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COMPASSION OF HIGHER ORDER MODES DAMPING TECHNIQUES FOR SUPERCONDUCTING 9-CELL STRUCTURE

Ya.V. Shashkov, N.P. Sobenin, A.Mitrofanov, National Research Nuclear University MEPhI (Moscow Engineering Physics Institute), Moscow, Russia
V. Zvyagintsev, TRIUMF, Canada's National Laboratory for Particle and Nuclear Physics, Vancouver, BC, Canada

Abstract

Modern types of accelerators, such as Energy recovery linacs, require low values of higher order modes (HOM) Q_{ext}. In accelerators with high current HOM could lead to high losses for the modes excitation, beam instability and beam break up. HOM couplers and waveguides are often used in such structures for HOM damping. Unfortunately they could lead to a violation of the axial symmetry of the accelerating field and negatively affect the beam emittance. Also these devices are subject for multipactor discharge and could be difficult in maintaining and fabrication. In this paper we examine several ways of HOM damping with ridged, fluted and corrugated drift tubes which are devoid of the above-mentioned drawbacks. The influence of the parameters of the drift tube on the HOM damping and on the parameters of the fundamental wave were analyzed.

INITIAL DESIGN

As a reference point for simulations 9-cell 1300 MHz superconducting accelerating cavity (Fig. 1a) [1] was analyzed. In order to estimate efficiency of HOM damping in such structure electrodynamic characteristics (EDC) [2] were calculated for the structure without couplers but with ideal load boundary conditions on at the end of drift tubes. EDC of operating mode presented in Table 1.

In order to estimate HOM frequency range dispersion characteristics (Fig. 1b) for TM_{010} modes and HOMs were plotted. The most dangerous HOMs for the structure are dipole modes TE_{111}, TM_{110}; quadrupole modes TE_{211} and TM_{210} and monopole mode TM_{011}. Line $\beta_{phase} = 1$ is also presented on the graph. Intersection points of dispersion characteristics with $\beta_{-phase} = 1$ line (synchronous point) represent modes with the highest interaction between particles and modes and requires additional attention. External Q-factor Q_{ext} and shunt impedance R_{sh} for HOMs and operational mode presented on the Fig 2 and 3. Q_{ext} values were calculated in CST Microwave Studio [3].

Comparison of the results with similar structures [4] showed that Q_{ext} for operating mode is nearly the same, for dipole modes it is three orders higher, 4-5 orders higher for quadrupole modes and for 2nd monopole HOM its two times higher.

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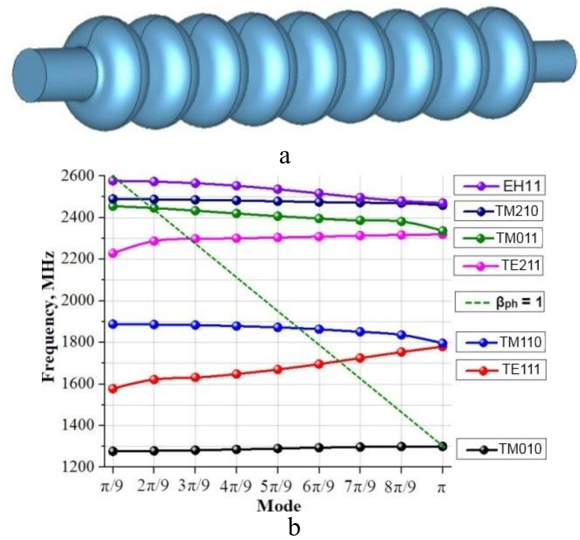

Figure. 1.Genearal view (a), dispersion characteristics (b), for 9-cell cavity with cylindrical beam pipes

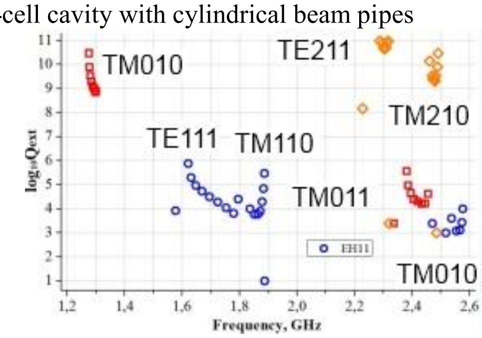

Figure. 2. Q_{ext} for 9-cell cavity with cylindrical beam pipes

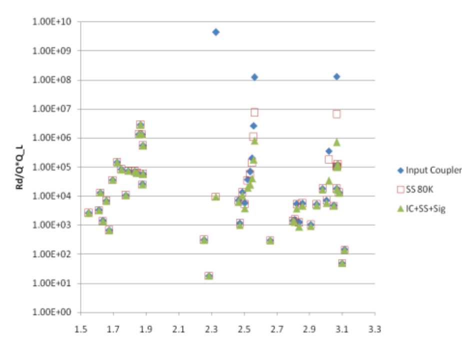

Figure. 3. R_{sh} (d) for 9-cell cavity with cylindrical beam pipes. Diamond - loaded just with input couplers, square - loaded in addition with stainless steel damping rings, triangle - stainless steel damping ring on coupler side and Sigradur damping ring on tuner side [1]

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FLUTED, RIDGED AND CORRUGATED BEAM PIPE

Simulation of 9-cell structures with fluted, ridged and corrugated beam pipes were performed. Previously these designs were successfully applied for HOMs damping in single cell cavities [5]. EDC of operating mode for these structures are presented in Table 1.

Fluted beam pipes are presented on Fig. 4a. Number and form of those flutes can be chosen on purpose to achieve higher values of HOMs damping. The best results for damping of dipole and quadrupole HOMs were obtained for a structure with fluted beam pipes with 3 flutes [5,6]. The structure with 4 flutes had problems with quadrupole HOMs damping with certain polarization.

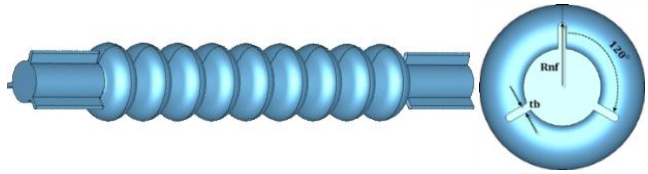


Figure. 4a. 9-cell cavity with fluted beam pipe

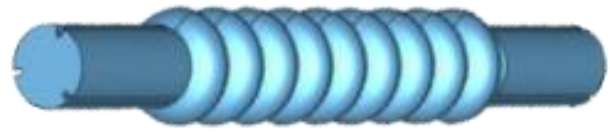
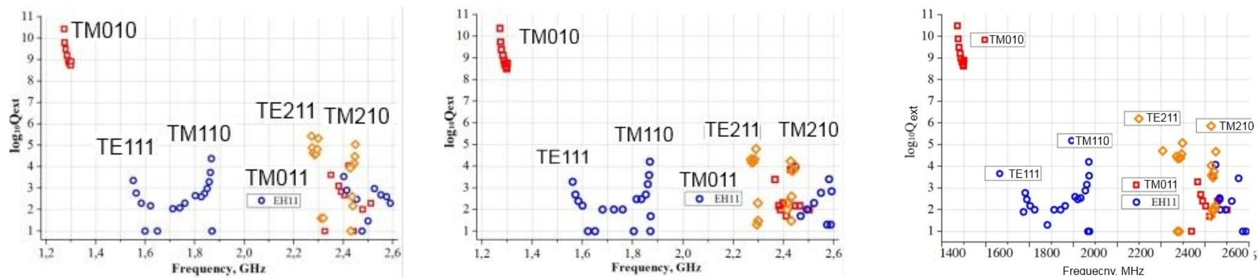


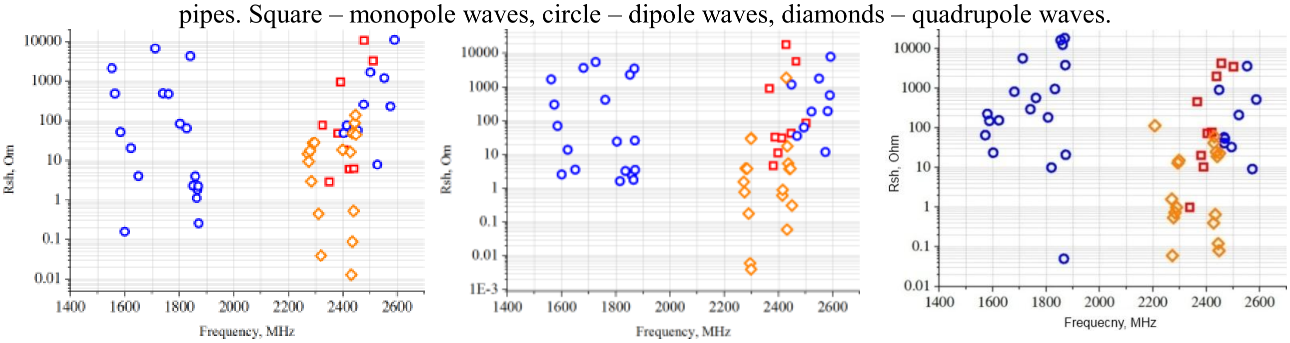
Figure. 4b. 9-cell cavity with ridged beam pipe


Figure 4c. 9-cell cavity with corrugated beam pipe



a b c

Figure. 5. Q_{ext} for HOMs in 9-cell elliptical cavity with a) fluted beam pipes; b) ridged beam pipes; c) corrugated beam pipes. Square – monopole waves, circle – dipole waves, diamonds – quadrupole waves.



a b C

Figure. 6. R_{sh} for 9-cell elliptical structure with a) fluted beam pipes; b) ridged beam pipes; c) corrugated beam pipes. Square – monopole waves, circle – dipole waves, diamonds – quadrupole waves.

The main advantage of fluted beam pipe is that H_{21} cut-off frequency is below of the quadrupole HOMs band. This is true not only for quadrupole but also for dipole HOMs. The operational mode remains trapped in the structure due to high cut-off frequency of TM_{01} mode. Cut-off frequency values for modes TE_{11}, TM_{01}, TM_{21} in fluted beam pipe are respectively 1330, 1972 and 2004 MHz.

In order to get the same cut-off frequency cylindrical beam pipe beam pipe radius should be 65.5 mm for TE_{11} wave and 72.8 mm for TE_{21}, however it will cause reduction for TM_{01} cut-off frequency (on 248MHz and 396MHz correspondingly). It could create to negative effect for shunt impedance of operating mode.

Table 1. EDC of operating mode TM_{010} for structures with different beam pipes (f=1300 МГц)

	Cylindrical	Fluted	Ridged	Corrugated
R_{sh}/Q_{ext}, Ohm	980	973,8	951.9	970.2
$E_{s\ max}/E_a$	2.1	2.2	2.3	2.2

Comparing Q_{ext} (Fig 5a) and R_{sh} (6a) results for the 9-cell structure with fluted (Fig. 4a) and for cylindrical beam pipes (Fig. 1a) and results obtained for the similar structures [4], we can conclude that this method is very effective because of we see reduction of Q_{ext} values were

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reduced by two orders of magnitude monopole and dipole and by five orders for quadrupole HOMs.

Another structure that provides conditions for HOMs propagation is ridged beam pipe structure (Fig. 4b). The ridged beam pipe geometry is symmetrically opposed to fluted beam pipe. Typically it has 3 grooves in beam pipe, evenly distributed on azimuth on 120º angle. EDC of operating mode presented in Table 1.

Results for Q_{ext} and R_{sh} in 9-cell structure with ridged beam pipes are presented on Fig 5b and 6b.

We found that the results for ridged beam pipe are even better than for fluted beam pipe. All the dipole and monopole modes have Q_{ext} values lower than 10^4, quadrupole modes lower than 10^5.

The last design to check was structure with corrugated beam pipe (Fig. 4c). From the results of Q_{ext} and R_{sh} presented on Fig 5c and 6c are very close to achieved for structures with fluted and ridged beam pipes.

CONCLUSIONS

Propagation of HOMs from 9-cell structure was compared for cylindrical, fluted and ridged beam pipes. The comparison has been done based on calculated external quality factor Q_{ext} and R_{sh} in the models with beam pipes loaded with RF ports at the ends. In the result the fluted and ridged beam pipes showed R_{sh} for HOMs 3 orders of magnitude lower than for structure from Figure 1a. We are planning to precede development of HOM dampers for 9-cell structure based on this result.

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