INNOVATIVE MECHANICAL SOLUTIONS FOR THE DESIGN OF THE HIGH INTENSITY PROTON INJECTOR FOR THE EUROPEAN SPALLATION SOURCE

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Abstract

The design of the 2.45 GHz, 0.1 T microwave discharge Proton Source for the European Spallation Source (PS-ESS) has required on-purpose solutions in order to maximize the beam brightness, keeping a very high reliability figure. The mitigation of maintenance issues has been the main guideline through the design phase to maximize the MTBF and minimize the MTTR. The mechanical design has been based on advanced solutions in order to reduce as much as possible the venting time for the plasma chamber, to facilitate the replacement of extraction electrodes and/or plasma chamber, and to simplify any after-maintenance alignment procedure. The paper will describe the strategy which has driven the design phase, the solutions adopted to fulfil the project goals and the results of the assembly phase recently concluded at INFN-LNS with successful first plasma.

INTRODUCTION

The Proton Source for ESS (PS-ESS) (see Fig. 1) was designed with a flexible magnetic system and a compact tetrode extraction system with the goal to minimize the emittance and the time needed for the maintenance operations [1].

The PS-ESS source body has been designed with the aim to fulfil the needs of an industrial installation. In particular, in order to maximize the MTBF and minimize the MTTR, the entire assembly has been designed by taking into account the allotted times for maintenance operations. In particular, efforts have been done to optimize the following operations:

- Source opening and closing procedures;
- Easy replacing of the extraction electrodes and plasma chamber;
- Automatic realignment of the plasma chamber on the extraction electrodes, after the maintenance operations;
- Easy replacement of the internal inserts of the matching water-cooled transformer which is used as impedance matching system, maintaining the same outer structure.

MECHANICAL DEVELOPMENT

Hereinafter a description of the mechanical solution adopted is presented for the subsystems constituting the body source. In particular, the extraction electrodes assembly, the suspension based on a pin junction and the water-cooled radiofrequency injection system will be described.

ESS Body Source

The body source is mechanically divided into two distinct parts as it is shown in Fig. 1:

- A movable part consisting of: injection system, plasma chamber, magnetic system and extraction column, called hereinafter "part A";
- A fixed part consisting of the extraction electrodes together with the first element of LEBT which also houses the vacuum instrumentations, called hereinafter "part B".

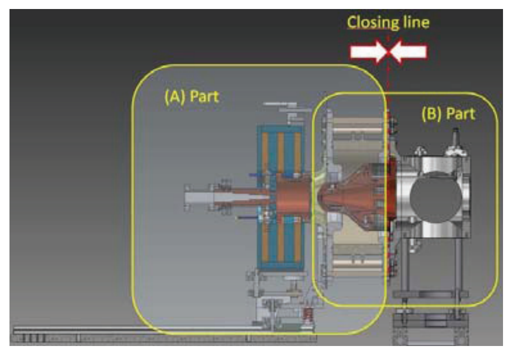

Figure 1: A view of the ESS source body totally assembled on its supports in the high voltage platform.

Part A

The part A consists of:

1) Insulating Al_2O_3 column
2) Oxygen Free High Conductivity Cu plasma chamber (OFHC)
3) RF waveguide and matching transformer
4) Magnetic system

Parts 1, 2 and 3 are rigidly joined together, and mounted on a single block supported on a "pin joint", as discussed in a next paragraph, which naturally allows several degrees of freedom.

On the other hand, the magnetic system is independent and it has an adjustable position.

The pin joint and the magnetic system can mutually translate along the beam line until the desired position.

Part B

The part B is composed by a stainless steel chamber, which is the first component of the LEBT, rigidly joined to the extraction electrode assembly. The first component is mechanically decoupled from the rest of the LEBT through

ISBN 978-3-95450-186-1

a bellow and it plays an important role in the alignment strategy.

The chamber is very compact (237 mm along the axis line) and it houses the outputs of the cooling channels for the electrodes, the feedthrough for the repeller electrode, the pumping groups and all the vacuum diagnostic components. This is the first element that need to be aligned because it includes the calibrated holes for the coupling with the part A (movable part) equipped with two conical pins.

Figure 2 represents the source body separated in its two parts.

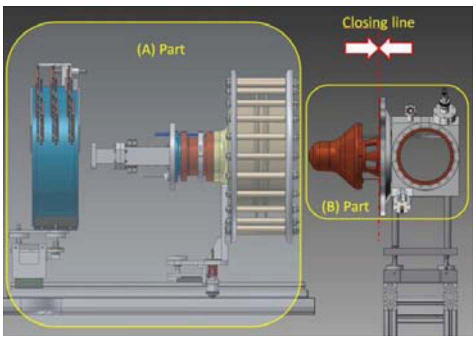

Figure 2: A view of the ESS source body with the extraction column open and with the magnetic system separated parts.

Extraction Electrodes Assembly

The cooled extraction electrodes assembly has been conceived as two separate blocks:

1) the three electrodes assembly which includes the first grounded electrode, the repeller electrode (with insulators) and the second grounded electrode (Fig. 3);
2) the support for part 1, water cooled and connected in the geometric and dimensional tolerance to the LEBT first element (Fig. 3).

The extraction electrodes unit has been designed for a really fast maintenance, preserving at the same time an optimal alignment even after replacing them with a new or regenerated set. This point can be reached thanks to a self-centering conical coupling with a cooled part fixed to the "first component" (see Fig. 1 and 2).

The latter is a key aspect of the mechanical design; in fact it gives the possibility of a quick change of the setup, by using different diameters or shapes of the electrodes; the cooling is obtained by conduction, taking advantage of the large contact surface that comes out from the tapering (see Fig. 3).

This represents a novelty for the ion source mechanical development.

Pin Joint

The "pin joint" has the important role of supporting the Al_2O_3 insulator, the plasma chamber, the RF waveguide; these components are rigidly mounted together in the geometric and dimensional tolerance, keeping them in the concentricity range of ± 0.1 mm.

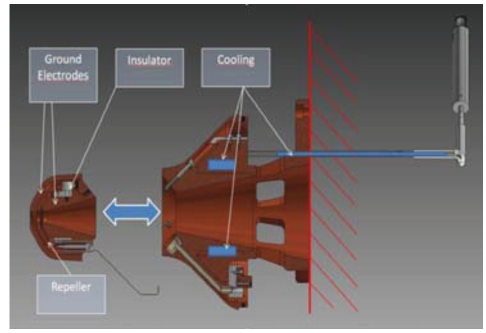

Figure 3: ESS extraction electrode unit: view of the main components and their assembling procedure.

Moreover, this pin joint allows to support and adjust the parts above mentioned in order to fit the position of the LEBT first element.

Looking at Fig. 4, it is evident that the entire load has several degrees of freedom that permit to find an easy and precise coupling with the fixed part "B" (see Fig. 1 and 2).

This suspension gives a very useful flexibility during both the commissioning phase and all the maintenance operations.

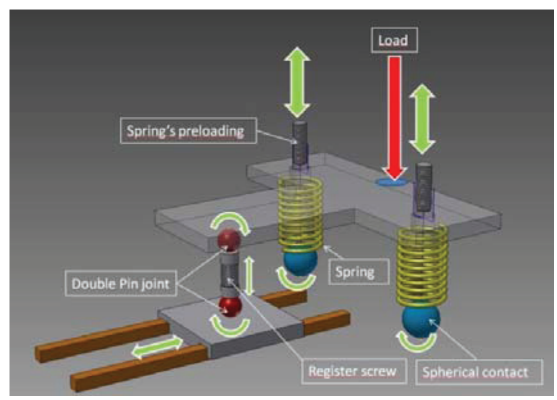

Figure 4: Suspension based on double pin joint.

In this type of suspension, the spherical double joint is really important because it compensates any eventual misalignments; it is equipped with an additional adjusting screw to fit to the theoretical position of the center of the "first component" already previously aligned. The entire system, also including springs and their adjusting screws, makes the system highly versatile and flexible, within 1 mm of diameter.

Moreover, this flexibility allows an automatic alignment because the system can ben rigidly connected to the fixed and already aligned extraction electrodes part.

Microwave Injection System

Even the water-cooled microwave waveguide provides the opportunity to easily change the step geometry to test

ISBN 978-3-95450-186-1

different profiles with the aim to optimize the coupling in operating conditions.

In Figure 5 it is possible to observe that the multisection matching transformer can be easily replaced and it can assume different geometries, the removable internal parts may be realized by using conventional machine tools without using the more complex electric discharge machining.

The matching transformer has also grooves for gaskets used for the cooling system and the vacuum tightness.

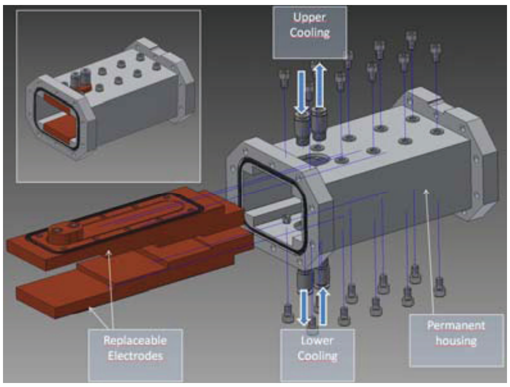

Figure 5: Matching transformer.

MECHANICAL ASSEMBLY AND FIRST TESTS

Figure 6 shows a picture of the two parts A and B before the final assembly of the full source including the insulating column and the extraction electrodes, the plasma chamber, the magnetic and extraction systems and the LEBT components. The first LEBT element houses the water and electrical connections for the repeller electrode, two turbo molecular pumps and vacuum gauges, gas inlet and the residual gas analyser.

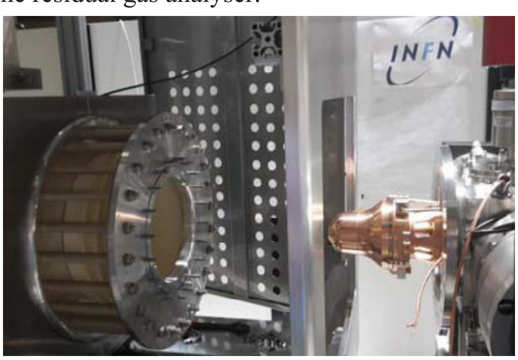

Figure 6: Proton source before the finally assembly of the extraction column.

The insulation of the extraction column and the vacuum tightness has been successfully verified through HV and vacuum leak tests. The extraction column (at operating pressure of $6 \cdot 10^{-6}$ mbar) has been tested without any sparks at 90 kV for 1h e 30' at 19.2 ◦C e 38% humidity level. These promising results have been obtained well above the nominal operating voltage of 75 kV.

The whole assembly has been successfully vacuum tested and the base pressure reached from a cold start is $5 \cdot 10^{-7}$ mbar in 12 hours.

CONCLUSION

The assembly of all mechanical parts was satisfactory for all points of view. The source is now fully assembled and the main disassembly procedure described in this work can be done without removing cooling pipes, sensors cables and all 500A cables of the magnetic system. This result allowed to satisfy the expected time for venting, replacing and mounting that are parts of the requirements specified in the contract signed between ESS and INFN. The plasma chamber conditioning is on-going and the test under thermal load is also satisfactory.

ACKNOWLEDGMENT

The authors would like to acknowledge the support of INFN technical staff and of the mechanical workshop for the valuable work done in the design and manufacturing of several items of the ESS setup.

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ISBN 978-3-95450-186-1