MEASUREMENT OF HIGHER ORDER MODES ELECTRODYNAMIC CHARACTERISTICS FOR ARRAY OF TWO 2400 MHz CAVITIES

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Abstract

In the frameworks of the High Luminosity Large hadron collider (HL-LHC) upgrade program an application of additional superconducting harmonic cavities operating at 800 MHz is currently under discussion. As a candidate, the two cavities with grooved beam pipes connected by the drift tube were suggested. In this article of measurements of Q_{load} are performed for the aluminum model of array of two cavities connected by drift tube. Field distribution of Fundamental Mode (FM) and Higher Order Modes (HOM) were measured for aluminum prototype with a frequency of the operational mode of 2400 MHz, and their comparison with the simulation results.

INTRODUCTION

At present the project aimed at Large Hadron Collider luminosity upgrade (HL-LHC) is being developed at CERN [1]. The implementation of 800 MHz harmonic cavities in LHC should provide a possibility to vary the length of colliding bunches in LHC which can lead in number of positive effects [2]. In order to supply the required harmonic voltage several single cell superconducting cavities are to be used.

One of the main goals of the cavity design is to fulfill strict HOM damping requirements. That is why in order to check the simulation results and to investigate eventual HOM properties the scaled version of this array of two cavities with grooved beam pipe was manufactured.

SINGLE CELL CAVITY

In [3] it was shown that it is possible to reduce the external quality factor of the most dangerous dipole HOMs lower 100 and below 1000 for HOMs in the higher frequency range.

In order to verify the results obtained by numerical simulations a scaled aluminium cavity prototype with the frequency of the fundamental mode of 2400 MHz was built. The prototype was designed in a modular form (Fig. 1) so that it is possible to carry out measurements for different lengths and shapes of the drift tubes and to further carry out measurements for a chain consisting of two such cavities. The prototype assembly consists of the beam pipe with a larger radius, the cavity body, the beam tube with a smaller radius having a feedthrough for power input and two shorting plates.

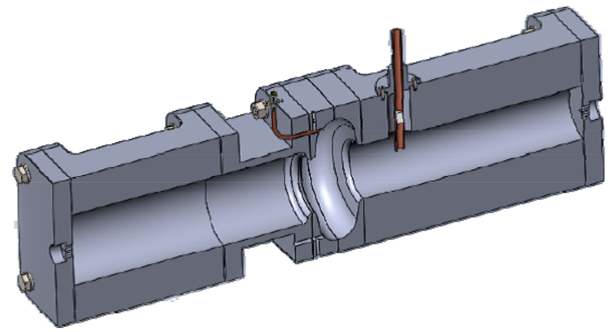

Figure 1: General view of single cell cavity.

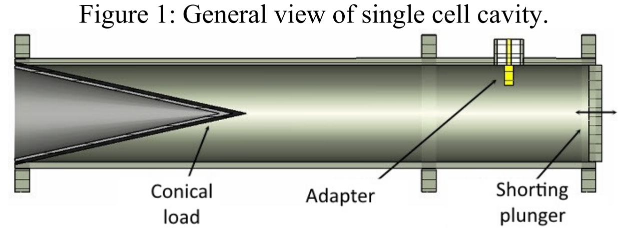

Figure 2: The scheme of the reflection coefficient measurements of the load.

In order to achieve a high HOM damping efficiency a load with the lowest possible reflection coefficient should be produced since in namely this case all the stored energy of these modes will be dissipated in the load.

A cone coated with a layer of graphite was manufactured for the use as a load for the HOM damping. Before carrying out experiments to determine the effectiveness of the HOM damping a dedicated study was conducted for measuring the reflectance of the loads with different length and the thickness of the graphite coating. The load with the lowest reflection coefficient (-25.3 dB) was chosen to perform the experimental measurements of HOM damping efficiency. The scheme of the reflection coefficient measurements of the load is presented on the Fig. 2. The conical load was placed in the drift tube with bigger radius.

First, the measurements were performed for the length of the drift tube of 200 mm. The Q's of the HOM were significantly reduced (Fig. 3). But it also appeared that the Q-factor of the operation mode was also affected. For this reason the length of the drift tube was increased up to 400 mm (Fig. 4). After the increasing of the drift tube length the Qload of the operation mode returned to its initial value while the HOM Q's values remained the same.

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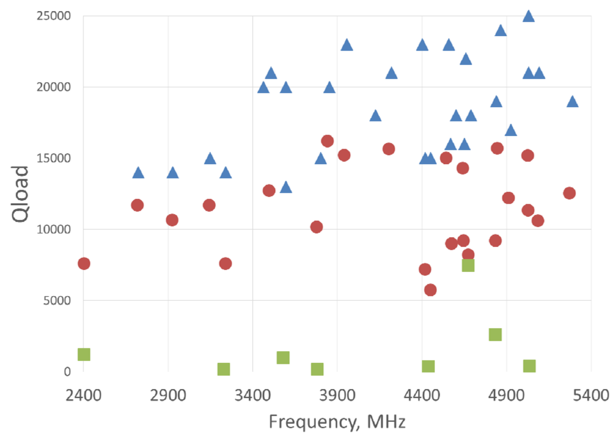

Figure 3: Q_{load} of the cavity with a corrugated pipe length of the drift at the drift tube 200 mm. Triangles – Q_0 calculation, circles - Q_0 measurements, square - Q_{load} measurements.

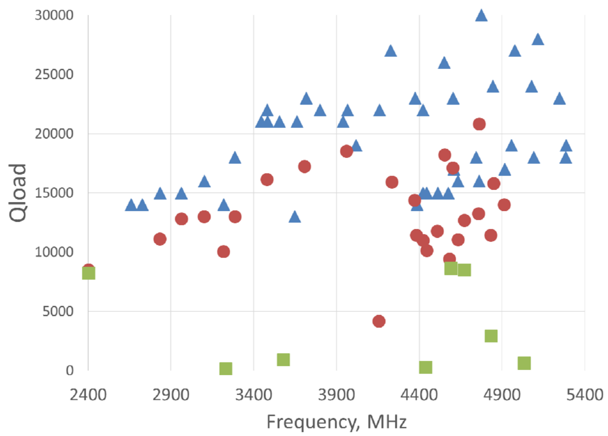

Figure 4: Q_{load} of the cavity with a corrugated pipe length of the drift at the drift tube 400 mm. Triangles – Q_0 calculation, circles - Q_0 measurements, square - Q_{load} measurements.

Also a comparison was made between calculated Q_{load} in the CST [4] program with measurement results. The comparison results are shown in Fig. 5 and 6.

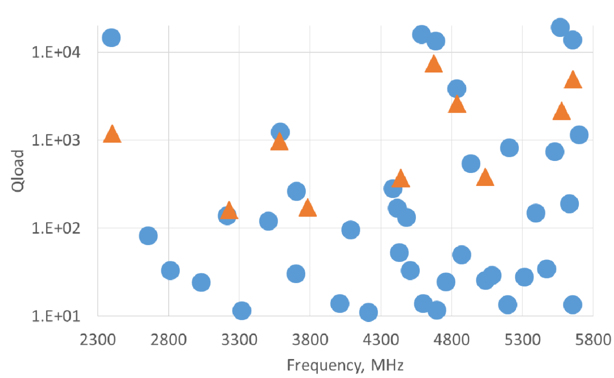

Figure 5: Comparison of CST Q_{load} and measured Q_{load} for the cavity with grooved beam pipe (200 mm). Circles – CST Q_{load}, triangles – measured Q_{load}

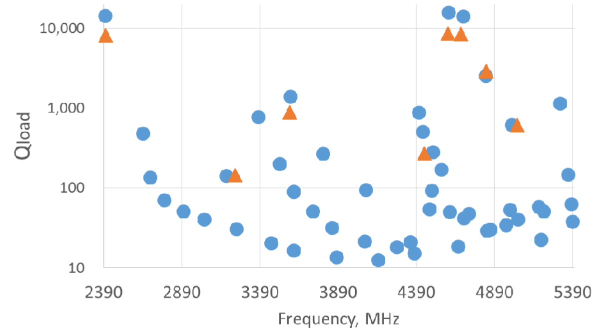

Figure 6: Comparison of CST Q_{load} and measured Q_{load} for the cavity with grooved beam pipe (400 mm). Circles – CST Q_{load}, triangles – measured Q_{load}.

From Fig. 5 and Fig. 6 it can be seen that the calculated and measured Q_{load} result to be in a good agreement for the modes that we were able to detect. Other modes have significantly lower values of Q_{load} and cannot be identified. The modes in the region around 4500 MHz are the quadrupole ones with an R/Q values of 10^{-4} and therefore they do not pose any threat for the beam. Q_{ext} for these modes are of the order of 10^4-10^5.

Q_L MEASUREMENTS IN ARRAY OF TWO CELLS

After measurements of HOM damping in single cell cavity investigation of an array of two cells were performed. The CST model of the array of two cells is presented on Fig 7. The calculated Qext values for the array of two cavities are presented on Fig. 8.

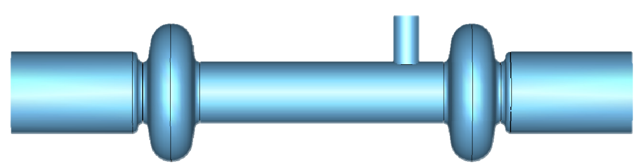

Figure 7: Array of two cells structure model.

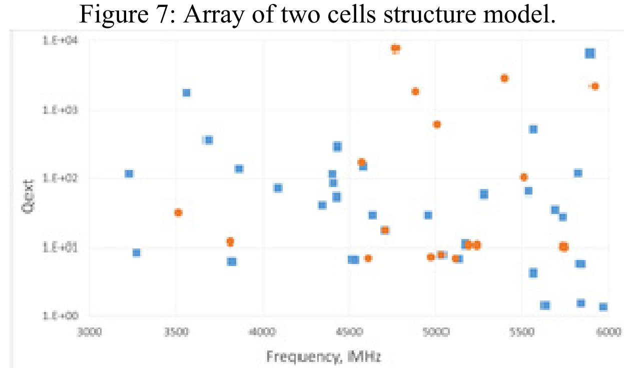

Figure 8: Calculated Q_{load} values for the array of two cavities. Circles – monopole modes, – Dipole, quadrupole, etc.

The General view of manufactured and assembled prototype is presented on Fig. 9.

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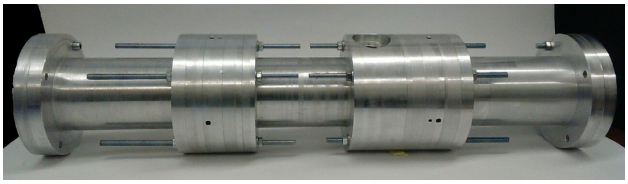

Figure 9: General view of the assembled prototype.

The results of HOM damping are presented on Fig. 10.

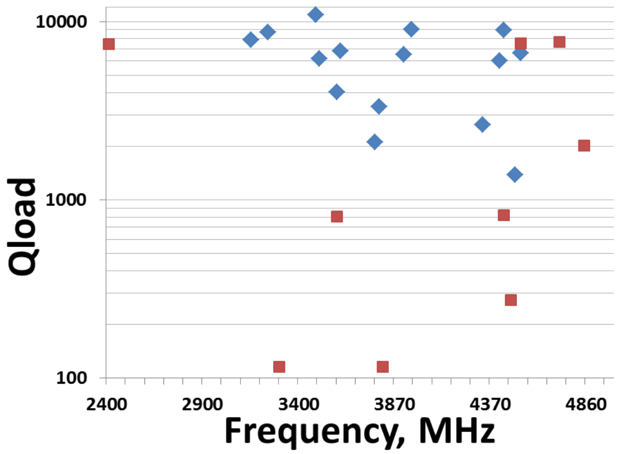

Figure 10: Q_{load} of the cavity with a grooved beam pipe. Triangles – Q_0 calculation, circles - Q_0 measurements, square - Q_{load} measurements.

From Fig. 10 it can be seen that the practically all the HOM have values of Q_{load} lower than 1000. Except for the quadrupole modes in the region around 4500 MHz with an R/Q values of 10^{-4}.

CONCLUSIONS

Thus, the performed measurements have confirmed that there are no dangerous HOM trapped in the single cell cavity and array of two cavities with grooved beam pipe. The presence of some residual HOM detected experimentally and having $Q_{load} < 1000$ is explained by the fact that the prototype was built with the shorting plates at the ends (or using the damping load only from one side) and others are the HOM with R/Q lower than 10^{-4}. This situation is reproduced very well by simulations as seen in Fig. 4 and Fig. 5.

REFERENCES

[1] L. Rossi, "LHC upgrade plans: options and strategy", in Proc. 2nd Int. Particle Accelerator Conf. (IPAC'11), San Sebastian, Spain, September 2011, p.908.
[2] T. Linnecar and E. Shaposhnikova, "An RF System for Landau Damping in the LHC", LHC Project Note 394, 2007.
[3] Ya. V. Shashkov et al. "Comparison of higher order modes damping techniques for 800 MHz single cell superconducting cavities", Nuclear Instruments and Methods in Physics Research A, v. 767, 2014, p 271–280.
[4] https://www.cst.com/