. Sagara et al., Fusion Eng. and Design 41 (1998) 349.
[3] A. Sagara et al., J. Nucl. Mater. 258-263 (1998) 2079.

Table 1 LHD and FFHR design parameters.

Parameters	LHD	FFHR-1	FFHR-2
major radius : R	3.9	20	10 m
av. plasma radius : $<a_p>$	< 0.65	2	1.2 m
fusion power : Pf (GW)	-	3	1 GW
external heating power : Pex	< 20	100	100 MW
neutron wall loading : Pn	-	1.5	1.5 MW/m2
toroidal field on axis : B_0	4	12	10 T
average beta : $< \beta >$	> 5	0.7	1.8 %
enhancement factor of τ_{LHD}		1.5	2.5
plasma density : ne(0)	1.E2	2.E20	2.8E20 m-3
plasma temperature : Te(0)	> 10	22	27 keV
effective ion charge : Zeff	1.5	1.5	
alpha heating efficiency : $h\alpha$	-	0.7	0.7
alpha density fraction : $f\alpha$	-	0.05	0.05
synchrotron reflectivity : Reff	-	0.9	0.9
hole fraction : fh	-	0.1	0.1
av. heat load on divertor	< 10	1.6	1.5MW/m2
number of pole : ℓ	2	3	2
toroidal pitch number : m	10	18	10
pitch parameter : γ	1.12<1.25 <1.37	1	1.15
coil modulation : α	+ 0.1	0	+ 0.1
av. helical coil radius : $<a_c>$	0.975	3.33	2.30 m
coil to plasma clearance : δL	0.03	1.1	0.70 ~ 1.25 m
coil current : I_H	7.8	66.6	50 MA/coil
coil current density : J	(53)	27	25 A/mm2
max. field on coils : Bmax	(9.2)	16	13 T
stored magnetic energy	1.64	1290	147 GJ.
construction cost	50 Byen		

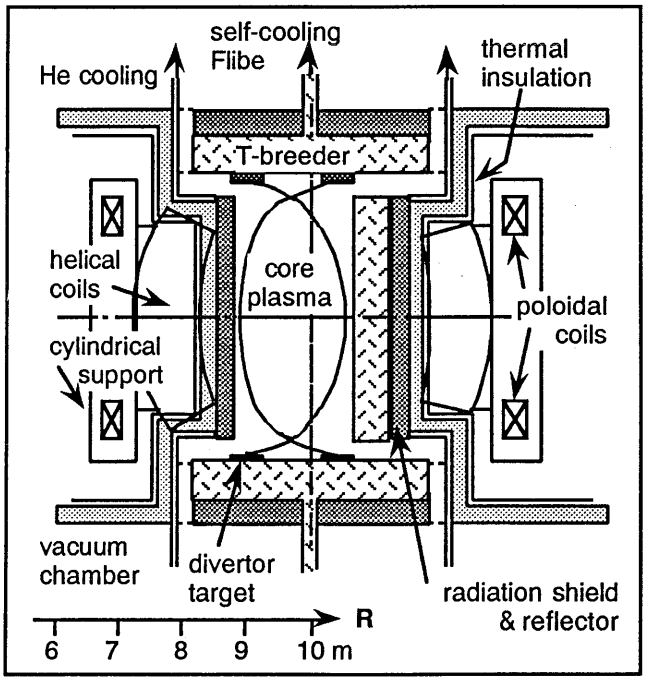

Fig. 1 Schematic illustration of FFHR-2.