CONCEPTUAL DESIGN OF THE CRYOMODULE FOR THE TRASCO SC LINAC

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Abstract

On the basis of the experience gained from the design of the TTF cryostat, we present a conceptual design of the TRASCO 700 MHz cryomodule. The guidelines used for this design are: 1- a sliding cavity support that allows to install semi-rigid power couplers is used; 2- the cavity string, including couplers, is assembled in the clean room and pre-aligned outside the vacuum vessel. The alignment is kept during the cold mass assembly; 3- in order to increase the linac availability, each cryomodule is cryogenically independent. The results of the preliminary engineering design phase are discussed.

1 INTRODUCTION

The French-Italian collaboration (ASH and TRASCO) has developed a common design for a high intensity proton linac [1] to be used in an ADS system [2]. The design of the superconductive high-energy section consists of three different beta RF cavities[3] working at 704MHz in sub-cooled helium. The beam dynamic lattice[4] of the low beta section imposes a modularity based on two cavities string. The actual cryomodule design is in a preliminary phase but we already have many fixed guidelines.

2 SPECIAL REQUIREMENTS

2.1 ADS requirements

The design of the cryomodule was based mainly on the requirements of an ADS in term of reliability and system engineering. The cryomodule reliability is dominated by the vacuum (insulation, coupler and beam) system and by the helium cooling distribution. Fast access to the module and easy repairing, during maintenance time, complete the requirements. To achieve these requirements the cryomodules we are designing are completely independent from each other. The cryogenic transfer line runs along the modules string and the connection boxes link the modules to the helium supply. Vacuum ports and RF distribution have also their own connections. Each cryomodule can be physically separated from the line with no perturbation on the working condition of the others.

2.2 RF requirements

The discussions with the groups working on cavities and couplers development suggested other guidelines for the preliminary design. To ensure good RF cavity performances the cavities need to be completely assembled in good cleaning condition (at least class 100)[5] and all the connections to external ports have to be closed in the clean room. The power coupler is another critical component that needs to be completely assembled and closed in the clean room. These constraints result in the necessity of considerable clearance space to fix the cold mass (that is the cavity string with the couplers and the thermal shields) in the vacuum vessel. The operation has also to prevent the alignments.

3 COLD MASS, SUPPORTS AND VACUUM VESSEL

3.1 Cavity sliding supports

In the low and intermediate beta section of the linac two cavities compose a cavity string. The cavities are connected to a semi-rigid power coupler, so they need to slide during the cooldown to compensate for the thermal contraction.

The support studied is similar to the one of the TTF third generation cryostat. The cavities are supported by four parallel pads welded on the helium tank. The pads are used as the sliding surfaces. A fixture with rolling needles, loading springs and reference screws clamps the pad, leaving the longitudinal direction almost free [6]. To define the cavity cold position, the fixture nearest to the coupler is longitudinally fixed. The reference screws have the displacement freedom needed to align the cavity.

The total longitudinal compensation requested to this device is in the order of few millimetres (for the low beta section the computed contraction is 1.7mm, while for the higher beta section is 2.8mm). During cooldown the longitudinal movements can produce misalignments. A request of ±0.2 mm for vertical tolerances results in a required parallelism for the pad surfaces of 40mrad, that can be quite easily achieved during fabrication.

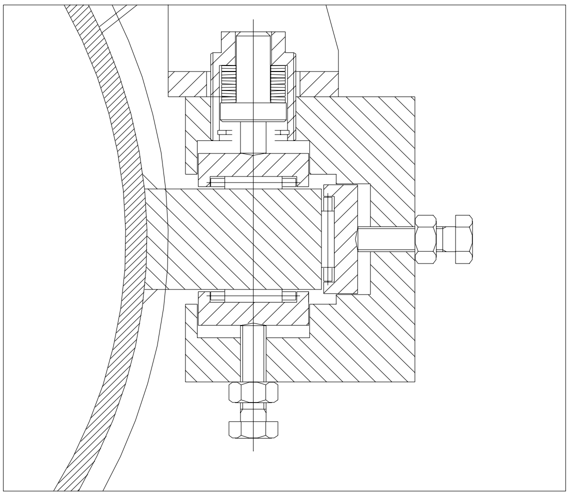

Figure 1: Cavity sliding fixture. The sliding pad is clamped by the rolling needles. Horizontal e vertical position is defined by reference screws. A spring loaded system (above) keeps the force on the needles constant.

The cavity sliding fixture is sketched in Fig.1. The reference screws and the loading springs press the needles on the central pad through a pivot joint (spherical head) to allow self compensation of the parallelism errors.

3.2 Cold-Warm transitions and thermal shields

The transition from the sliding fixture to the warm part of the module is done by fibreglass (G10 class) supports. The preliminary design of this component is presented in Fig. 2, together with its FEM model.

The fibreglass support is machined to a shape that fits the module cross section; the transition to the stainless steel sliding fixtures is actually screwed but a stiffer connection, based on an interference joint, is under development. To minimize the 2K losses, the support is thermalized at 30K-40K, at the intersection with the thermal shield, and a large vertical hole is machined on the body to reduce its thermal section while preserving the required mechanical stiffness. The actual design has a thermal load per support of 0.2W and 3 W, respectively at 2K and 30-40K.

The mechanical stability checks are derived from the TTF qualification of the composite support system[7]. Both the system response to a constant transverse load and its eigenfrequencies are computed. The deformation of a single support, induced by a transverse load, is 0.5 μm/N while the first natural eigenfrequencies of the support constrained at its own base are 343Hz and 519Hz.

As qualified in the TESLA cryomodules, the thermal shield is sustained by the G10 supports and actively cooled by a pressurized helium gas pipe, thermally connected to the panels by finger welding[9]. The shield is divided in two sections that are closed around the cavity string during the final assembly. Both copper and aluminium panels have been considered. On the basis of the experience gained with TESLA, we have preferred the self supporting aluminium solution instead of the copper one that can be based on thinner panels but needs a supporting frame.

Experience and calculations on the efficiency of MLI (Multi Layer Insulation) suggests the use of 30 layers. Materials and assembly procedure will be taken by the experience we gained during the TTF commissioning and operation [10].

3.3 Cavity string frame

The G10 supports of Fig. 2, which sustain the cavity string and the thermal shield, are fixed on a stiff stainless steel (SS) frame.

This frame stays at room temperature and provides the mechanical rigidity to the string. Three reference supports are used to reduce the deformations induced by gravity and external forces, while increasing the natural eigenfrequencies. A static deformation of 0.2mm, due to the weight of the cavity string, thermal shield and ancillaries, has been computed and the eigenfrequencies of the frame are all above 300Hz.

The frame supports consist of linear sleds and rails that allow the lateral movement of the whole frame preserving the cold mass alignment.

The frame is used as a reference for the alignment of the cavity string during the cold mass assembling, the alignment is achieved with the sliding supports regulation and it is referred to the frame. The alignment, preserved during the whole assembly of the cold mass, is then transposed to the vacuum vessel references.

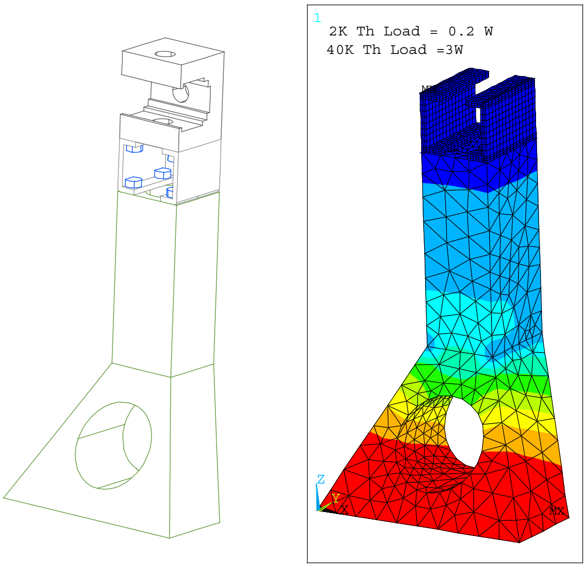

Figure 2: G10 cavity string support. A sliding fixture is mounted on each support by screws. The support is heat sunk to the thermal shield to minimize the 2K losses and its base is at room temperature. Computed thermal losses are 0.2Wat 2K and 3W at30-40K.

3.4 Vacuum vessel

The vacuum vessel provides the necessary connections of the cold mass, mainly vacuum and cryogenics. The requirement to assemble the string and the couplers in clean condition results in a space and clearance request. The definition of the procedure for the cold mass fitting into the vacuum vessel is critical because of the alignment that has to be preserved and transferred to the external references on the vacuum vessel. The solution of a flanged pipe vessel (like the TTF cryomodule) has been investigated but results in many complications and restrictions that could affect the couplers development. Instead, we preferred to develop a vessel design with a large lateral flange (Figure 3) that allows a lateral sliding of the cold mass fully assembled, including couplers, on the support frame.

The vessel sliding system consists of aligned rails designed on the sleds profile, to allow an easy lateral movement while the longitudinal direction is fully constrained. In the inner part of the vessel some reference surfaces are machined to define the rails seat and to reproduce the string alignment into the vessel.

The vessel is based on a standard 38'' pipe and its flanges, for couplers and cold mass insertion, are milling machined and referred to the external cryomodule references, together with the rail settings.

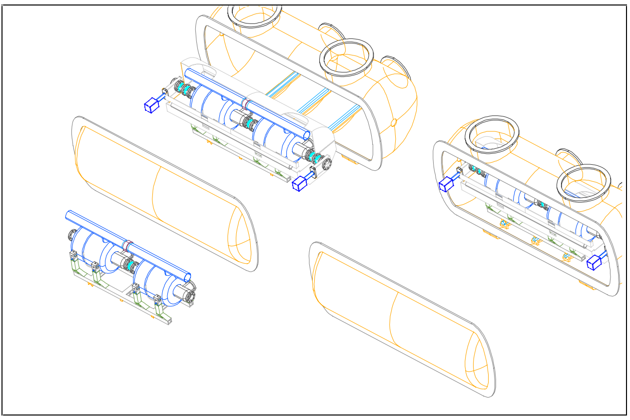

Figure 3: The cavities string (on the left) is assembled and closed in a class 100 clean room. System is aligned and cold mass is assembled. The rail-sled system allows to preserve alignment during the cold mass insertion into the vacuum vessel.

4 ASSEMBLING PROCEDURE AND ALIGNMENTS

Cavities and couplers are handled and cleaned in a class 10-100 clean room. The fully assembled string exits from the clean room with the beam line completely closed and under vacuum.

The string can then be fixed on the stainless steel frame witch has the G10 support and the lower part of the thermal shield already mounted. The frame is mounted on a movable desk that has a rail system similar to the one in the vessel and with exactly the same alignment references. Using the reference screws of the sliding feature the cavities string can be aligned with respect the reference planes of the assembling desk. Once aligned the cavity lateral and vertical position is fixed and preserved by the spring loaded system.

The longitudinal position is fixed near the coupler port to minimize the movements during the cooldown. Once the cold mass is completely assembled (Superinsulation is wrapped, shield are welded , sensor are connected and ancillary components are fixed) it is moved in front of the large flange of the vacuum vessel (figure 3). The vessel has three reference planes (machined when the axis of the vessel are defined) where the rail are univocally positioned and fixed. The rail position is the same of the ones on the desk where cavities were aligned. The system can now slide inside the vessel keeping its alignment. Once cold mass over the frame is inside the vessel, its position is fixed by screws.

The connections to the cryogenic ports and the fixing of the coupler flanges complete the assemble. The alignments references are moved, during the assembly, from the cavity string to the supporting frame and then to the vessel, for the module positioning in the linac tunnel.

These alignment and referring criteria have been applied and successfully tested during the fabrication, assembly and installation of the TTF cryomodules at DESY[10].

REFERENCES

[1] C. Pagani et al. “Upgrade of the TRASCO SC Linac Design at 700 MHz”, EPAC 2000 Vienna

[2] C. Pagani et al. “Scientific issue and status of Franco-Italian collaboration on the linear SC accelerator for ADS”, OECD-NEA 1999, Aux en Provence

[3] D. Barni et al. “SC Cavity Design for the 700 MHz TRASCO Linac”, EPAC 2000 Vienna

[4] P. Pierini et al. “Validation of the 700 MHz TRASCO SC Linac Design by Multiparticle Simulations”, EPAC 2000 Vienna

[5] C. Pagani et al. “Status and perspectives of the SC cavities for Tesla”, CEC 99 Montreal

[6] D. Barni et al. ”Friction measurements for sc cavity sliding supports in long cryostats”, CEC 99 Montreal

[7] C. Pagani et al. “Further improvements of the Tesla Test Facility (TTF) Cryostat in view of the Tesla Collider”, CEC 99 Montreal

[8] D. Barni et al. “Cooldown simulation for the Tesla Test Facility Cryostats”, Advance in cryogenic Engineering 43A p.315

[9] C. Pagani et al. “Design of the thermal shields for the new improved version of the TTF cryostat”, Advance in cryogenic Engineering 43A p.307

[10] C. Pagani et al. ”Construction, commissioning and cryogenic performances of the first tesla test facility (TTF) cryomodule”, Advance in Cryogenic Engineering 43A p. 87