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Concept design of DEMO divertor cassette remote handling: Simply supported beam approach

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HIGHLIGHTS

- The present work focused on a new approach to the design of DEMO Divertor Cassette Remote Handling Equipment.
- The work provides an alternative approach to the design based on the concept of a simply supported beam.
- The approach proposed focuses a Divertor Cassette mover that performs the maintenance of the three cassettes at each port.
- First rough dimensioning of the main components has been provided and demonstrating the feasibility of the design solutions.
- The main idea of the work consisted on a design capable to use knowledge already adopted in industrial contexts.

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ABSTRACT

The present work focused on the development of a new approach to the concept design of DEMO Divertor Cassette (DC) Remote Handling Equipment (RHE). The approach is based on three main assumptions: the DC remote handling activities and the equipment shall be simplified as much as possible; technologies well known and consolidated in the industrial context can be adopted also in the nuclear fusion field; the design of the RHE should be based on a simply supported beam approach instead of cantilever approach. In detail, during the maintenance activities the barycentre of the DC is centred with respect to DC supports. This solution could simplify the design of RHE with a consequent reduction of the design and development costs. Moreover also the DC remote handling tasks shall be simplified in order to better manage the DC maintenance processes. For this reason the DC assembly and disassembly process has been simplified dividing the main sequences in basic movements. For each movement a dedicated tool has been conceived.

1. Introduction

One important objective of the EU fusion roadmap Horizon 2020 is to develop a conceptual design of a demonstration fusion power reactor (DEMO) to follow ITER. Most nations involved in the construction of ITER view DEMO as the last step towards the actual exploitation of fusion power [1]. DEMO could be defined an industrial facility in the sense that it shall be able to generate electricity to the grid. Due to this the main design driver will be maximizing of DEMO availability. In this context one of the most important activities is design and management of DEMO maintenance. A key DEMO maintenance activity is the complete exchange of the Divertor Cassette (DC) system at scheduled intervals. The DEMO DC replacement lifetime is assumed to be ~2 full power year (fpy). In the 20 year lifetime of DEMO reactor, which is equivalent to 6 fpy at 30% availability, ~2 Divertor replacements are foreseen [2]. For this reason the analysis of the feasibility of the DC remote maintenance is a driver activity in the maintenance design of the facility. Moreover the development of the remote maintenance system for DEMO will be driven by the need of minimizing plant down-time and maximizing its availability, in order to have a low cost electricity [3].

Due to this it will be necessary, already at the initial stage of the design, to evaluate all feasible approaches to the design of the DC Remote Handling Equipment (RHE). As aforementioned, the most important consideration is the availability and short down-times

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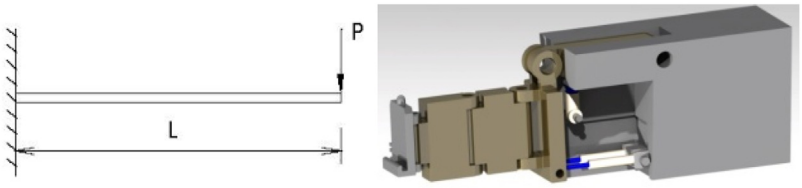

Fig. 1. Cantilever approach [5].

of the reactor. The availability is greatly affected by the efficiency of reactor maintenance. Avoiding complex operations in the vessel and reducing the complexity of the design of the components are the main guidelines.

DEMO tokamak in 2014 reference configuration [4] has sixteen ports for the DC maintenance. For each port three cassettes should be handled inside or outside of the vacuum vessel.

In the reference scenario, the DC maintenance port is inclined of a 45° angle.

The present work deals with the concept design of DEMO Divertor Cassette (DC) Remote Handling Equipment (RHE), with particular reference to the divertor mover. The work has been developed thanks to the consolidated collaboration between the University of Naples Federico II, the Remote Operation and Virtual Reality Centre Team (ROVir) at VTT Technical Research Centre of Finland and the ENEA Brasimone research centre.

To date a cantilever approach was already studied in [5]. According to the Systems Engineering approach the pre-concept design stage is the phase in which the design team has the opportunity to lead to new ideas which then could be developed into the initiation of a new project. A great deal of creative systems engineering is done in this exploratory stage, and the design team leading these studies is likely to follow a new idea into the concept stage. Often the Pre-Concept activities identify the enabling technologies [9]. Other studies on design of DC cassette of DEMO focused on the implementation of systematic approaches based on the systems engineering paradigms [6].

In this optic our work provides an alternative approach to the design of DEMO DC RHE, based on the concept of a simply supported beam. The paper focuses on the main concepts and ideas about the approach proposed. It is clear that the design here proposed has to be deeply investigated in future during a detailed design phase. Often the evaluation of different design solution in the pre-concept phase avoids recalls and rework in later stages. The present work does not presume to replace previous studies carried out on the RHE [5] but integrates them in optic of a Systems Engineering approach [9].

As practically the RHE design is driven by the assumption that during the remote handling tasks the DC centre of mass is always centred with respect to the DC supports. This aspect contributes to simplify the design of the RHE. Moreover technologies well known in industrial field can be used also in the design of the RHE. According to this approach the remote maintenance sequences are divided in simple tasks and for each task a dedicated remote handing tool has been provided.

2. Cantilever vs simply supported beam approach

Previous studies [5] have been developed on the design of RHE with a cantilever approach. This approach provides a DC mover that performs the maintenance of the three cassettes at each port. Once the reactor port is opened and the reactor is ready for maintenance intervention, the transportation cask with the remote handling equipment is docked to the port. The DC mover put the DC and DC end-effector inside the vacuum vessel through the 45° lower port [4]. Once the DC is inside the vacuum vessel, the DC end-effector

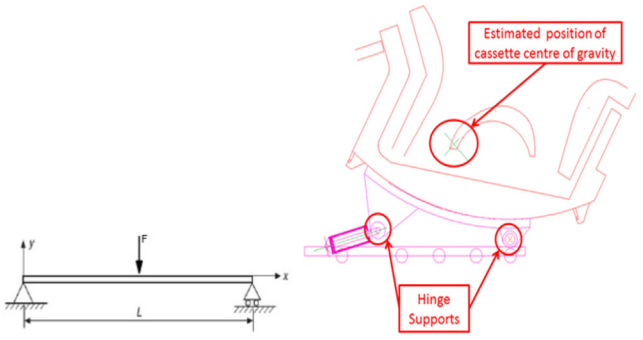

Fig. 2. Simply supported beam approach.

places the DC in position. This last task is the most critical from the DC mounting point of view. In detail the DC end-effector grabs the DC from one side, like a cantilever. Moreover the DC end-effector performs movements both radial and toroidal direction.

The end-effector is composed by a lifting arm (Fig. 1) linked to the DC mover by means of a rotational joint and a hydraulic actuator. In other words the toroidal movements of the DC are assured by rotational joints. This aspect could generate problems in the positioning of the DC from the point of view of the coupling tolerances between the DC and its supports. Due to this, appropriate rotational joints with high positioning accuracy shall be developed.

In the simply supported beam approach the DC barycentre is centred with respect to DC supports (Fig. 2).

From the conceptual point of view no rotational joints are needed in the DC radial and toroidal movements. The right positioning of the DC with respect to its in-vessel supports could be assured by mechanical stops. In the detailed design phase right tolerances of mechanical stops will be defined in order to guarantee the right positions of the DCs.

The main idea, on which is focused the present approach, consists in adapting technologies already well known in the industrial context, to the nuclear fusion field. Moreover, the DC assembly process has been simplified dividing the main assembly sequence in basic movements. For each movement a dedicated system has been developed.

Using this approach during the RH activities, any problems related to DC positioning could be easily identified and solved. Starting from the assumption that the DC is similar to the body of a truck (Fig. 3) and to a funicular railway (Fig. 4) in terms of mass and occupancy area, technologies used in the truck and railway industries can be adapted to the remote handling of DC.

2.1. Divertor cassettes maintenance

The assembly sequence was divided in simple steps. Each movement is done by a single system. This approach contributes to simplify the equipment dedicated to each motion. The DC assembly sequence is composed by three different motions:

- DC translation along 45° lower port axis