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THE DETERMINATION OF THE 805 MHZ SIDE COUPLED CAVITY DIMENSIONS FOR THE FERMILAB LINAC UPGRADE

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Abstract

In order to achieve the proper frequencies and coupling in Side Coupled Accelerator Structures, it is often necessary to model the cavities. In order to reduce the number of modeling steps and hence reduce machine shop time and cost, we have drawn heavily upon previous LAMPF experience and present day numerical calculation programs. Using a few aluminum cavity models at selected machine energies, we have been able to predict the frequency and coupling of our structures with good accuracy. This paper will describe the steps used to determine the cavity dimensions that meet our structure requirements.

Introduction

The Fermilab Linac Upgrade Project[1] will increase the energy of the existing 200 MeV Linac to 400 MeV by replacing the last four drift tube cavities of the original Linac with higher gradient side coupled (SC) cavity accelerating structures. The determination of cavity dimensions required the synthesis of numerical simulation data and aluminum model measurements. Mechanical fabrication issues also played a role in the structure's design.

Design Constraints

The overall constraints placed on the design of the LINAC cavities derives from the power, beam dynamics and initial accelerating cavity analyses. These constraints result in a machine which accelerates the beam from 116 MeV to 400 Mev with seven independently powered SC modules. Beam dynamics considerations leads to the separation of the modules into sections separated by quadrupoles. Each of the sections has 16 identical accelerating cavities (of length $\beta\lambda/2$), and the SC Linac sections are designed at 28 different energies. The program SUPERFISH was used to optimize the shape of the accelerating cavities for high ZT^2 and reduced surface electric field.[2] The unslotted accelerating cavity frequencies, f_{SF}, used in these SUPERFISH runs were determined as outlined below. The major cavity radius of the accelerating cells was held constant at 13.455 cm to simplify their manufacturing.

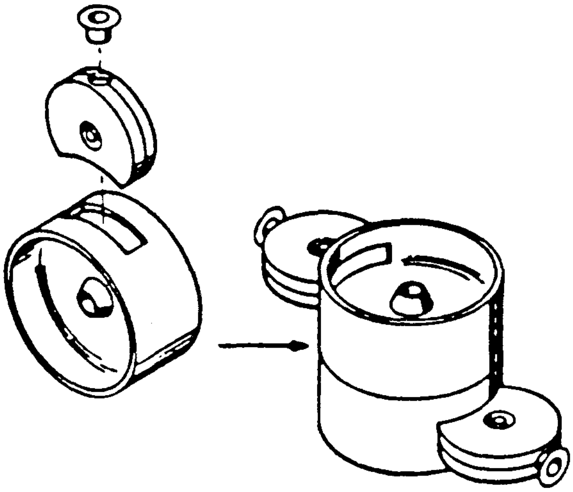

Figure 1: Segmented SC Cavity Design

Design Choices

Fermilab has chosen the LAMPF segmented construction for the new SC Linac. In the segmented design, two half accelerating cavities are machined from roughed-out copper cylinders of length $\beta\lambda/2$. The side cavities are also made from roughed-out cylindrical pieces. These two half accelerating cavities along with one full side cavity consitute a basic segment for the Fermilab design. This design permits higher speed lathe operations due to the symmetry of the

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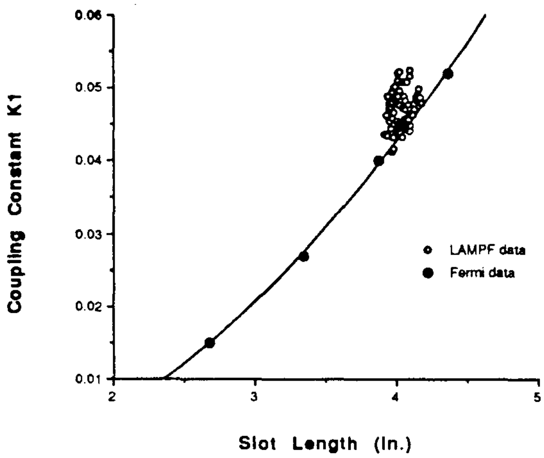

Figure 2: SCC Slot Length vs Nearest Neighbor Coupling Constant, k_1

cavity parts.[3] The Fermilab segmented design is illustrated in Figure 1.

The next goal of the design is an SC structure which has a constant nearest neighbor coupling constant k_1, a flat electric field from cell to cell on the beam axis and is simple to manufacture. Since the accelerating cavity shape is now fixed, the side cavity shape and location with respect to the accelerating cavities can be used to ensure a constant k_1.

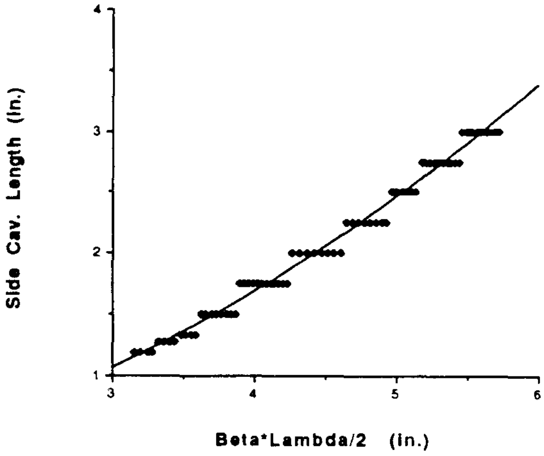

Figure 3: LAMPF Side Cavity Length vs Accelerating Cavity Length

In order to better understand the design of side cavity structures, a study of the design of LAMPF[4] was carried out and aluminum SC cavity models were constructed and measured. Combining LAMPF data with the aluminum model data reveals that the geometric parameter which correlates closest to k_1 is the slot length, shown in Figure 2. The LAMPF data, illustrated in Figure 3, shows that the side cavity length increases with increasing accelerating cavity length (and energy) in a step-like manner. The step-like changes in the LAMPF side cavity length cause the slot length and hence k_1 to vary with β. In the Fermilab SC cavity design these variations in k_1 are eliminated by continuously changing the side cavity length with β in such a way as to keep the slot length constant. The center to center distance between the accelerating and side cavities and the side cavity radius are held constant for all βs.

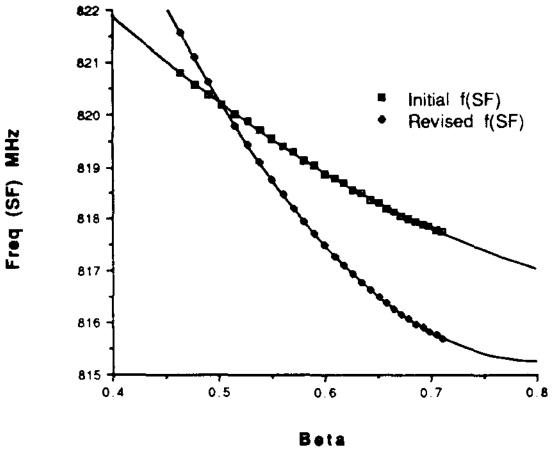

Figure 4: f_{SF} vs β for the Fermilab SCC

Accelerating Cavity f_{SF} and Slotting

In SC cavity structures the side cavities are inductively coupled to the accelerating cavities via a slot. The resonant frequency of the unslotted accelerating cavity, f_{SF}, drops when it is slotted. The attachment of a side cavity to the slotted accelerating cavity pieces creates a basic segment. After stacking the basic segments and tuning them, the resulting SC module resonates at a mode[5] frequency $f_{\pi/2}$ equalling 805 MHz.[6] Therefore, f_{SF} needs to be known before slotting and stacking takes place. Initially, the f_{SF} was determined by taking the f_{SF} vs β graph for LAMPF and shifting the curve for dimensional differences between the Fermilab aluminum cavity models and LAMPF. Subsequently, prototype copper cavity sections were fabricated and measured. This new data led to a revision of the initial f_{SF} curve. Figure

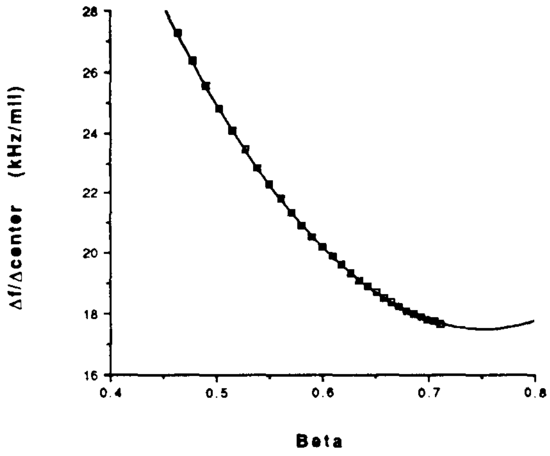

Figure 5: $\Delta f/\ \Delta center$ vs β for the Fermilab SCC

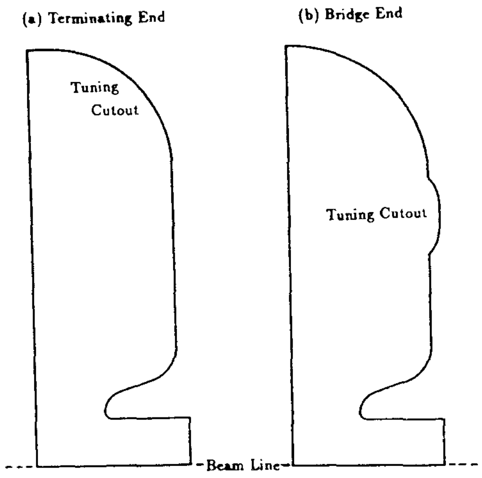

Figure 6: End Accelerating Cavity Cutouts, (a) Terminating (b) Bridge

4 shows the initial and modified curves.

The frequencies f_{SF} were chosen so that for a slot length of 10.516 cm k_1 equals 0.05. In practice the slot is not cut to the full length, rather it is cut to approximately 10.433 cm. This slot length corresponds to a slot depth[6] of 7.264 inches. Fine tuning of $f_{\pi/2}$ is accomplished by slightly varying the slot length. This results in $k_1 = 0.048 \pm 0.001$ (see Figure 5). The variation in k_1 for LAMPPF was 0.042 to 0.052.

The accelerating cavity sections are terminated with end cavities whose electromagnetic properies are different from interior cavities.[6] This difference arises from the fact that they either posses only one coupling slot, in the case of terminatig ends, or one of the two slots couple into a bridge coupler with a $k_1 \approx 0.1$. During tuning[6] material is removed from the outer wall of the terminating ends and just below the slot of the bridge ends. Figure 6 shows these cutouts.

Summary

The combination of numerical electromagnetic simulation programs, a few key measurements of prototype cavity structures and numerically controlled machining has allowed us to fabricate SCC cavity modules in an accurate, repeatable manner. This paper has outlined the rationale behind the dimensions of the Fermilab SC Linac.

References

1. R. J. Noble, The Fermilab Linac Upgrade, *1990 Linear Accelerator Conference*, (September 1990).

2. P. Zhou, Geometry Optimization Study of the Side Coupled Structure Using SUPERFISH, *Fermilab LINAC Upgrade Note*, (February 1989).

3. M. P. May, J. R. Fritz, T. G. Jurgens, H. W. Miller, J. Olsen, and D. Snee, Mechanical Construction of the 805 MHz Side Couple Cavities for the Fermilab Linac Upgrade, *1990 Linear Accelerator Conference*, (September 1990).

4. G. R. Swain, LAMPF 805-MHz Accelerator Structure Tuning and Its Relation to Fabrication and Installation, *Los Alamos Scientific Laboratory*,**LA-7915-MS**, 112 (July 1979).

5. D. E. Nagle, E. A. Knapp, and B. C. Knapp, Coupled Resonator Model for Standing Wave Accelerator Tanks *Rev. Sci. Instr.*,**3:11**, p.1583 (1967).

6. H. W. Miller, T. G. Jurgens, Q. A. Kerns, R. Padilla, and Z. Qian, Tuning Methods for the 805 MHz Side Coupled Cavities in the Fermilab LINAC Upgrade, *1990 Linear Accelerator Conference*, (September 1990).