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Thermal analyses for the design of the ITER-NBI arc driven ion source

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Abstract

This paper is focused on the assessment of the thermal behaviour in nominal operating conditions of two components of the ITER-NBI ion source: the arc-discharge chamber and the filament cassette assembly. The study is based on hydraulic, thermo-mechanical and thermo-electrical calculations performed by means of 2D and 3D finite element (FE) models, with inputs coming partly from the ITER reference design documentation and partly from the design review activities presently in progress. The paper describes the results of the analyses, comparing the alternative cooling design with the reference one, and highlights some open issues that should be worked out before finalizing the design.

Keywords: Injector; Arc chamber; Finite element analyses

1. Introduction

The design of the first ITER NB Injector and the ITER NB Test Facility is presently in progress in the framework of EFDA contracts with the contribution of several European Associations. One of the components currently studied by Consorzio RFX is the arc driven negative ion source (Fig. 1), which is designed to produce a D^- beam of 40 A at 1 MeV for 3600 s pulses, generated in the ion source via a surface production process in a caesium-seeded arc-discharge of 790 kW total power.

The design of the ion source started with a review of the reference design [1] and was developed through a detailed activity of 3D CAD modelling and FE analyses.

The complete 3D CAD modelling of all the components of the beam source assembly (ion source and accelerator) was carried out to demonstrate the feasibility of the proposed design and to assess the installation and maintenance schemes presently foreseen.

The finite element analyses, described in the following sections, were carried out to verify the thermal behaviour in nominal operating conditions of two

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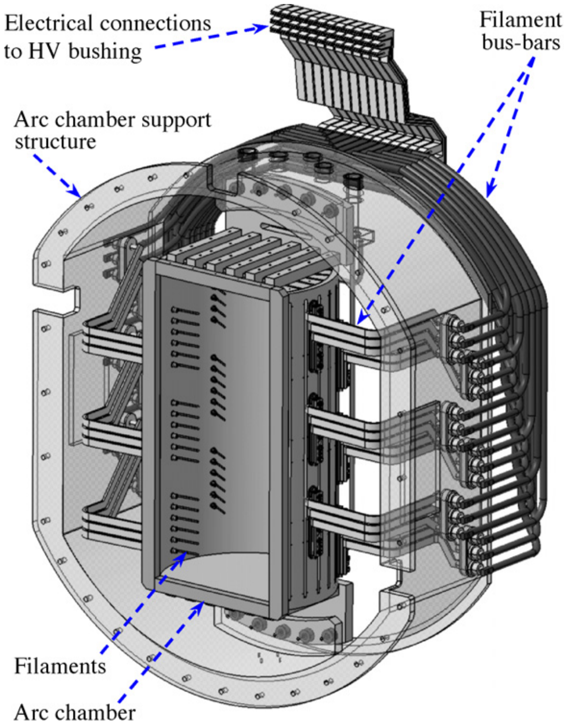

Fig. 1. 3D model of the arc driven ion source assembly. Extractor and ion source electrostatic shield are hidden for clarity.

components of the ITER-NBI ion source: the arc chamber and the filament cassette assembly.

2. Thermo-hydraulic and thermo-mechanical analyses of the arc chamber

2.1. Arc chamber description

The “KAMABOKO” shaped arc chamber [2–5] is made of oxygen-free high conductivity (OFHC) copper and is designed as described in ITER DDD5.3 [1]. Twenty columns of samarium–cobalt permanent magnets are embedded in the top and bottom lids and in the arc chamber wall with an angular pitch of 12° to form a line cusp magnetic configuration. Cooling channels with 10 mm internal diameter and a pitch of 40 mm are located on each side of the magnet columns in order to minimize the magnet temperature increase and to keep the inner wall temperature close to 40 °C. A preliminary assessment of the present design of the arc chamber has been completed considering hydraulic, thermal and mechanical aspects.

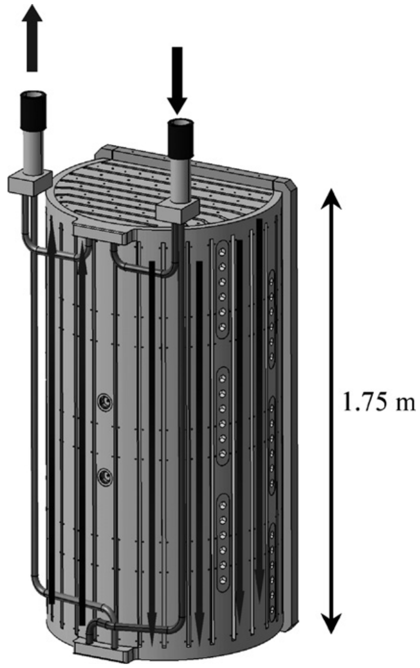

Fig. 2. CAD model of the arc chamber with inlet/outlet manifolds.

2.2. Hydraulic analyses of the cooling circuit

The cooling circuit of the arc chamber is split in two parts, each of them devoted to cool in series half of the chamber wall (right or left) and one lid (top or bottom). The two parts have common inlet and outlet manifolds as shown in Fig. 2.

3D FE hydraulic analyses of the circuit have been carried out to calculate pressure drops and water flow rates in the cooling channels, necessary to compute the heat transfer coefficients used in the following thermal analyses. The coolant parameters at the inlet are 2 MPa water pressure, 20 °C temperature. Three different total water flow rates have been considered: 15, 20 and 25 kg/s.

2.3. Thermal analyses

2.3.1. Operating conditions considered for the analyses

Several power distributions have been considered applied to the inner wall of the arc chamber to take into