DESIGN, FABRICATION AND TESTS OF THE SECOND PROTOTYPE OF THE DOUBLE-LENGTH CLIC PETS*

L. Sanchez#, J. Calero, D. Gavela, J.L. Gutierrez, F. Toral, CIEMAT, Madrid, Spain
D. Gudkov, G. Riddone, CERN, Geneva, Switzerland

Abstract

The future collider CLIC is based on a two-beam acceleration scheme, where the drive beam provides to the main beam the RF power through the Power Extraction and Transfer Structures (PETS). The technical feasibility of some components is currently being proved at the CLIC Experimental Area (CLEX). Two double-length CLIC PETS will be installed in CLEX to validate their performance with beam. The first prototype was produced and validated in 2012. This paper is focused on the engineering design, fabrication and validation of the second prototype. Taking into account the results of the first prototype, some modifications have been included in the design to ease fabrication and assembly. The fabrication techniques are very similar to the ones used for the first prototype. Mechanical measurements on single parts and different assembly stages will be reported. Finally, several tests such as vacuum tightness and RF measurements with low power have been realized to validate the device. These results are compared with the first prototype ones.

INTRODUCTION

The PETS is one of the most important components in the two-beam acceleration scheme of CLIC, since the RF power is generated in its periodic structure and transferred to the main beam [1]. Its engineering design is being widely developed through several stages and different PETS prototypes [2]. The double-length CLIC PETS was requested by CERN to generate the needed RF output power to feed with 65 MW the accelerating structures with the available beam current of 30A in the CLIC module (installed at CLEX) [3]. The present current in the drive beam at CLEX does not allow operating the two-beam module at parameters of CLIC (current of 100 A), so the active length of the structure had to be increased to compensate the lower available current.

The design, fabrication and validation of the double-length CLIC PETS presented here correspond to the second prototype manufactured at CIEMAT. The first prototype was successfully tested [4] but several design modifications has been carried out in order to ease manufacturing and assembly.

DESING MODIFICATIONS

The modifications in the PETS design will be exposed hereafter. A detailed explanation of materials selection, mechanical design, fabrication and joint techniques used can be found in a paper published previously [4].

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laura.sanchez@ciemat.es

PETS General Description

The PETS consists of eight Cu OFE rods with 79 regular cells. It includes RF ceramic absorbers of silicon carbide fixed by aluminium supports. The rods are joined by electron beam welding (EBW). The PETS also has two compact couplers to allow the power recirculation, cooling the whole structure and providing the external reference for aligning and fastening the PETS onto the CLIC module. Each compact coupler is composed of pieces made of OFE copper and 1.4429 grade stainless steel, joined by vacuum brazing. The joint between bars and couplers is made only by mechanical contact, supported by the outer tank. This tank (made of 1.4404 grade stainless steel) is joined by arc welding (TIG) to an additional stainless steel ring brazed to the coupler. An artistic view of the PETS is showed in Fig 1.

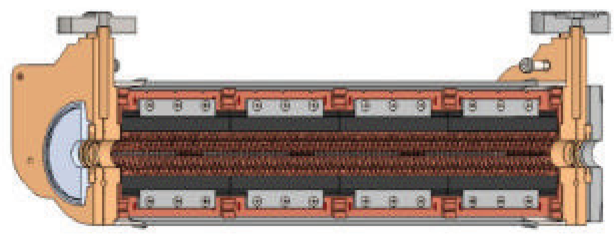

Figure 1: double-length CLIC PETS artistic view.

Design Modifications

As it has been commented previously, the PETS structure is supported by a vacuum tank welded to the compact couplers. The weld joint was designed to produce a contraction during welding suitable to guarantee electrical contact between the set of bars and compact couplers in their contact area, close to the beam hole.

Consequently the positioning of couplers and bars is a critical stage during assembly. Fig. 2 shows the contact area between both parts of the PETS. It can be observed that this area was relatively small, turning out to be more arduous to assemble than expected. For this reason dimensional modification was done in the second prototype:

- Increasing the contact area by increasing the outer diameter from 40.5 mm to 50.0 mm.
- Increasing the positioning step of the compact couplers and bars 0.85 mm in length.
- Relaxing dimension tolerances of the fitting.

As consequence the length of the bars had to be modified in order to keep constant the total length of the assembly.

In both sets of pieces, geometrical and superficial tolerances on these areas are very demanding, being 0.005

mm the required perpendicularity in the bars and 0.02 mm the flatness in the couplers. In both cases the superficial roughness (Ra) was 0.4 micron.

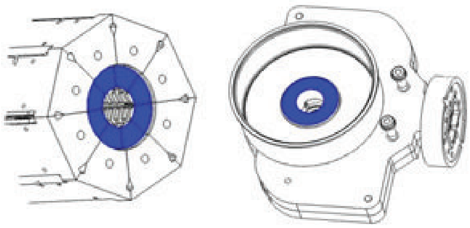

Figure 2: Contact areas between bars and couplers.

The increasing of the contact area between couplers and bars allowed a safer and more precise assembly, assuring the proper alignment with no re-machining of any part.

Other minor changes in the design were also implemented, such as relaxing the required tolerances for the pin/hole fitting of the couplers used for alignment during the brazing (from m_6/H_7 to k_6/E_6) and reducing the Ra roughness of the ceramic absorbers down to 0.8 micron (Ra compatible with UHV requirements).

SECOND PROTOTYPE MANUFACTURING AND ASSEMBLY

A detailed explanation of the manufacturing and assembly stages of the double length CLIC PETS can be found elsewhere [4].

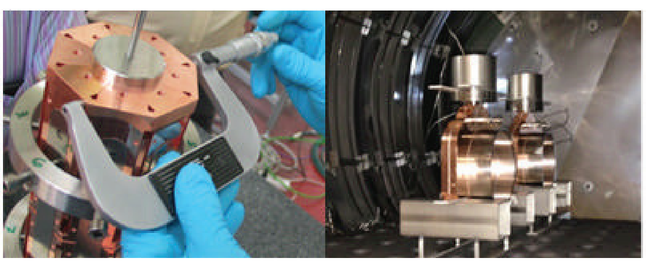

Figure 3: Dimensional checking during bars assembly (left) and compact couplers vacuum brazing (right).

It is important to note that dimensional and geometrical tolerances of individual parts and complete structure were similar to those achieved in the first prototype resulting that parts and final structure were within tolerances. These tolerances on the parts were achieved by means of precision machining using diamond tools and stress relieve heat treatments. The precision assembly was made by vacuum brazing, EBW and TIG welding, obtaining no significant deformation of the structure after assembling and with a parallelism of the couplers less than 0.01mm which is within the tolerance requirements.

As example, Fig.3 shows two steps of the manufacturing of the second PETS, such as bars mechanical assembly and compact couplers brazing.

Similarly to first PETS, helium leak tests were carried out on compact couplers and final structure, obtaining leak rates less than 10^{-13} Pa·m^3·s^{-1}. Fig. 4 shows the helium leak test after the final welding.

Figure 4: Assembled PETS and leak test.

RF MEASUREMENTS

Similarly to the first prototype, RF measurements were taken to verify the right performance of the structure. The most important parameter is the detuning respect the nominal frequency (11994 MHz).

RF Behaviour of Compact Couplers

S-parameters were measured on both compact couplers as Fig. 5 shows. Similar values of S-parameters were obtained for the first and second prototypes. Table 1 resumes the data taken at 11994 MHz.

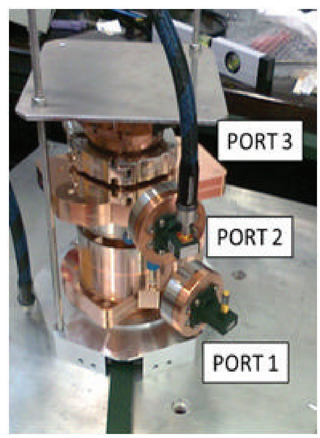

Figure 5: RF measurements on compact couplers.

Table 1: S-parameters of the PETS Couplers

S(dB)	1st PETS	2nd PETS
S_{11}	-39.28	-38.3
S_{22}	-37.90	-39.8
S_{12}	-0.29	-0.25
S_{13}	-41.34	-33.1
S_{23}	-41.14	-35.3

It is worth to point out that S_{12} is -0.25 dB, meaning that power transmission from RF port to beam pipe port is produced with no significant power losses. Additionally, measurements of S-parameters were taken using spacers with different lengths as Fig.6 summarizes. Both compact couplers perform similarly, since measurements deviation using different spacers is less than 1 %.

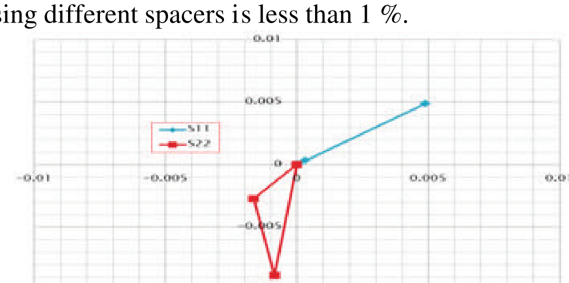

Figure 6: S-parameters of the PETS couplers taken by using different length spacers.

RF Behaviour of PETS. Bead Pull Method

The complete structure was measured using the bead pull method. Measures were taken before and after final welding of the vacuum tank. This method consists of placing a conducting object (bead) in the structure and measuring the field perturbation by means of the S_{11} parameter. It allows to deduce the synchronous frequency of the RF structures.

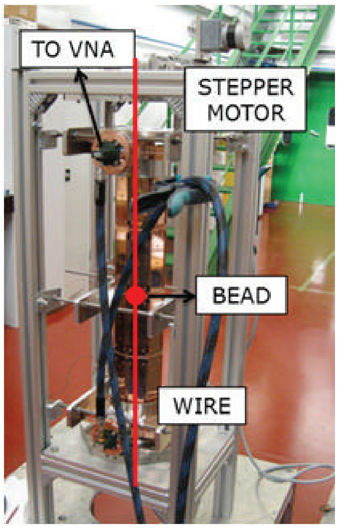

Figure 7: Bead pull test bench.

The bead pull test bench used for measuring the PETS is shown in Fig. 7. It consists of a mechanical support in which a stepper motor moves a nylon wire where the bead is fixed. In this case, a 4mm diameter, 2 mm high cylindrical copper bead was used. The wire slides through one calibrated piece placed at both ends of the PETS. It determines the position of the bead, which is off-centred 10.00 mm from the axis of the structure since the electric field at the centre is not high enough to provide a good sensitivity with this test.

Figure 8 shows the results of the measurements, both before and after final welding of the vacuum tank. Transmission parameter S_{21} is -0.5 dB in both cases, meaning that the losses are low. Results show an excellent synchronism of the structure since the distortion of the ellipse due to the phase change is minimum at a 5 MHz shift of the nominal frequency. It means that no significant frequency detuning is produced neither before nor after tank welding. The results are in agreement to those obtained at CERN, where the PETS was validated before installing in the CLIC module. CERN results show an excellent performance of the structure, with a frequency detuning by +0.5 MHz from the nominal one.

CONCLUSION

The second prototype of the double-length CLIC PETS has been successfully manufactured and low power tested. Several design modifications were implemented with respect to first one in order to ease the assembly. Tolerances and vacuum requirements of the PETS were achieved by using similar machining and joint techniques than in the previous prototype.

Bead pull method was selected for the RF characterization of the final PETS confirming the excellent performance of the structure with no significant detuning with respect to nominal frequency.

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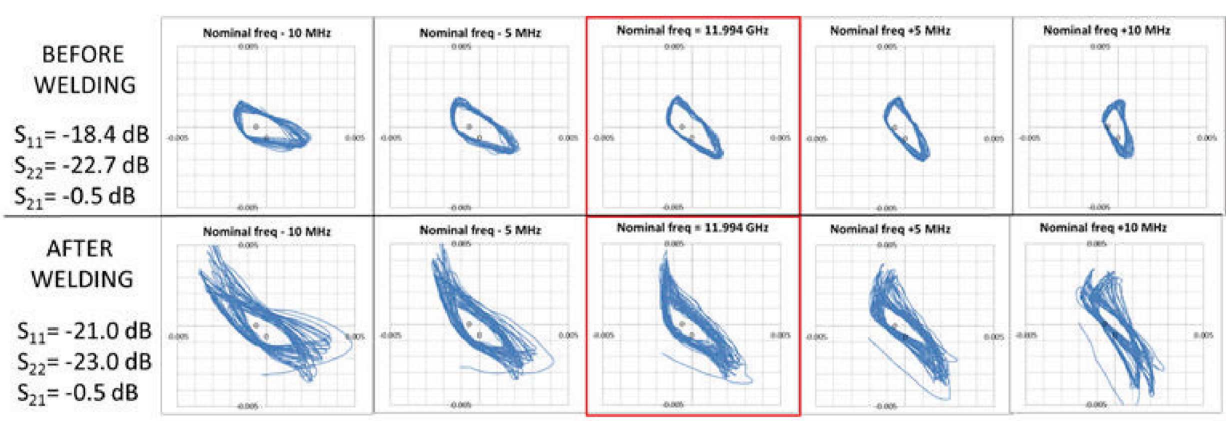

Figure 8: Perturbation in S_{11} at different frequencies around nominal one measured before and after final welding.

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