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Improvement of IFMIF/EVEDA bayonet concept back-plate design

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ABSTRACT

In the frame of the Engineering Validation and Engineering Design Activities (EVEDA) phase of the International Fusion Materials Irradiation Facility (IFMIF) project, a supporting lithium loop has been designed and is currently under construction at Oarai (Japan) with the main objective to test several technological solutions to be adopted in the future IFMIF plant. Among these, the lithium target system represents one of the most critical components as it will be exposed to high-energy intense neutron flux and consequently to severe irradiation damage rates (up to 60 dpa/fpy). For this reason, it must be designed for periodic replacement. The solution proposed by ENEA is based on the so-called back-plate bayonet concept which consists of a replaceable element that can be inserted to and removed from the permanent structure of the target assembly by means of a sliding-skate mechanism. Recently, the design of the bayonet back-plate has been revised and some important modifications have been introduced in order to improve its functionality and optimize its features in terms of compactness, robustness and remote maintainability. Several design solutions have been conceived to achieve better performance including smaller overall dimensions, sealing load reduction, gasket retention system improvement, positioning and centering effectiveness and optimized detachment mechanism. Moreover, a new variable-curvature geometry for the lithium channel profile has been calculated using an analytic approach based on the simplified Navier–Stokes equations in order to avoid the fluid dynamic instabilities evidenced in the old profile. In this paper, the new design features of the back-plate are presented, along with the main outcomes obtained from the engineering assessment performed so far.

1. Introduction

The neutron source of International Fusion Materials Irradiation Facility (IFMIF) is based on neutron stripping which occurs when an accelerated beam of deuterons impinges on a free surface flow of lithium. In order to guide the lithium flow in an hydraulically acceptable way, the so called *back-wall* or *back-plate* is placed behind it. In the frame of the Engineering Validation and Engineering Design Activities (EVEDA) phase of the IFMIF project, a lithium test loop is under construction at the Oarai site in Japan to support and validate the technological solutions to be adopted in the future IFMIF plant. Among these, the back-plate (BP) represents one of the most critical components as it will be exposed to a high-energy intense neutron flux and consequently to severe irradiation damage rates (up to 60 dpa/fpy). Within the EVEDA lithium test loop project, ENEA is in charge for the design and manufacture of one of the two BP concepts to be qualified for IFMIF. This is the removable BP concept as alternative to the integrated concept developed by the Japan Atomic Energy Agency (JAEA). The integrated concept requires that, when the back plate is dangerously degraded, due to the effects of neutron irradiation and exposure to high velocity liquid metal flow, the whole target assembly, including the integrated back plate, is replaced. On the other hand, the replaceable concept foresees that only the back plate is replaced, while the rest of the target assembly, being less exposed to neutron irradiation, can survive for a longer time. The weight and the cost of the BP, with respect to the entire target assembly, is one order of magnitude smaller, so limiting the nuclear waste build up and making easier the replacement operations. The solution proposed by ENEA to implement the removable BP concept is based on the so-called back-plate bayonet concept. It consists of a fixed plate (the so-called interface frame), the removable back plate, the tightening mechanisms contained in the lateral guides, the gasket and the tightening bolts. The frame has to be welded to the rest of the target assembly and represents the fixed interface of the flanged connection. The fixed frame and the removable back plate are internally shaped with the inner hydraulic profile for the lithium flow.

2. Engineering design

2.1. Mechanical and technological design

Several designs of the IFMIF/EVEDA removable BP have been developed by ENEA through the years in an effort to constantly

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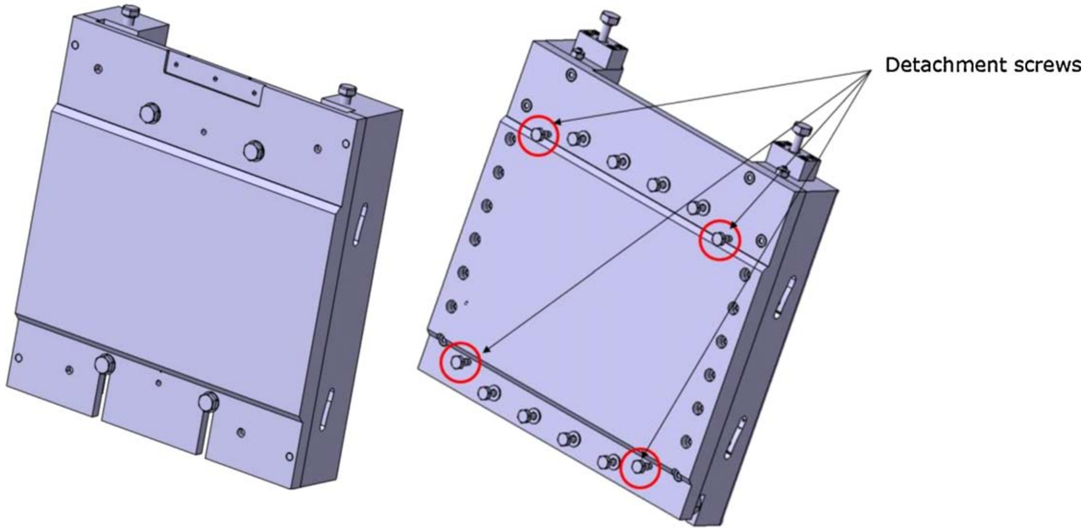

Fig. 1. Previous (left) and actual (right) design of ENEA bayonet BP (back side).

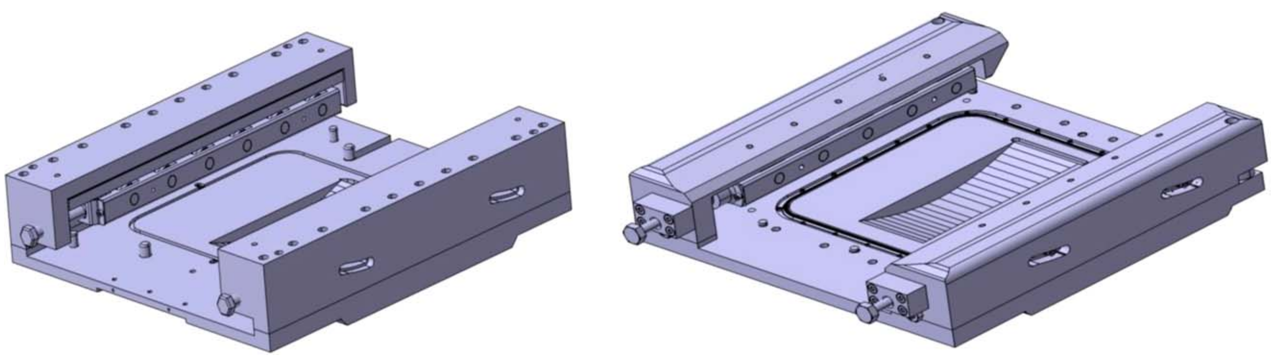

Fig. 2. Previous (left) and actual (right) design of ENEA bayonet BP (front side).

improve the technological and mechanical solutions and to optimize the engineering concepts. A new version of such design has been recently proposed, which presents various improvements with respect to the previous solution [1]. A comparison of the two designs is shown in Figs. 1 and 2.

A significant reduction of the BP overall dimensions have been achieved in order to improve the thermo-mechanical behavior, to increase the stiffness of the structure and to limit the weight. A new design for the lateral L-shaped elements with shorter length and a reduced number of rollers (from six in the previous design to five in the new design) has been proposed to guarantee a higher robustness and to facilitate insertion and extraction of the BP (see Fig. 2). The sharp profiles at the lower edge of the L elements have been smoothed so to avoid blockage during insertion (Fig. 3). Moreover, two rollers of the same type of those installed in the sliding skates have been introduced laterally to guide the BP during insertion and extraction operations. The central pins on which the rollers are mounted (perpendicular to the BP plane) serves also as alignment element for the L-shaped parts. Four pins working as spacers have been placed on the BP front to prevent its contact with the frame and therefore to avoid damage of the gasket during insertion/removal phases. As shown in Fig. 1, eight bolts instead of four have been adopted to supply the sealing closure force on the upper and lower parts of the BP. Although this choice might have some impact on the remote handling operations and strategy, it is justified by the need to obtain a more uniform pressure on the gasket perimeter and to reduce the tightening load on the bolts.

In addition, four screws have been added to aid the detachment of the BP from the frame during replacement operation. This is necessary since lithium penetrations in the interface between BP and frame can lead to a very high sticking force (of the order of tons) on the two components. The exact evaluation of such force and the effectiveness of the proposed detachment system will be part of the engineering validation activities to be performed in the EVEDA lithium loop in Japan.

Among the major improvements, revised positioning and centering systems have been introduced in the design. Concerning positioning, two screws instead of fixed pins, have been adopted (see Fig. 4) to permit adjustment of the vertical BP position dur-

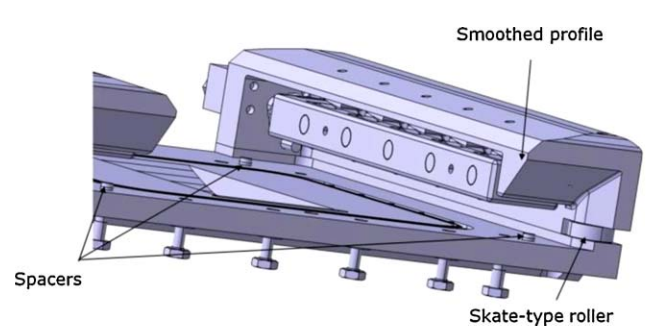

Fig. 3. Detail of the L-shape element design with rolling skates.