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SCIENCE DIRECT
Fusion Engineering and Design 81 (2006) 13–24
Fusion Engineering and Design
www.elsevier.com/locate/fusengdes

Overview of research and development activities on fusion nuclear technologies in Japan

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Received 9 May 2005; received in revised form 5 July 2005; accepted 5 July 2005
Available online 20 December 2005

Abstract

Strategy and research and development activities (R&Ds) on fusion nuclear technologies in Japan are reviewed. The fusion program of Japan places a clear stress on energy oriented R&Ds in two areas: those directly to ITER and those for high performance and more challenging options of fusion nuclear technology (FNT) components and systems. Collaboration between Japan Atomic Energy Research Institute (JAERI), universities, National Institute for Fusion Science (NIFS) and industries was strongly encouraged to attain the goal. Recent activities including development of solid and liquid breeding blankets and other FNT issues like PMI, tritium process, fusion safety, inertial fusion and modeling, are summarized, and it is stressed that fusion researchers in Japan concentrate on the development of ITER and eventually for fruition of fusion reactor.

Keywords: Fusion nuclear technology (FNT); Fusion program; Blanket engineering; Fuel processing system; Fusion safety; Reactor system design

1. Introduction

The Council for Science and Technology Policy (CSTP) of Japan, chaired by the prime minister and responsible for the entire science and technology policy in Japan, emphasizes the importance of energy development for the national economy and security as well as from global environmental aspects. Atomic Energy Commission of Japan regards fusion as an important basic program that is expected to lead to a candidate of an innovative energy technology in the future.

The world fusion program is now opening a new era for operation and exploitation of ITER, where the scientific and technological feasibility of fusion energy for peaceful purposes will be demonstrated through experimentation of burning plasmas integrated with key reactor technologies. ITER is the first 'nuclear' tokamak reactor in the world, bridging the gap between currently operating 'non-nuclear' large tokamaks and a first demonstration fusion power plant (DEMO). Fusion nuclear technologies (FNTs) will play an essential role in the ITER program.

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0920-3796/$ – see front matter © 2005 Published by Elsevier B.V.
doi:10.1016/j.fusengdes.2005.07.025

In expectation that the construction of ITER will be initiated shortly, the ITER facility will be made operational in the middle of 2010's and its technical objectives will be met in early 2020s. Research and development on FNT in Japan will be implemented extensively through: participating in ITER Joint Implementation to demonstrate technologies essential to DEMO in an integrated system; participating in the ITER test blanket module (TBM) program to examine performances of the proposed breeding blankets; participating in accompanying FNT programs deemed necessary for DEMO; and deploying fundamental and academic programs for a wide spectrum of FNT issues, with a programmatic objective to establish a sound technical basis for DEMO in a timely and consistent manner.

The present paper overviews the strategy and R&D activities on FNT in Japan, and its program is introduced in Section 2. Sections 3 and 4 highlight recent achievements on the breeding blanket and structural materials; and for other FNT issues, respectively.

2. FNT research and development program of Japan

The fusion program of Japan has been implemented in accordance with the Third Phase Basic Program on Fusion R&Ds [1]. In line with the overall fusion program of Japan, the FNT program places a clear stress on energy-oriented R&Ds with the following two aspects: those directly related to ITER, and those for higher performances and more challenging options of FNT components and systems. Japan Atomic Energy Research Institute (JAERI) has been assigned in the Third Phase Basic Program as the organization responsible for the first aspect, while universities and National Institute for Fusion Science (NIFS) mainly cover the latter aspect.

The former category above includes, inter alia, safe and reliable operation of large-scaled tritium fuel processing system, sufficient radiation shielding by blankets to assure sound operation of superconducting magnet system, and reliable and long-lived plasma facing components (divertor and first wall) against high heat and particle loads. Technical information on these issues can be obtained through participation in the construction and operation of the ITER facility.

With regard to the R&Ds directly related to ITER, a wide spectrum of R&Ds have been accomplished during engineering design activities (EDA) and are on going as a part of ITER transitional arrangements (ITA), as described in Section 4, to support the construction and operation of ITER. JAERI, as domestic agency, will make in kind contributions for the FNT components, as agreed by the parties, and preparations for key components procurement are in progress in collaboration with the ITER team and domestic industries

The breeding blanket is an essential component to realize fusion energy utilization. The fusion program of Japan stipulates that JAERI is responsible for the development of base line breeding blanket concepts (water-cooled, solid breeder pebble bed with reduced activation ferritic/martensitic steel (RAFM) as a structural material) in collaboration with universities and NIFS. On the other hand, NIFS and universities explore more advanced and challenging blanket concepts, such as liquid or high temperature gas-cooled blankets, as well as cover discipline-based researches to support the above development, in various fields of the blanket technology. Extensive R&Ds have been conducted on solid breeding blanket concepts so as to introduce the TBMs in ITER from the beginning of its operation. R&Ds on alternative and advanced blanket options are also in progress with an objective to realizing the TBMs in ITER.

In Japan, basic policy of ITER safety regulation was established by the ITER Safety Regulation Working Group of the Ministry of Education, Culture, Sports, Science and Technology (MEXT) in November 2002, based on some key documents published in the past [2]. The Working Group issued a final report on a fundamental approach to ensure ITER safety as well as on basic procedures to confirm ITER safety for construction, operation and decommissioning, on the basis of safety features of ITER.

An ad hoc working group of MEXT discussed future direction of national fusion research and issued a report in January 2003, where centralized fusion research program was elaborated with a list of four specific programs of the highest priority. Development of the breeding blankets and structural materials, including International Fusion Materials Irradiation Facility-Engineering Validation and Engineering Design Activities (IFMIF-EVEDA), is in the list of the highest priority for the evaluation of materials compatibility for