

IMPROVEMENTS OF BUILDCAVITY CODE

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Abstract

Recently, we improved the BuildCavity code, which is a graphics interface to SUPERFISH for the study of superconducting cavities of elliptical shape. Now it works with last SUPERFISH 7 and can be installed also on newer Windows systems such as Win 7 and 8. Several improvements have been done in the code. As an example, a design of ESS medium-beta cavity with BuildCavity will also be presented.

INTRODUCTION

BuildCavity (written as BC in abbreviation) is a code devoted to design an elliptical cavity that has been written ten years ago at LASA and has been used widely also in other labs [1, 2]. As a graphics interface to SUPERFISH (SF in abbreviation) [3], BC allows changing interactively the cell geometries on the screen, executing SF and tuning the inner cells of a multicell structure by iterating through a series of SF runs, storing the simulation results for the analysis of the dependence of the cell e.m. performances from the geometrical parameters that define its shape (as described in [1]). Separate tuning routines for the end cells (including the beam tube) are available, and a multicell cavity can be assembled and analyzed automatically from inner and end cells in the database that stores the geometrical and electromagnetic parameters of the cells.

After more than ten years without updating, the old version BC 1.3.4 is still functional, but outdated. This BC version does not work with the later distributions of SF, version 7 and needs version 6, no longer under distribution. In the new version, several instructions have been modified to match with the updates of SF 7.

Besides, several improvements have been performed on the code during the design activities of the ESS medium-beta cavity at INFN. Firstly, we have added the possibility to adjust the equator radius also on the end cell at the Pickup side, which is a very effective to maintain a good end-cell shape without modified the wall angle, thanks to the large frequency sensitivity of the equatorial region. Previous version of the code allowed this option only on the Fundamental Coupler (FC) side. Second, a post-process function allows BC to generate directly an APDL script file for ANSYS to perform mechanical analysis and structural simulations, while originally the cavity model for ANSYS had to be generated by an external auxiliary code. With this function, we can easily combine the RF cavity design by BC with the structural analysis by ANSYS, to perform design iterations to reach the desired e.m. and mechanical specifications.

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So far, the latest version is BC 1.4.3.

The second section of this paper presents the main improvements on BC, and the third section presents the design of the ESS medium-beta cavity as an example of the BC use.

IMPROVEMENTS ON BUILDCAVITY

The code framework has not been modified, and a few additional functions were added. Figure 1 shows the interface of “Build MultiCell Cavity”, in which the main improvements have been added. In the lower-left part of the screen, users can choose different end-cell types from the database. In the lower-right portion, the function “Generate ANSYS mesh file” is available after the cavity has been modelled with RF simulations by running “SuperFish Execution”.

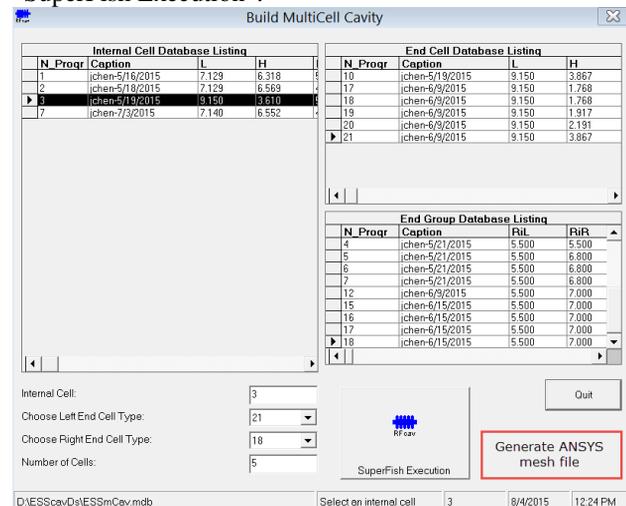


Figure 1: BC interface to generate a multi-cell cavity.

End-cell Types

After the definition of the inner cell geometry of a multicell structure, end-cells need to be tuned separately, with the proper inclusion of the attached beam pipes. The beam-pipe size affects the maximum surface fields, the cavity R/Q and the higher-order-modes (HOMs) propagation. Keeping the same radius of the beam tube as the inner cell irises leads to a high R/Q value, while enlarging the beam pipe is usually necessary at the fundamental coupler (FC) side to provide correct coupling and frequently performed at the opposite side in order to prevent HOM trapping in the structure and for the cavity interconnection.

Enlarging the beam pipe size with respect to the inner cells increases the volume of the capacitive region, therefore the tuning to the correct frequency requires a corresponding increase of its inductive region. There are three ways to accomplish this task according to the cell

parameters: reducing the slope angle of side wall, lowering the equator elliptic ratio ($R= B/A$) or increasing the equator radius. In general, small slope angles should be avoided (especially in reduced-beta elliptical structures, in order to ease the etching and rinsing processes needed after fabrication) and an equator elliptic ratio greater than one is generally preferred to avoid multipacting. For a greater tuning flexibility, a slightly increase on equator diameter is an effective solution, due to the high frequency sensitivity of the equatorial region to the radius. Such a strategy implies however an additional deep-drawing mold for the modified geometries of the inner cell adjacent to the end groups during the cavity fabrication stage. Table 1 summarizes the relevant parameter changes needed to tune the end cells in the three ways mentioned before, for the ESS medium-beta cavity being designed at INFN. All other end cell geometrical parameters are fixed to the values shown in Table 2. As one can see, the tuning with the slope angle requires a very strong variation of the geometry, leading to a very steep wall which is undesirable for the cavity processing stages. On the contrary a small (1 mm) increase in the equator size is sufficient to obtain the same effect, and generally results in better RF cavity properties.

In many cases, a cavity with two large beam pipes is preferred to ease HOM propagation in the beam pipe region, to ease fabrication stages and to simplify the bellows connections between two cavities in one cryomodule. Before updating, BC was only capable to tune the end cells of one side of the cavity (usually the RF pickup side) by tuning slope angle. Equator tuning was available for the FC side, usually employing a larger beam diameter to ease the coupling condition for high current cases. BC has been modified so one can choose the two types of tuning for both end cells: tuning with the slope angle or tuning with the equator size,. The interface to choose inner and end cells from the database is shown in Fig. 1.

Table 1: Three Tuning Ways for the End Cell With Larger Beam Pipe

Tuning method	Inner cell	End cell
Tuning slope angle	7 deg.	3.9 deg.
Adjusting elliptic ratio, R	1	0.77
Tuning equator radius	186.36 mm	187.36 mm

Input File for ANSYS

A design of multi-cells cavity needs the confirmation of its mechanical performances after 2D design by BC and SF. Also several RF-mechanical coupled parameters, such as the Lorentz force detuning coefficient K_L and the vacuum sensitivity K_{vac} are necessary to fully qualify the cavity design. As a powerful tool for mechanical analysis, the Finite Element (FE) code ANSYS [4] is suitable to calculate the main mechanical parameters, by further applying the Slater theorem with the SF-computed fields. In addition, ANSYS HFSS can be used to perform 3D

simulations of electromagnetic fields, such as HOM analysis. Unfortunately, there is no standard connection of geometric model between SF and ANSYS, usually one needs to provide the geometry translation.

Based on this consideration, we have developed a new function on BC which now allows generating the input file for ANSYS directly from SF mesh result. This feature allows keeping the matching between SF and ANSYS nodes, without need to field or geometry resampling.

A CAVITY DESIGN BY THE CODE

In order to better understand the functions improved in BC, the design of the ESS medium-beta cavity ($\beta = 0.67$), is taken as an example. INFN-LASA will deliver in-kind the medium-beta elliptical cavities for ESS. These cavities are designed at INFN, and need to satisfy with project-based boundary condition for compatibility with other designs [5]. Therefore, the cavity design is constrained by several requirements, e.g. number of cells and physical length.

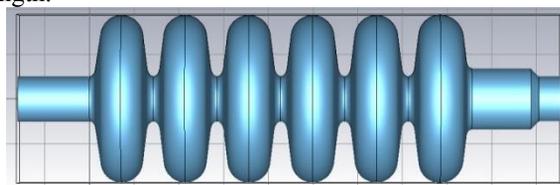


Figure 2: A design of smaller beam-pipe cavity.

For the ESS medium-beta cavity, the beam pipe radius of the FC side is determined by the coupling requirement and the coupler design. For the beam pipe at the opposing (pickup) side we have two choices: using the same radius as the inner cell iris or the same radius at the FC side.

Table 2: Half-Cell Parameters for ESS Medium-Beta Cavity

Parameters	Inner cell	End half cell
Iris radius (cm)	5	6.8
Length (cm)	7.13	7.13
Alpha (degree)	7	7
Ratio at equator, R	1	1
Ratio at iris, r	1.7	1.5
Wall distance, d (cm)	1.2	1.1
Equator radius, D (cm)	18.636	18.736

With the first option, a slightly higher, about 3%, R/Q, is obtained by the SF calculations (compared to the values in Table 3), due to the smaller beam-pipe radius. The CAD geometry of this cavity shape is shown in Figure 2. This choice, however, significantly reduces the HOM propagation due to its higher cut-off frequency, although in the case of the ESS medium-beta cavity the HOM induced power is not a problem [6].

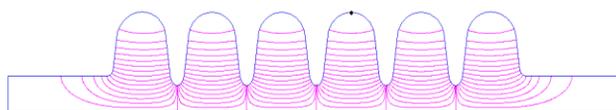


Figure 3: A cavity with slightly large equator radius at the end cells designed by BC and SF.

Table 3: Cavity Parameters for the ESS Medium-Beta cavity

Parameter	Value
Frequency (MHz)	704.435
R/Q @beta=0.67 (Ohm)	343.86
Cell-to-cell coupling	1.55%
E_p/E_{acc}	2.67
H_p/E_{acc} (mT/(MV/m))	5.11
Flatness	1.25%
Effective beta	0.689
K_{L0} – fixed ends (Hz/(MV/m) ²)	-0.78
Tuning sensitivity K_T (kHz/mm)	-205

Mainly for the considerations expressed above, and to simplify the interfaces specifications for the cavity helium tank, a symmetrical cavity with beam pipes of the same large diameter at both cavity ends has been preferred. By means of the BC improvement, a geometry with a slightly larger equator diameter at end cells is chosen. The cell parameters of the cavity are shown in Table 2, in which we can see that the equator radius of end cells is only 1 mm larger than that of inner cell. The 2D cavity profile designed by BC and SF is shown in Figure 3. The main cavity RF parameters are given in Table 3. The HOMs finding up to 2.3 GHz shows no dangerous modes for this cavity design and are reported elsewhere [6].

CONCLUSION

BuildCavity, a tool to design a superconducting elliptical cavity, has been improved recently. After updating, it works with the last SUPERFISH 7 on the new

Windows platforms. Several new functions have been added in the code. The improvement on end-cell type allows users to freely apply different tuning strategy at both cavity ends. Moreover the function of generating mesh file for ANSYS makes the mechanical analysis and 3D simulation more convenient and effective. With the updated code, a primary design with reasonable shape and good performance of ESS medium-beta cavity has been obtained. Further improvement on BuildCavity is also underway.

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