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Japanese contribution to the DEMO-R&D program under the Broader Approach activities

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ABSTRACT

Several technical R&D activities mainly related to the blanket materials are newly launched as a part of the Broader Approach (BA) activities, which was initiated by the EU and Japan. According to the common interests for these parties in DEMO, R&Ds on reduced activation ferritic/martensitic (RAFM) steels as structural material, SiC_f/SiC composites as a flow channel insert material and/or alternative structural material, advanced tritium breeders and neutron multipliers, and tritium technology are carried out through the BA DEMO R&D program, in order to establish the technical bases on the blanket materials and the tritium technology required for DEMO design. This paper describes overall schedule of those R&D activities and recent progress in Japan carried out by JAEA as the domestic implementing agency on BA, collaborating with Japanese universities and other research institutes.

1. Introduction

In parallel to the ITER program, Broader Approach (BA) activities [1] are being initiated by the EU and Japan, aiming at early realization of the fusion energy. The BA activities include the International Fusion Materials Irradiation Facility-Engineering Validation and Engineering Design Activities (IFMIF-EVEDA) [2], the International Fusion Energy Research Center (IFERC), and the Satellite Tokamak [3]. As a part of the IFERC project, several technical R&D activities [4] mainly related to blanket materials are newly launched for DEMO.

The breeding blanket is the most important component in DEMO. In addition to R&D on one of the most promising blanket types, the pebbles bed concept [5,6], parties are pursuing also R&D on more advanced concept such as a helium cooled lithium lead blanket concept [6]. According to the common interests of these parties in DEMO, R&Ds on reduced activation ferritic/martensitic (RAFM) steels [7,8] as structural material, SiC_f/SiC composites [9] as a flow channel insert material and/or alternative structural material, advanced tritium breeders [10] and neutron multipliers [11], and tritium technology relevant to the DEMO operational condition are carried out through the BA DEMO R&D program.

2. Objectives and schedule

Overall schedule is shown in Fig. 1. The BA DEMO R&D activity is divided to phases 1 and 2. In phase 1 [4], preparation of R&D equipment to be installed at the Rokkasho BA site and preliminary R&D using existing facilities was carried out. In phase 2, substantial R&D will be implemented by the EU and Japan. Round robin experiments and joint work at the Rokkasho BA site are also planed.

Reduced activation ferritic/martensitic (RAFM) steels are considered as main candidate materials for structural applications in DEMO. For the manufacture and operation of DEMO, engineering databases of RAFM steels including irradiation effects are indispensable. The objectives on RAFM steel R&D are (1) establishment of the fabrication technology including joining technology, (2) modeling of irradiation effects on mechanical properties and micro-structural evolution, and (3) modeling of the thermo-mechanical deformation and radiation induced swelling.

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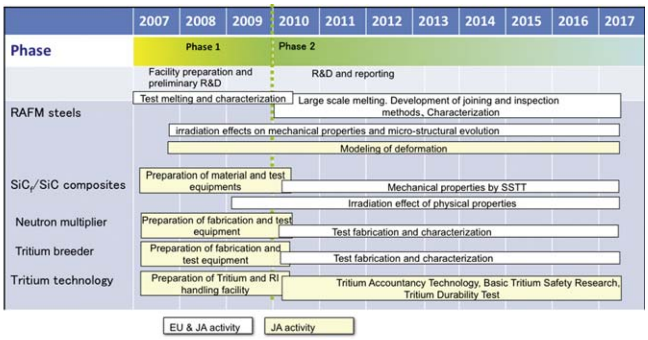

Fig. 1. Overall schedule of the BA DEMO R&D activity.

Recently, SiC_f/SiC composites can be regarded as a potential candidate material of the DEMO reactor, not only for a flow channel insert in liquid breeder blanket but also for structural components. In the BA, (1) test standards and material database of mechanical properties of SiC_f/SiC composites and (2) material database of physical/chemical properties of non-irradiated and irradiated SiC_f/SiC composites will be developed.

Neutron multipliers with lower swelling and higher stability at high temperature compared with present metal beryllium are desired in pebble bed blankets for DEMO. Beryllides such as $Be_{12}Ti$ and $Be_{12}V$ are the most promising advanced neutron multipliers. However, presently available beryllide is too brittle material to produce pebbles. Here we are aiming at the establishment of production technique for beryllides and the pebbles despite the extreme brittleness of beryllides.

JA and EU, Li_2TiO_3 and Li_4SiO_4 pebbles are candidate of the tritium breeder in the DEMO blankets, respectively. We are aiming at the establishment of scalable and reliable production technique of tritium breeders for DEMO.

The tritium technology is one of the most significant subjects for fusion DEMO plants, where a continuous or quasi-continuous operation is required for the main fuel and the blanket tritium loops. Here we subject the development of monitoring and analysis technique of tritium in these loops. Also a basic tritium behavior database such as solubility, diffusivity, permeability, will be developed.

3. Recent progress in Japan

The construction of the R&D building at the BA Rokkasho site was completed March 2010. Now the test equipments are under installation. Intensive R&D will start at Rokkasho soon. In parallel to the construction, preliminary R&Ds have been carried out by JAEA, which is a Japanese implementing agency for the BA, collaborating with Japanese universities and other research institutes.

3.1. RAFM steels

A 5-ton melting of F82H (F82H-BA07) was performed recently, with Electro Slag Re-melting (ESR) as the secondary melting process. The ESR-produced ingot was forged to square bar shaped slabs with 400 mm × 150 mm cross-section. Plates of F82H with various thicknesses (15–90 mm) were fabricated from forged F82H-BA07 [4]. The detailed evaluation of F82H-BA07 heat was started on mechanical properties such as tensile, Charpy impact, fatigue, and creep properties. As shown in Fig. 2, 15 mm thick plates of the F82H-BA07 heat have equivalent performance to the F82H-IEA heat [12] on its high temperature strength. Also it was found the F82H-BA07 has better high cycle fatigue life than the F82H-IEA produced by Japan, which is reporter in Ref. [13].

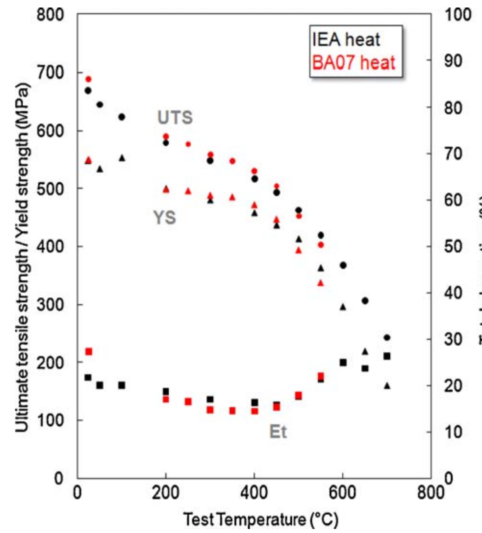

Fig. 2. Tensile properties of F82H-BA07 and F82H-IEA heats.

On the joining technology, various welding methods, such as Tungsten inert gas (TIG), electron beam (EB), Yttrium–Aluminum–Garnet (YAG) laser and fiber laser welding, have been assessed on hot/cold cracking sensitivity, residual stress, etc., for the F82H-BA07. There is little or no susceptibility to solidification cracking of F82H with small impact of Ta content, compared with that of stainless steels [13]. Also in case of the EB welding for 45 mm thick plate, typical thickness of the heat affected zone was 1.8 mm.

3.2. SiC_f/SiC composites

On the mechanical properties, critical failure parameters for the failure evaluation have been investigated first of all and acoustic emission (AE) technique has been applied to the failure detection. Fig. 3 shows the tensile strain and cumulative AE events as a function of the tensile stress for a chemical vapor infiltration (CVI)-SiC_f/SiC composite plate. The AE technique detected failure events at about 40% smaller stress than the proportional limit stress, showing that the AE technique has a potential to detect failure events before the proportional stress limit.

On the fundamental physical properties, electric conductivity of chemical vapor deposition (CVD)-SiC has been investigated

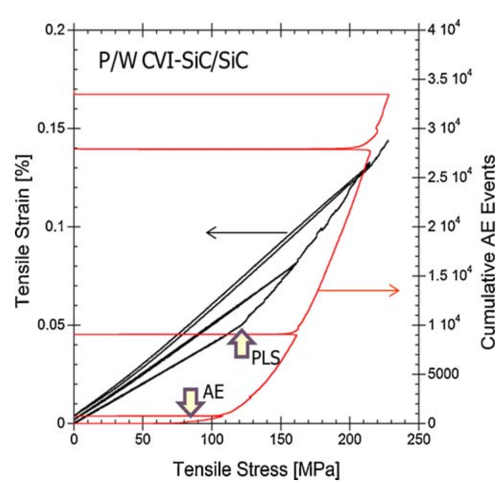

Fig. 3. Tensile strain and cumulative AE events as a function of the tensile stress. Here PLS is a proportional limit stress.