STRUCTURAL MECHANICAL AND RF MEASUREMENTS ON THE SUPERCONDUCTING 217 MHz CH CAVITY FOR THE CW DEMONSTRATOR AT GSI*

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Abstract

Together with the new horizontal cryomodule and two superconducting (sc) 9.5 T solenoids the sc 217 MHz Crossbar-H-mode (CH) cavity [1] represents the continuous wave (cw) demonstrator and brings sc rf technology to GSI. A reliable operability of the sc CH cavity is one major goal of the demonstrator project. Furthermore, the successful beam operation of the demonstrator will be a milestone on the way to a new sc cw linac at GSI for a competitive production of Super Heavy Elements (SHE) in the future. The production of the cryomodule and the solenoids is almost finished while the cavity has been completed except for the helium vessel. In this paper structural mechanical as well as related rf measurements on the sc 217 MHz CH cavity are presented.

INTRODUCTION

Currently, the production of the sc 217 MHz cavity [2] (see Fig. 1) for the cw demonstrator project is finished except for the titanium helium vessel. The cavity consists of 4 mm niobium sheets, has 15 equidistant arranged accelerating cells and a design gradient of 5.1 MV/m. It is equipped with nine static tuners, a 10 kW cw power coupler which is currently under development, several flanges for surface preparation and two fast frequency tuners. First performance tests of the cavity at 4 K with low rf power are expected in June 2015 at the Institute for Applied Physics (IAP), Frankfurt. As other sc cavities the 217 MHz CH structure is very susceptible to external influences like Lorentz-force detuning, microphonics or pressure variations as well. All caused mechanical deformations can change the resonance frequency of the cavity. Changes of the frequency due to evacuation and cooling down to 4 K have to be compensated by the static tuners during the respective production phase. Furthermore, the pressure sensitivity of the cavity is an important quantity regarding variations in the liquid helium bath as well as in the helium loop. These variations can be adjusted accordingly by the dynamic tuning system of the cavity [3]. Several rf measure-

ments have been performed during each production step in order to adjust the cavity to its design frequency. Initially the frequency was designed higher than the operating frequency and lowered successively by reducing the end cap length and inserting static tuners. The following measurements have been performed before the last two remaining static tuners were welded into the cavity as the tuner ports were temporarily sealed with rings made from teflon.
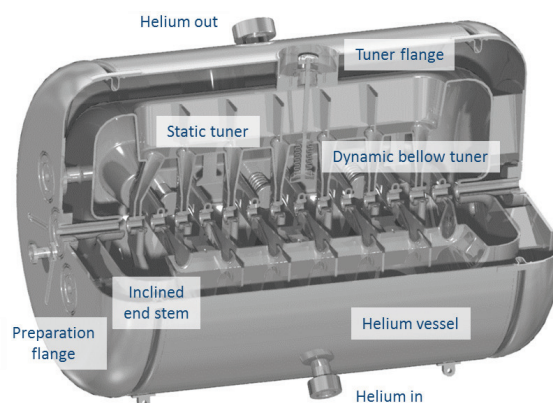

Figure 1: Layout of the sc 217 MHz CH cavity.

EVACUATION OF THE CAVITY

To study the cavity's resonance frequency change caused by evacuation and its pressure sensitivity, coupled structural - high frequency electromagnetic simulations [4] have been performed. For the analysis model the girders of the cavity were chosen as a fixed support while 1 bar pressure on the surface of the cavity walls was used as an applied load. These boundary conditions allow to simulate the mechanical behaviour of the self-supporting cavity during the evacuation process. The resulting deformations appear mainly at the central region of the cavity walls and at the end caps (see Fig. 2 top). As one can see, the results show that the maximum displacement at the end caps is around 0.23 mm while the deformation at the walls is about 0.17 mm. This leads to an increase of the resonance frequency and yields to a pressure sensitivity of 38 Hz/mbar. Additionally, the relative permittivity ϵ_r is decreasing during the evacuation pro-

4: Hadron Accelerators

A08 - Linear Accelerators

cess which in turn will lead to an increase of the resonance frequency of 64 kHz. Thus a total frequency shift of about 102 kHz has to be considered. Figure 2 (bottom) shows the corresponding von Mises stress of the cavity due to 1 bar pressure difference. The maximum peak was found to be 30 MPa which is located at the curved area of the end caps. This is still acceptable in comparison to the yield stress of niobium at room temperature (70 MPa). Higher peaks of up to 180 MPa can be found at the stiffening ribs between the girders. These artefacts arise from a singularity of the mesh in these areas and can be neglected.
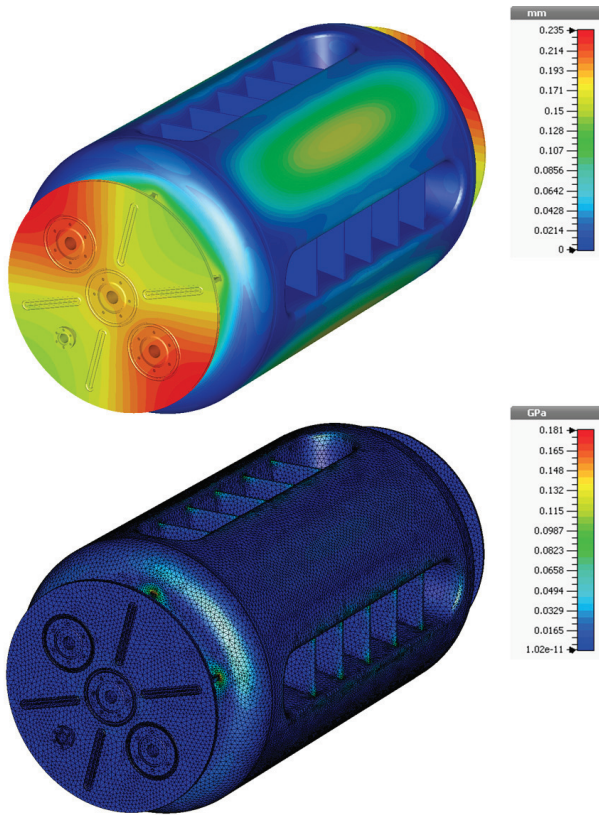

Figure 2: Deformation and max. von Mises stress of the cavity due to the evacuation process.
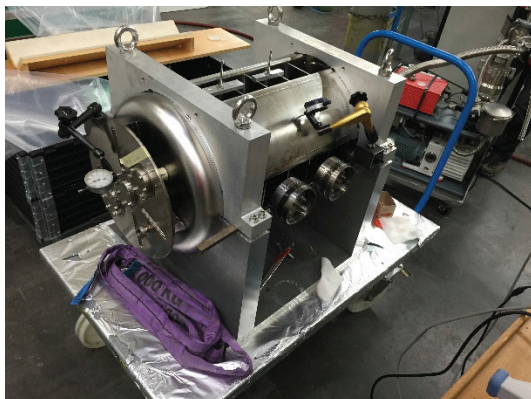

Figure 3: Evacuation of the cavity.

To verify the simulation results the deformation of the cavity walls, of the end caps as well as the related frequency shift was measured under evacuation at room temperature. Figure 3 shows the measurement setup. The displacement of the flexible elements was measured with three probe indicators mounted on the cavity. Both end caps show a similar behaviour under evacuation. The results of the measurements show that the maximum deformation at the end caps is around 0.35 mm which is 50 % higher than simulated (see Fig. 4 top). This discrepancy results from numerous welding seams which soften the material in this region. In Figure 4 (bottom) the measured displacement of the cavity wall due to 1 bar pressure difference is shown. In that case the maximum displacement was found to be 0.14 mm which corresponds to the simulation very well. After ventilation of the cavity the walls show a hysteresis because the material was still under mechanical tension at that time. Figure 5 de-
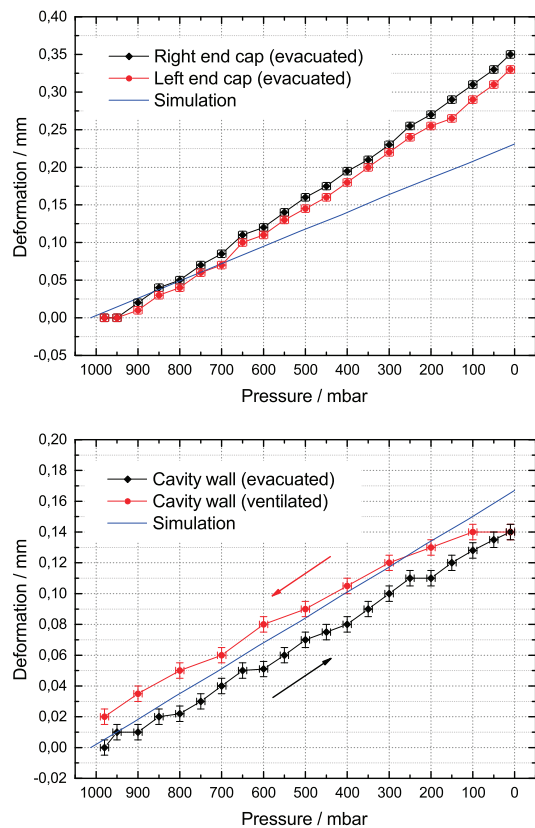

Figure 4: Measured deformation of the end caps (top) and of the cavity wall (bottom) at 1 bar pressure difference.

scribes the related measured frequency shift. It also shows a hysteresis whether the cavity is evacuated or ventilated. The total frequency shift is 11 % higher than expected. According to that, the measurements show a good agreement with the simulation. A total frequency shift of 113 kHz was measured and subsequently compensated with the remaining static tuners during the completion of the cavity. Regarding first performance test at 4 K further attachments like the support frame will stiffen the cavity additionally, which will lead to a slightly smaller frequency shift.
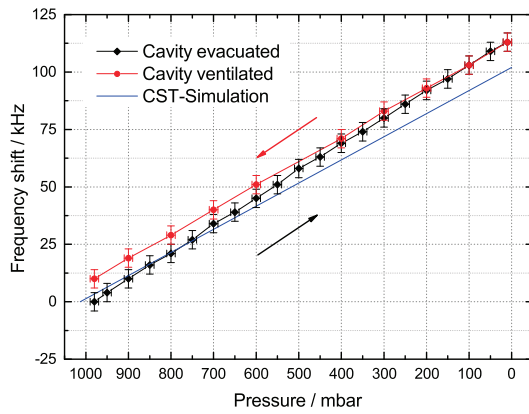
Figure 5: Measured frequency shift due to evacuation.

Figure 6: Position of the temperature probes.

CAVITY COOL-DOWN

Caused by cooling down from room temperature to 4.2 K the cavity shrinks symmetrically in all dimensions. The thermal shrinkage and the related frequency shift has been determined by the total linear contraction ($\Delta L/L = (L_{293\,K} - L_{4,2\,K})/L_{293\,K}$) from room temperature to the indicated temperature. In this context the thermal contraction data for niobium at different temperatures was used from literature [5]. Based on this the cavity shrinkage after cooling down to 4.2 K is about 1 mm in longitudinal and 0.6 mm in transverse direction which yields to an increase of the resonance frequency of 310 kHz. This offset was compensated with the remaining static tuners as well. To validate the expected behaviour the cavity has been cooled down with liquid nitrogen while the frequency change was measured. The cavity was equipped with six temperature probes (T_1–T_6) along the side of one end cap (see Fig. 6). Figure 7 shows the measured frequency shift during cooling down the cavity in comparison with the mentioned assumption. Since the cavity could not completely be covered with liquid nitrogen because of a vacuum leakage, the fill operation had to be stopped at a mean temperature of 93 K. A total frequency shift of 298 kHz was measured whereas the corresponding estimated value is 268 kHz. Thus the measurement results confirm the performed estimation very well.

SUMMARY & OUTLOOK

The production of the sc 217 MHz CH cavity is finished except for the helium vessel. Several structural mechanical as well as rf simulations have been performed and validated by appropriate measurements during each production step to analyse the cavity's behaviour considering different external influences. All measurement results confirm the simulations and assumptions very well and the cavity's operating frequency could be reached. In the next step the cavity will be high pressure rinsed and afterwards delivered to the IAP for first cold tests with low rf power. First performance tests and rf conditioning of the cavity are planned in June 2015.
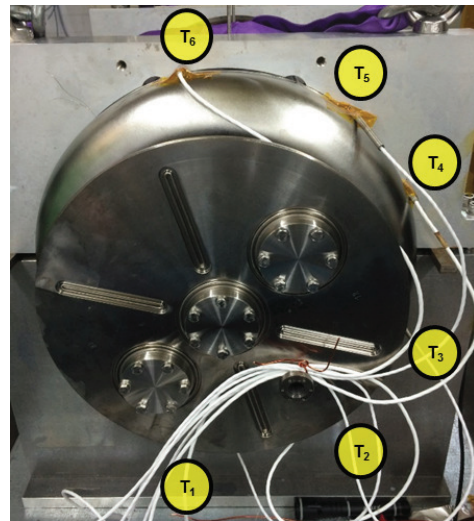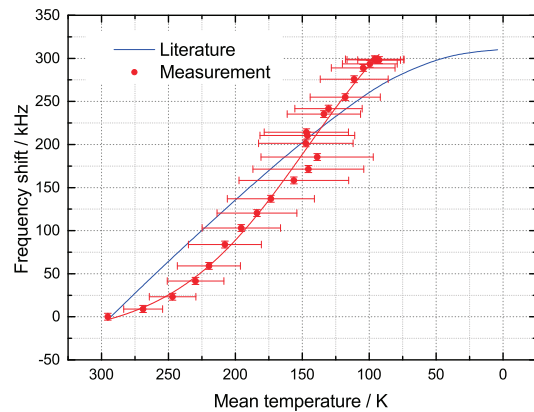

Figure 7: Frequency shift due to cavity shrinkage.

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