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System Design of Circulating Liquid Metal Coil for Protecting Laser Beam Ports and Laser Sources
レーザー核融合に用いる光源防御用の循環式液体金属コイルシステムの開発

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A possible method for protecting beam ports and laser sources from alpha particles which are produced by a nuclear fusion in the Fast Ignition Laser Fusion Power Plant (KOTO-Fast) is proposed. A dipolar magnetic field generated by a coil installed at the tip of the beam port is used for protecting the alpha particles coming into the inside of the beam port and colliding to the tip surface of the beam port. The intensity of 0.9 [T] of the magnetic flux density at the tip of the beam port is large enough for achieving the 10 % reduction of the collision energy of the alpha particles to the tip surface of the beam port compared with the case without protection. In the present study, a system design of circulating LiPb liquid metal coil is proposed. The temperature increase of LiPb liquid metal coil is estimated 11 K/shot in case for taking the joule heat of the coil current and heat load of the fusion into consideration. As a result, it is necessary to circulate all of the liquid metal in the coil for one time per 22 seconds. The required flow rate in the circulation system is estimated around 1 m^3/h.

1. Introduction

The laser fusion power plant (KOYO-F) driven with cooled-Yb:YAG, ceramic lasers was conceptually designed by Norimatsu et al.[1] The design of this reactor is based on the Fast-Ignition scheme. The KOYO-F is a more realistic power generation plant with smaller power output than the previous plant KOYO [2]. As a protection of the first wall, LiPb liquid wall chamber has been proposed. In our past research [3], we proposed a method of protection from fusion-produced alpha particles by using an artificial magnetic field generated by the LiPb liquid metal coil. We conducted a numerical simulation for evaluating the reduction of alpha particles by changing intensity and configuration of the magnetic field.

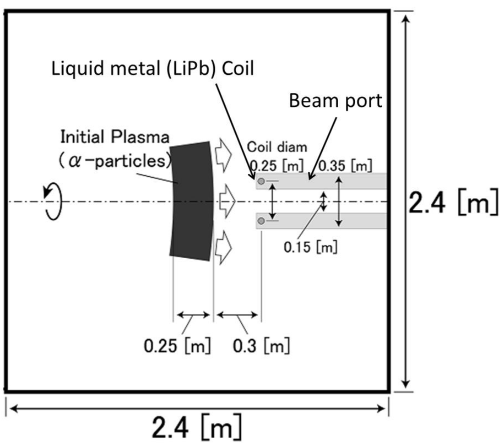

Fig. 1 Simulation Model [3]

Simulation model is shown in Fig. 1. The targeted reduction level of alpha particles is less than 10 % of the load without protection by the magnetic field. As a result, the intensity of 0.9 [T] of magnetic flux density at the tip of beam port is large enough for achieving the 10 % reduction. In the present study, a system design of circulating LiPb liquid metal coil was proposed.

2. System design of circulating LiPb liquid metal coil

In the nuclear power plant KOYO-F, LiPb liquid wall chamber is used. So the liquid metal conductor in the present coil system also adopts the same LiPb metal since the total system of the power plant becomes simple. Figure 2 shows the configuration of the LiPb liquid metal coil installed at the tip of the beam port. The coil diameter is decided by the size of the beam port. The pipe for the liquid metal coil is used the SiC in order to prevent the radioactivation from the neutron irradiation by the fusion reaction.

The amount of alpha particles produced by the nuclear fusion near the beam port is calculated based on the fusion energy of 200 [MJ/shot] in KOYO-F. The required coil current estimated by the past numerical simulation is 190 [kA turn] for producing the magnetic flux density 0.9 [T] at the center of the coil. The temperature increase of LiPb liquid metal coil is estimated 11 K/shot in case for taking the joule heat of coil current and heat load of the fusion into consideration. As a result, it is necessary to circulate all of the liquid metal in a coil for one time per 22 seconds. The required flow rate is estimated around 1 [m^3/h].

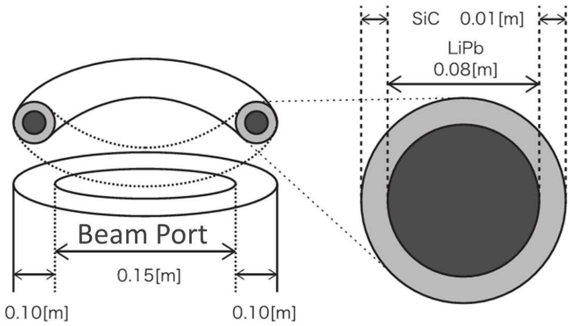

Fig. 2 Configuration of Liquid metal coil

Figure 3 shows the conceptual design of the circulating liquid metal coil system. For the circulation of the liquid metal LiPb for one time per 22 seconds, the single-entry pump and solenoid valve are required. In order to exchange the heat load of the liquid metal in the coil, the heat exchanger is also required. It is necessary to install some tanks in the way of equipment for absorbing a pressure change in the connecting pipes. The equipment mentioned above is selected to satisfy the system requirement.

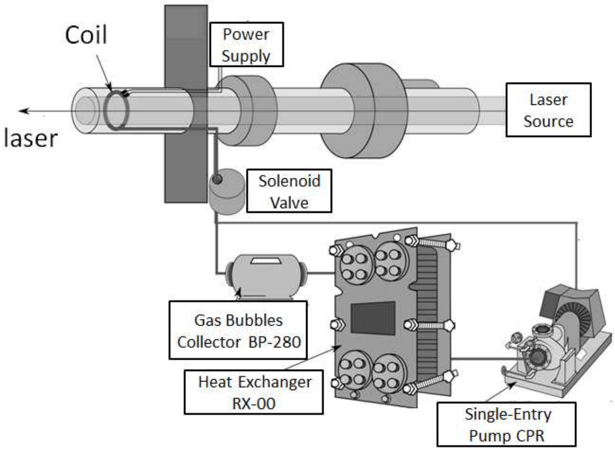

Fig. 3 Design of the circulating liquid metal coil system.

4. Summary and Future Plan

In the present study, the system design of circulating LiPb liquid metal coil was proposed. The temperature increase of LiPb liquid metal coil is estimated 11 K/shot in case for taking the joule heat of coil current and heat load of fusion into consideration. As a result, it is necessary to circulate all of the liquid metal in a coil for one time per 22 seconds. The required flow rate is estimated around 1 m^3/h.

Now we are under preparation of the experimental setup for electrical current test of liquid metal coil. It is easy for the electrical current test to use the liquid metal at ordinary temperatures. After we confirm whether the required magnetic field strength 0.9 [T] at the center of the coil can be obtained by the electrical current test, we are going to start the experimental setup for circulating the liquid metal in the coil.

References

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