

AN ALTERNATE SIDE COUPLED STRUCTURE FOR THE FERMILAB LINAC UPGRADE

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Abstract

An alternate side coupled structure (SCS) is being investigated. Comparisons are made to the traditional SCS. Mechanical comparisons include the relative cost and ease of fabrication. This discussion also addresses the use of CNC machining. Electrical comparisons include field distributions and coupling constants. Measured and numerical data are presented. The coupling constant of the alternate SCS is adjusted by independently changing either the separation of the coupling and accelerating cavity centers or the length of the slot. These two parameters are not independent in the traditional SCS design.

Introduction

The Fermilab LINAC upgrade project will increase the energy of the existing 200 MeV LINAC to 400 MeV.¹ The project provides for the replacement of the LINAC's last four drift tube cavities with higher gradient RF accelerating structures. Fermilab is investigating several structures including the disk and washer (DAW) and the side coupled (SCS). This paper reports on current investigations of an alternate side coupled RF accelerating structure (ASCS). The goal of this investigation is to reproduce the electrical characteristics of the SCS's accelerating cavity in the ASCS, while gaining design advantages in using a banana shaped side cavity.

Electrical Comparisons

The ASCS is a modification of the classical SCS. Referring to Figures one² and two, the accelerating cavity of the ASCS is identical to that of the SCS. Also, the side cavity of the ASCS is banana shaped, which contrasts with the round SCS side cavity. Therefore the two structures have different coupling apertures. Two intersecting circles define the SCS's aperture, while the ASCS's aperture is defined by the intersection of a circle and a banana shaped contour.

The nearest neighbor coupling constant, traditionally three to five per cent, can be selected more readily with the ASCS than with the SCS. With the SCS, the coupling constant is determined by the center to center distance of the cavities. On the other hand, the ASCS design permits the coupling constant to be changed by changing the 'banana' length as well as the center to center distance. This is illustrated below in Figure three. The ASCS structure is capable of realizing a coupling constant as large as ten per cent.

The ASCS and the SCS were numerically modeled using MAFIA.³ The frequency of resonance of banana cavity versus spacing of the stub gap is plotted in figure four. The data shows a slope of about 1.48 MHz per mil. The gap spacing indicated is

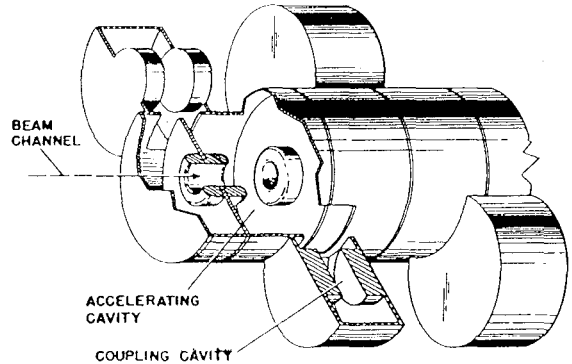


Figure 1: Classical SCS

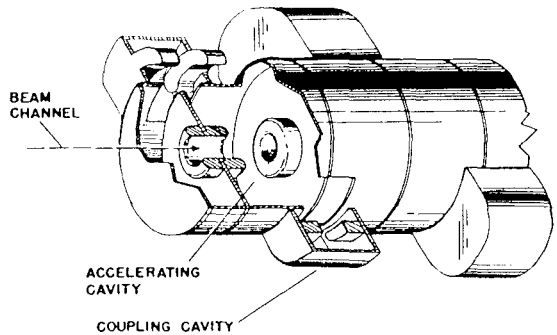


Figure 2: Alternate SCS

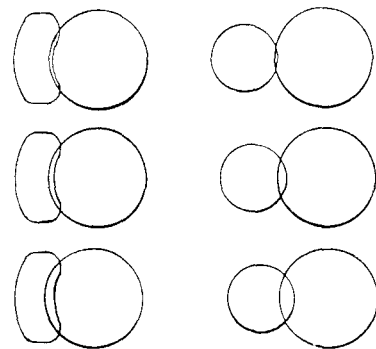


Figure 3: Coupling Aperture Variation

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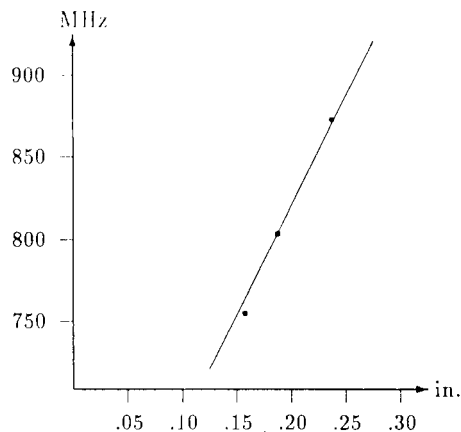


Figure 4: Frequency of Resonance v.s. Stub Gap

the distance from a side cavity stub to its image. This assembly consisted half of an accelerating cell shorted at its nose cone and coupled to half of a (banana) side cavity. Metal plates terminate the cavities at their midplanes.

MAFIA modelling of an assembly consisting of one (banana) side cavity and two half accelerating cavities, without the nose cones shorted and terminated as above, gave an accelerating mode frequency of 779 MHz with a nearest neighbor coupling, k , of 0.103, where:⁴

$$k \approx \frac{4}{\pi} \left(\frac{\omega_u - \omega_d}{\sqrt{\omega_u \omega_d}} \right)$$

and ω_u and ω_d are the frequencies immediately above and below the $\pi/2$ frequency. The Q of this mode was calculated to be 15,700. Nonaccelerating modes were identified at 771, 844, 1177, 1513, 1646, and 1838 MHz. The geometry input to MAFIA were 'first cuts'. It is entirely reasonable to expect that further investigation would lead to a k that is greater than the above value.

The banana coupling cavity alone (no slot to accelerating cavity) was measured. The first mode resonant frequency showed a 1.75 MHz per mil stub gap sensitivity. The gap spacing is defined as above. Other measurements indicated that the nearest neighbor coupling constant changes very little with frequency.

Mechanical Comparisons

Here, two versions of the ASCS are compared with the SCS. The first is a monolithic version in which the half of one accelerating cavity and half of one coupling cavity are machined into one encompassing slab. The second is a segmented version where two half accelerating cavities, aligned back to back, are machined into a single slab. Two half side cavities are then brazed on to the accelerator slab. Figure five illustrates the two versions. The monolithic version is located above the segmented version. There the relative sizes of accelerating and coupling cavities are of no significance, the purpose of the illustration is to show the boundaries of each segment or slab.

The reduced overall size of the monolithic design resulting from the banana shape over the classical circular shape is significant. Also, the resulting elliptical symmetry of this shape allows for consideration of closed die forging at the billet stage. This enjoys the advantage of considerably less machining stock and thus lower cost because of the near net shape yielded.

Reduced overall part size and weight would be of great benefit all through the fabrication, tuning, and assembly phases. This

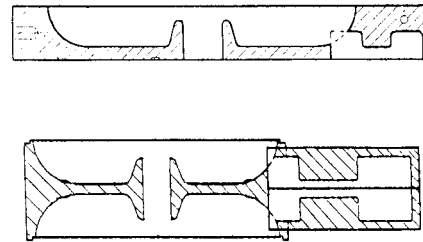


Figure 5: Monolithic v.s. Segmented Construction

design lends itself to fabrication using CNC machine tools. The close dimensional tolerances and degree of uniformity should yield dividends in the form of reduced labor at the tuning stage.

The segmented side cavity version of the banana shape enjoys many of the above advantages. It provides a contrasting study to the above in having only one half as many accelerator cavity joints but additional joints and parts associated with the segmented side cavities.

Finally, it is believed that applying electrochemical milling to this design could result in a significant cost benefit.

Future Investigations

The investigation of the ASCS is continuing. Additional cavities with varying dimensions need to be machined and measured. Computer runs with a variety of 'banana' lengths and differing amounts of cavity overlap are also needed. The flexibility of the ASCS side cavity shape may allow a smaller energy loss in the side cavity than seen in the classic SCS. The accelerating mode electric field along the beam path has to be studied. Further work will address these and other issues.

References

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