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Thermo-mechanical design of the SINGAP accelerator grids for ITER NB injectors

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Abstract

The SINGle Aperture–SINgle GAP (SINGAP) accelerator for ITER neutral beam injector foresees four grids for the extraction and acceleration of negative ions, instead of the seven grids of the Multi-Aperture Multi-Grid (MAMuG) reference configuration.

The grids have to fulfil specific requirements coming from ion extraction, beam optics and thermo-mechanical issues.

This paper focuses on the thermo-hydraulic and thermo-mechanical design of the grids carried out by Consorzio RFX for the design of the first ITER NB injector and the ITER NB Test Facility. The cooling circuit design (position and shape of the channels) and the cooling parameters (water coolant temperatures, pressure and velocity) were optimized with sensitivity analyses in order to satisfy the grid functional requirements (temperatures, stresses, in plane and out of plane deformations). The design required a complete modelling of the grids and their support frames by means of 3D FE and CAD models.

Keywords: Injector; Negative ions; Accelerator; Grids; Design

1. Introduction

The four grids of the SINGAP beam source, shown in the sketch of Fig. 1, are: the plasma grid (PG), the extraction grid (EG), the pre-acceleration grid (PAG) and the grounded grid (GG) [1,2].

The design of the grids have to be a compromise optimization in order to fulfil in the meantime conflicting requirements coming from physics and engineering issues. For this reason several thermo-hydraulic and thermo-mechanical analyses have been carried out and the main results are presented in the following sections.

2. Description of grids design

The overall dimensions of the grids are about 1.6 m × 0.9 m. The PG, EG and PAG, shown in Fig. 2, have 1280 small apertures (about 15 mm diameter) and are fixed to the ion source with suitable electrical insulators. Each of these grids is vertically subdivided in four parts (0.4 m × 0.9 m) named segments. The GG shown in Fig. 3 has 16 large apertures. It is made of

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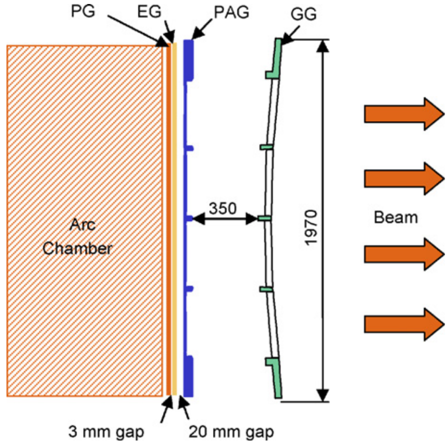

Fig. 1. Conceptual sketch of SINGAP grids.

a single OFHC Cu piece, sustained by a support and adjusting frame connected to the beam source vessel. The grids are heated during the beam pulses by power deposition (from ions and electrons) and by radiation [3,4]. In order to control the temperatures, four separate cooling circuits for the four grids allow an independent adjustment of the water flow rates and temperatures. The coolant is demineralized water. The inlet temperature and pressure of water are presently fixed at 55 °C and 2 MPa in the ITER reference design [5].

The PG segments are made of 6 mm thick molybdenum plates that cover the opening of the ion source chamber (arc driven or radio frequency driven) and are exposed to the source plasma. Water cooling pipes are housed inside horizontal grooves machined on the surface facing the plasma. In order to keep the average temperature of the grid in the range of 250–300 °C, low conductance thermal bridges connect the pipes to the molybdenum plate.

EG and PAG segments are made of electrodeposited OFHC copper. Magnets are embedded in grooves between adjacent apertures, while the cooling channels are horizontally located between the magnets and the heated surface facing the plasma grid as shown in Fig. 2c. The critical issues for these grids are the conflicting requirements coming from beam optics (small thickness and relatively large magnets) and the need of relatively large cooling channels to exhaust the heating power.

The GG is 70 mm thick and "V-shaped" in the vertical cross section to provide vertical beam groups

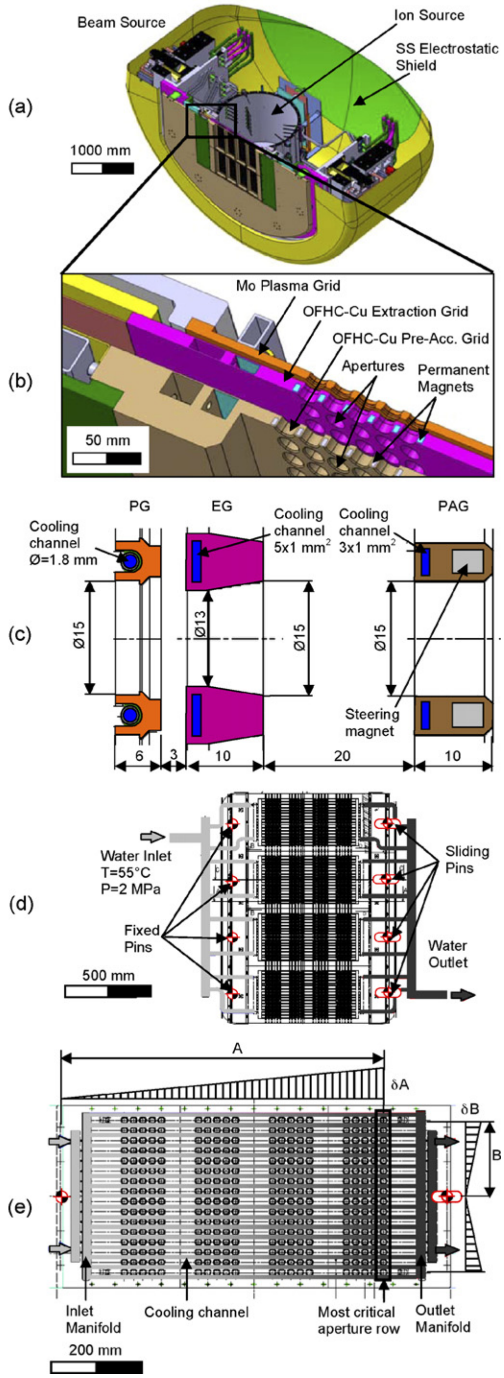

Fig. 2. Plasma, extraction and pre-acceleration grids: (a) beam source overview; (b) grids detail; (c) grids vertical section; (d) grid cooling scheme; (e) segment cooling scheme, with aperture shifts.