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Study on Maintenance, Recycle, and Radioactive Waste Management of Fusion Reactor
Part I: Brief introduction of a new committee
核融合炉の保守・リサイクル・バックエンド対策に関する検討
１．趣旨説明

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A fusion reactor will generate 14 MeV neutrons after Deuterium-Tritium fusion reaction. The neutron will activate structural materials surrounding the plasma and the residual radioactivity will make the maintenance more difficult. When a disassembly of the fusion reactor would be foreseen, the recycle of the structural and functional materials would warrant serious consideration. Also, waste management is really important. To discuss the radioactive issues including decommissioning of the fusion reactor, a new committee established in the society. The presentation will introduce the outline of the activity.

1. Background

A fusion reactor will realize deuterium-tritium (D-T) reaction in high temperature and high density plasma which will generate 14 MeV neutrons and 3.5 MeV alpha particles as shown in equation (1).

$$D + T \Rightarrow n\ (14.1\ MeV) + \alpha\ (3.5\ MeV) \qquad (1)$$

Since the α particle is positively charged, it will remain in the plasma and the energy of 3.5 MeV will be released to the deuterium or tritium in the plasma resulting in raising the temperature of the plasma. The kinetic energy of 14 MeV which is carried by the neutron will be changed to thermal neutron when it collides with an atom in structural materials or coolant materials. The atoms which accepted one neutron will become radio isotopes. In case of emitting nuclide, it will emit alpha ray, beta ray, gamma ray or neutron.

Therefore, the maintenance of the fusion reactor must be carried out in such a radioactive environment. Since workers are not able to come in the highly activated area, the specific particular maintenance procedures must be considered and the design of the reactor must be performed taking into account such maintenance scenario.

Regarding the neutron reaction, the following tritium production process must be noted.

$$^{6}Li + n \Rightarrow T + \alpha + 4.8\ MeV \qquad (2)$$
$$^{7}Li + n \Rightarrow n' + T + \alpha - 2.5\ MeV \qquad (3)$$

The 14 MeV neutron came out of the plasma will hit lithium in the blanket and it produces tritium which will become a fuel for D-T reaction shown in equation (1). Since the tritium must be produced by the fusion reactor itself, the above reactions are really important to continue the D-T operation.

To produce tritium effectively, the neutron would be amplified using neutron amplify effect of beryllium and lead. Those reactions are written as follows:

$$^{9}Be + n \Rightarrow 2\ n + 2\ \alpha - 1.7\ MeV \qquad (4)$$
$$^{A}Pb + n \Rightarrow 2\ n + {}^{(A-1)}Pb - 7\ MeV \qquad (5)$$

From these reactions, one would understand that two neutrons will be obtained by hitting one neutron with one beryllium or lead atom. In case of beryllium, helium will be generated.

Since the neutron amplifier and the tritium multiplying will be performed in the blanket, the blanket materials will be activated. Also, diverters will be installed in the plasma vacuum vessel to control content of impurities in the plasma and high energy charged-particles will fly into diverter plates along magnetic fluxes. The heat load of the plate will become order of 10 MW/m^2 and must endure the thermal shocks by plasma disruption and ELM phenomenon. There blankets and diverters will be replaced during the reactor life because of the material deterioration by the neutron irradiation and the high energy particle collision.

During the operation of the fusion reactor, some radioactive waste will generate in gaseous, in liquid and in solid state. The waste management during operation must be included in the maintenance works and the practical scenario must be established.

The fusion reactor is destined to end the role of the production of fusion energy. The operation will end after a certain operation period (for example, 30 years). When the decommissioning will be carried out, the activated materials must be treated with a special attitude.

To discuss the above items, a new committee was established in The Japan Society of Plasma Science and Nuclear Fusion Research (JSPF) as a study group. This symposium will be carried out to present the topics concerning the radioactive issues in the fusion reactor and have fruitful discussions.

2. Target of Activity

The committee will specify a series of process regarding the activated equipments and materials. The equipments will be as follows:

Blanket, diverter, instrumentations in the reactor. Tritium plants. Hot cell. Plasma heating facilities. Water cooling system. Air conditioning system.

By focusing on the reactor itself, maintenance items during operation will be summarized. It will include the outline of the maintenance process, the replacement of the blanket and diverter cassettes and instrumentations, the transportation of these cassettes, the decontamination and the disassembly of the activated equipments, the disposal of highly activated materials and the recycle of the slightly activated materials. The low revel detecting and filtering system for the water cooling and air conditioning will also be touched.

Image of the facility to perform above works will be created and commoditizing of the concept will be practiced. It will be a trial activity to carry out such categorizing and imaging though out the life of the fusion reactor with an industrial and a technological sense.

In the first stage, the radiation issue of the fusion reactor will be broad overviewed. And the hot cell will be taken up to investigate the role and a conceptual trial design will be performed.

After the activities in a few years, it is under consideration to produce drafts of a plant specification and/or a guideline for the facility.

3. Committee Members

The committee consists of 11 researchers at present. The member and the affiliation are as follows:

Arata NISHIMURA (NIFS),
Shinzaburo MATSUDA (Univ. of Tokyo),
Toshio FUJISHIRO (RIST),
Yuji HATANO (Toyama Univ.),
Satoshi YANAGIHARA (Univ. of Fukui),
Kenichi FUKUMOTO (Univ. of Fukui),
Teruya TANAKA (NIFS),
Takumi HAYASHI (JAEA),
Kenji TOBITA (JAEA),
Hisashi TANIGAWA (JAEA),
Takashi KATO (Nikki JGC).

The member was determined based on the working field. Drs. T. Fujishiro and S. Yanagihara were welcome as an expert of decommissioning of the fission reactor. Prof. Y. Hatano and Dr. T. Hayashi are experts of the tritium experiments. Prof. K. Fukumoto is a specialist of neutron irradiation on structural materials and now is working for the safety of the fission reactor. Prof. T. Tanaka is working in neutronics and for a blanket design. Dr. H. Tanigawa is an expert of ITER blanket and Dr. K. Tobita has performed design activities of the fusion reactor. Dr. K. Kato is working for the fusion reactor design.

The committee will continue the discussion in two years at least and make a report on "Maintenance, Recycle, and Radioactive Waste Management of Fusion Reactor."

4. Structure of Symposium

The symposium will consist of two parts. The first part will have 5 short presentations including a brief introduction. In these talks, the present status and future works will be explained. The second part will be a general discussion among attendants chaired by Dr. S. Matsuda. The questions and comments on the radioactive structure, equipments, materials, processing and managements and so on are welcome and the scheme of the near future works will be formed based on the discussion.

The following presentations are scheduled:

1. Brief introduction of a new committee by Arata Nishimura. (10 min.)
2. Whole image of radioactive maintenance target by Takumi Hayashi. (15 min.)
3. Accumulation and removal of tritium by Yuji Hatano. (15 min.)
4. Outline of recycle scenario by Kenji Tobita. (15 min.)
5. Decommissioning and radioactive waste management by Satoshi Yanagihara. (15 min.)
6. General discussion among attendants chaired by Shinzaburo Matsuda. (20 min.)