Design Study of Coupled Cell Linear Accelerator Structures for the JHF 1GeV Proton Linac

Tatsuya KAGEYAMA, Takao KATO, Yuichi MOROZUMI,
Yoshishige YAMAZAKI, Kazuo YOSHINO

National Laboratory for High Energy Physics

ABSTRACT

Design study has been being made in order to search for the best accelerating structure (1296 MHz) for the high-β part of the JHF proton linac. Possible candidates for the accelerating structure are Alternating Periodic Structure (APS), Side-Coupled Structure (SCS) and Annular-Coupled Structure (ACS). This note shows the recent results of studies on a side-coupled structure, including numerical calculations with the MAFIA [1] codes (a three dimensional numerical solution program for the Maxwell's equations) and measurement of a model cavity.

INTRODUCTION

Standing wave coupled-cell linacs of $\pi/2$ mode are efficient and practical accelerating structures and have a high degree of stability and uniformity of the accelerating field against effects due to heavy beam loading and imperfections in machining and assembling. We have been investigating three different types of coupled cell structures: alternating periodic structure (APS), side-coupled structure (SCS) and annular-coupled structure (ACS). For the APS, accelerating cells and coupling cells are located alternately on the beam axis. The SCS has coupleing cells mounted on the side of the main accelerating tank body, and the ACS has coupling cells of annular-ring structure around the accelerating tank. The APS and the ACS are axially symmetric, except that they have coupling slots. Machining and assembling of axially symmetric structures are easier. This is a merit of the APS and the ACS. However, the shunt impedance of the APS is lower than that of the SCS because of the coupling cells located on the beam axis. This demerit becomes more serious as β becomes lower. On the other hand, the ACS was reported to have a problem that the quality factor of the accelerating mode is seariously decreased. At present, we are intensively making calculations with MAFIA in order to search for a possible remedy for this problem of the ACS.

Each of the three structures has merits and demerits. There are many things to be done before the best accelerating structure is fixed. As the first step of the practical design study, we have tried Computer Aided Design (CAD) of a side-coupled structure using the MAFIA codes. The results of the CAD work was checked by measurement of a model cavity of the SCS.

CAD and MEASUREMENT of a SIDE-COUPLED STRUCTURE

Fig. 1 shows a model of the side-coupled structure used in the CAD work with MAFIA. We made calculations by changing the distance between the center of the coupling cell and the beam axis (offset parameter shown in Fig. 1), in order to investigate the dependence of the coupling factor on the size of the coupling slot. The coupling factor is defined as a ratio of the passband width to the accelerating mode frequency. Fig. 2 shows a three-dimensional plot of a mesh geometry of the SCS model generated by MAFIA. The typical mesh size was $0.5 \times 0.5 \times 0.25$ cm^3. Fig. 3 shows coupling factors calculated with MAFIA as a function of offset parameter. As the offset parameter becomes smaller, the coupling slot becomes larger and hence the coupling factor becomes larger. As seen from Fig. 3, we have a coupling of 3.2% for an offset parameter of 12.0 cm. We also made MAFIA calculation on a single accelerating cell with no coupling slots, and compared the calculation results with those for the side-coupled structure with the offset of 12.0 cm. The comparison yielded the following results: The frequency variations of the accelerating mode and the coupling mode (Δfa and Δfc) caused by opening the coupling slots, are -23.3 MHz and -48.5 MHz, respectively. The decrease of the quality factor of the accelerating mode is 5.1 %.

A cold model cavity was designed according to the CAD results for the SCS with the offset of 12.0 cm. Finer design of the cavity dimensions was performed by calculation with SUPERFISH [2] (a numerical solution code for rf structures of axis symmetry) in the following manner: For the accelerating cell, the gap length between the nose cones was calculated so as to compensate the frequency variation (Δfa = -23.3 MHz) due to the coupling slots, and make the accelerating mode frequency equal to 1296 MHz. For the coupling cell, the gap between the electrodes was calculated so as to make the coupling mode frequency equal to 1296 MHz by compensating Δfc (= -48.5 MHz).

Based on these CAD results, the model cavity was fabricated from vacuum melted copper by numerically controlled cutting machines. From the measurements on the model cavity, we have obtained the following results: The passband width is 57 MHz, which corresponds to a coupling factor of 4.4 %. The accelerating mode frequency and the coupling mode frequency are 1295.3 MHz (Δfa = -24.0 MHz) and 1294.9 MHz (Δfc = -49.6 MHz), respectively. Considering the mesh size of $0.5 \times 0.5 \times 0.25$ cm^3, we could say that the CAD with MAFIA fairly predicts the properties of the SCS model cavity.

SUMMARY

We have demonstrated by the studies on the SCS mode cavity, that CAD with MAFIA could be a useful method in designing radio-frequency structures with coupling slots, or of no axis-symmetry. At present, we are studying on the application of CAD with MAFIA to the development of a new type of the annular-coupled structure.

REFERENCES

[1] T. C. Barts et al., MAFIA "A Three-Dimensional Electromagnetic CAD system for Magnets, RF Structures and Transient Wake-Field Calculations", Proceedings of the 1986 Linear Accelerator Conferrence, SLAC, 1986.

[2] K. Halbach and R.F. Holsinger, Part. Accel. 7 (1976) 213.

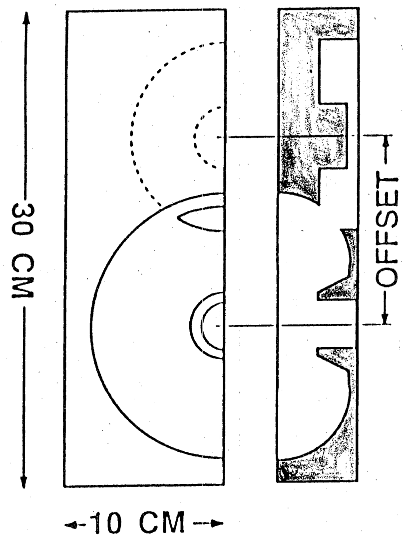

FIGURE 1 A Schematic Drawing of a SCS Model

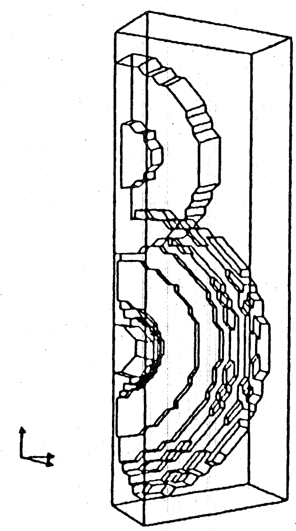

FIGURE 2 A Three-Dimensional Plot of the Mesh Geometry generated by MAFIA

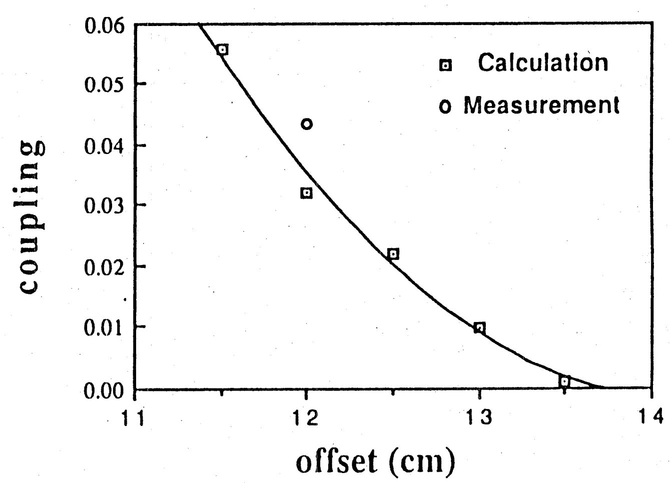

FIGURE 3 Coupling Factor as a Function of Offset Parameter