§22. Research on an Advanced Plasma Experiment Device with a Levitating Superconducting Coil

Ogawa, Y., Yoshida, Z., Himura, H., Nihei, H., Morikawa, J. (Univ. of Tokyo), Iwakuma, N. (Kyushu Univ.), Sumiyosi, F. (Kagoshima Univ.), Mito, T., Yanagi, N., Iwamoto, A., Maekawa, R.

Nonneutral plasma trapping with a toroidal device has many advantages in comparison with conventional linear device, and a proto type device (called Proto-RT) has been constructed and experiments of nonneutral plasma trapping has been carried out[1]. Electrons are injected into the toroidal device, and the buildup of the electric potential up to a few hundreds volts has been observed. Since nonneutrality of plasma yields a radial electric field, strong toroidal rotation is induced with the combination of the poloidal magnetic field. By introducing additional poloidal field with external poloidal coils and toroidal field, it is also possible to study trapping properties of nonneutral plasma for various configurations of magnetic surface.

Since the internal ring of the Proto-RT device is made of normal copper coil, the device should be equipped with the coil current feeder and the coil support rod, which intersect with the magnetic surface. Therefore, the life time of nonneutral plasmas might be limited by the interaction with these concrete obstacles. If the internal ring would be super-conducting levitating coil, we are free from these problems. In addition, relatively strong magnetic field might be available with the super-conducting coil, since the coil current density could be increased.

We have mainly two purposes with this internal ring coil device; one is nonneutral plasma trapping, and another is ultra high beta plasma confinement. S.M. Mahajan and Z. Yoshida have found a new relaxed state under the strong plasma flow, and claim that the confinement of the extremely high beta plasma might be possible[2]. This internal ring device is quite feasible to study this new relaxed state.

Here we have designed a toroidal device with a levitated super-conducting internal coil for the nonneutral plasma trapping experiments. From the viewpoints of plasma experiments and machine operation, high temperature (high-Tc) super-conducting coil seems to be very attractive. Advantages of high-Tc super-conducting coils are large heat capacity, which yields high power and/or long pulse plasma heating experiments, and high cooling efficiency of refrigerator, which makes it easy to maintain machine and to reduce operation cost. We have, therefore, paid much attention to the feasibility of the high-Tc super-conducting conductors as the levitated internal ring coil.

The basic specification of the levitated internal ring coil is as follows; the major radius of the coil is 40 cm, and the coil current is 500 kAT. The minor radius of the coil might be around 10 cm. The maximum magnetic field strength is estimated to be ~ 2T around the conductor. It is expected that the internal ring coil is levitating during a few hours or more.

At present, a Bi-2223 Ag-sheathed multifilamentary wire seems to be a most promising candidate for high magnetic field coil. Bi-2223 is a thin tape (typically, 3.5mm X 0.24mm) and the critical current density strongly deteriorates as the magnetic field is increased at the relatively high temperature regime (e.g., T > 40 K). There exists a residual voltage of the high-Tc super-conducting coil, and n-value around the critical current density is relatively small. We should, therefore, pay attention to the coil current decay due to the residual voltage.

Operation temperature regime is set to be between 20K to 40K or less. During levitating operation for a few hours the heat input energy to the levitated internal ring coil should be compensated with the temperature increase of the structural materials of the coil.

Based on these considerations and fabrication experiences, a levitated coil has been designed with a high-Tc super-conducting cable. Basic parameters are listed in Table I.

conductor size :	0.3mm x 3.5 mm
total turns : 250 x 25 = 6,250 turns	(15.7km in total)
conductor current :	Iop = 80 A
operation temperature :	T = 30 K
stored energy of the coil :	Wmag = 145 kJ
maximum field :Br,max = 1.68 T	Bz,max = 2.23 T
total resistance of coil :	R_{Ω}=2.8 μΩ
→ flow loss :	Q_{flow} = 17.9 W
→ current decay time :	τ = 4.5 hours

Table I. Design Parameters of High Tc Coil

References

1) Yoshida, Z., *et al.*, 17th IAEA Fusion Energy Conference, Yokohama, 1998, IAEA-CN-69/ICP/10(R).

2) Mahajan, S.M. and Yoshida, Z., Phys. Rev. Lett., **81**, (1998) 4863.