Future of LHD-type Device

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The LHD is a superconducting heliotron/torsatron type device with l=2 (m=10).The main device parameters are: B = 3T, a major radius of 3.75 m, a minor radius of ~0.6 m, ι(0)/_(a) = ~0.5 /~1.0. The objective of the LHD project is demonstration of (i) high confinement helical plasma relevant to reactor, (ii) high beta plasma,(iii) steady state operation with reliable heat removal, particle(including impurity) control. Its experiment started in March 1998. The experiment results so far are very promising, such as significant enhancement of the energy confinement due to the edge thermal transport barrier. The maximum stored energy exceeds 700 kJ at beam power of 3.5 MW. The central electron temperature is 3.0 keV with pedestal temperature (T_e(_ =0.9)) of 1.0 keV has been observed (at n_e = 2.4_10^{19} m^{-3} and B = 2.75 T). The present emphasis of the LHD experiment is to demonstrate high performance of the helical plasma at high power. This requires high NBI power and confinement improvement possibly through the edge plasma control.

The heliotron type devices exist for many years, but it is still unexplored concept compared with tokamaks. Particularly the plasma behavior in collisionless, higher beta regime has not been studied yet. It has just started in the LHD experiment. Design of the LHD device is based on the old experimental results in smaller devices and theories. The design space was rather narrow due to conflicting requirements between MHD stability, equilibrium and particle orbit considerations. Recent experimental results will alter optimized configuration of the heliotron -type device if it is designed for future high performance burning plasma device. The CHS (a small version of the LHD) result shows that stable plasma exists even if the plasma pressure exceeds the Mercier limit (we hope that further experimental tests in the LHD will confirm it definitely). It has also been predicted that the plasma confinement is probably bad in the edge region where unfavorable curvature exists . On the contrary, LHD discharges exhibit very good edge confinement, resulting in formation of the pedestal, similar to that of tokamak H-mode. Furthermore, the LHD pedestal does not have unfavorable properties of the H-mode pedestal, such as ELM, excessive confinement of the particles. I expect that the LHD experiment will continue to generate the positive results, as it does now.

As to steady state issues, the main advantage of the helical device is free of many problems associated with plasma current, such as high circulating power for current drive and disruption. Even though current disruption does not exist, rapid loss of the stored energy might happen due to MHD instability at high beta (in the LHD experiment, no rapid transport loss has been observed so far. A clear answer fot it will be obtained within a few years). In the conventional design, the steady state issues other than current associated problems, such as reliable heat removal and erosion are nearly the same as the tokamak case except for complexity of component geometry. Erosion and codeposition issues are common to all the magnetic fusion concepts. Data from one device will be transferable to other device design. But they are not definitive since erosion and codeposition are expected to be sensitive to the detail of the configuration. In the LHD type configuration, there are many options of the divertor magnetic configuration. Since the core plasma performance is influenced by the edge particle control significantly and thus selection of the divertor configuration need to be done by overall considerations. As an attractive option, the poloidal coil system can be modified to convert the double null helical divertor into multiple bundle divertor for easy handling of the heat flux and efficient pumping. Such an edge option profoundly influences the core plasma performance (high temperature divertor operation)

Next Step LHD : If the LHD experiment continue to generate positive result as it does now, we have to consider Next Step LHD. It will be optimized in terms of physics and reactor engineering and will demonstrate high performance helical plasma, possibly ignition in a steady state.If ITER class device (burning steady state device) is built, it must be successful in a real sense. Otherwise it will be an end of the magnetic fusion program (it will be very difficult to persuade the public to build another “ITER” based on the different magnetic concept. Thus the selection of the concept of “ITER” need to be prudent. Such a concept must demonstrate the plasma performance,which convinces the fusion community that it will lead to ignition, or near ignition. It must not have any fatal flaw in terms of reactor engineering . In this contexts, tokamak and helical devices, both need a next step before the ITER, i.e, devices which address the above foundamental issues.

* Please note that the view presented here is personal one.