Particle Accelerators, 1990, Vol. 32, pp. 27–32
Reprints available directly from the publisher
Photocopying permitted by license only

A TUNING METHOD OF POST COUPLERS FOR A LOW β DRIFT TUBE LINAC

FUJIO NAITO, TAKAO KATO, YOSHISHIGE YAMAZAKI
AND EIICHI TAKASAKI
National Laboratory for High Energy Physics, KEK
1-1 Oho, Tsukuba-shi, Ibaraki, 305 Japan

Abstract A tuning method of post couplers was studied using a cold model of the low β drift tube linac (DTL). Since the cell length varies rapidly along a tank in the low β region, it is not simple to adjust the post couplers to obtain the stabilized field. In the present study, we found a method to adjust the post mode frequency in the low β region. We also investigated dependence of the stabilization effect on a total number of the post couplers in DTL.

INTRODUCTION.

A 1 GeV high intensity proton linac will be constructed as an injector for a ring accelerator of the Japanese Hadron Project (JHP). The proton linac consists of a radio frequency quadrupole (RFQ), a drift tube linac (DTL) and a coupled cell linac (CCL). The DTL accelerates protons from 3 MeV to 150 MeV with an accelerating frequency of 432 MHz.

Accelerating field in a DTL without post couplers is easily distorted by some perturbations because a group velocity of accelerating TM010 mode vanishes in this case. The perturbations will arise from thermal detuning, beam loading and structure imperfection. Post couplers are used to stabilize the field against the perturbations by increasing the group velocity[1].

Usually distances between the post couplers and drift tubes have been set to a constant value. No significant difference has been observed by varying the distances along a tank in the previous studies[2,3]. In our design the cell length varies very rapidly along the beam axis in the low energy region. Thus a resonant frequency of each post coupler dependent upon the length of the drift tubes should be individually set to an optimum value by adjusting the distance between the post coupler and drift tube. However, little is known about a guiding principle for this kind of adjustment. The situation is further complicated by strong coupling among post couplers that is dependent upon the distance between post couplers. One of our purposes in the present study is to find a tuning method of post couplers to stabilize the accelerating field in the low β region.

In general it is preferable to reduce a number of the post couplers so far as it is possible to keep the field stability because post couplers decrease the Q value and increase the construction cost. Thus, we also studied dependence of the field stability upon the number of post couplers.

THE COLD MODEL OF DTL

We have constructed a cold model for the 432 MHz DTL to study the RF characteristics and test the mechanical accuracy of manufacturing and assembling. Design parameters are shown in TABLE-I. It is important that cell length varies by about 65% throughout a tank.

TABLE I Design parameters of DTL.cold model

Frequency	432	MHz	Number of tuner	4	
Radius	220.5	mm	Tuner radius	35	mm
Length	2585	mm	D/T* radius	40	mm
Number of cell	35		D/T bore radius	5	mm
Cell length	55.8 ~ 92.0mm		Max number of P/C*	34	
Acc. energy	3.0 ~ 8.5	MeV	P/C radius	6.5	mm
Material	Al-5052		Stem radius	7.5	mm

(*) D/T; Drift Tube, P/C; Post Coupler

Each post coupler has an eccentric tab. That is 28 mm long and 10 mm thick. We always aligned the tab vertically during the present study. Each of the end plates of both sides has a movable half drift tubes.

EXPERIMENT.

For discussing the field stabilization effect of the post coupler qualitatively it is useful to define a distortion parameter[3] D by

$$D = \sum_{i=1}^{35} \left| E_i - \langle E \rangle \right|$$

where E_i is an average electric field of the i-th cell on axis normalized by the maximum electric field and $\langle E \rangle$ is an average of E_i's. A perturbation is introduced by inserting four frequency tuners. And it gives rise to a 15 percent field tilt in the case of no post couplers ($D=3.6\times10^{-3}$). If post couplers stabilize the field, the value of D will be reduced even with the perturbation and can be a measure of the stabilization effect. We also define the L_i as a distance between the i-th post coupler and drift tube. Accelerating field on axis was measured by a standard bead perturbation method.

At first, 34 post couplers were inserted into the DTL by the same amount for all couplers, that is, L_i=constant. In this case it was not possible to find the distance L_i that stabilizes the field. It seems that the resonant frequencies of each post couplers are too different from each other to be coupled. Thus a fine tuning of each post mode frequency by adjusting the L_i's individually is required to stabilize the accelerating field. We used the following procedure to measure the resonant frequency of each post coupler;

1. We set all post couplers to make the L_i is minimum. Here frequencies of all of post coupler modes are lower than TM010 mode.

2. Pulling out only the i-th post coupler gradually, we observed a partial shift of resonant frequencies of post modes. Among them the highest frequency corresponds to the resonant frequency of the i-th post coupler. Thus, measuring the highest frequency as a function of L_i, we could obtain the L_i dependence of the resonant frequency of post couplers.

3. After taking this kind of data for all post couplers, we adjust values of L_i's to tune the resonant frequencies of all post couplers to a certain value. Keeping the condition that all frequencies are identical, we varied the positions of the post couplers and measured the field stability against the perturbation.

The best stabilization was achieved by adjusting the distances L_i's as shown in Fig. 1, resulting in the distortion parameter of $D=1.5\times10^{-3}$.

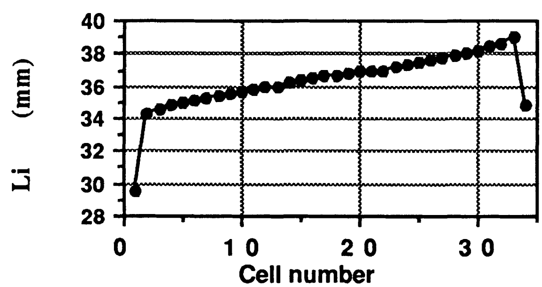

FIGURE.1 The distance L_i between i-th post coupler and drift tube vs. cell number.

The cell number dependence of L_i as revealed in Fig. 1 is qualitatively explained as follows. A length of a drift tube increases as the cell number increases, resulting in increase of capacitance between post coupler and drift tube. This increase is compensated by separating the post coupler from the drift tube, that is, moving L_i to keep an each post resonant frequency constant. The posts at the end cells (the first and 34-th posts) have no post to be coupled beyond the end plates. Equivalently speaking, the inductances of the posts are decreased. Thus, capacitances of the post couplers at end cells must be increased by decreasing L_i to tune their resonant frequencies.

In order to study the effect of the number of the post couplers on the field stability we attempted to reduce the number to 12 and 6. In contrast to the case of 34 posts, field stabilization was observed for both of the cases of 12 and 6 posts even with constant L_i. This result is in agreement with that of Ungrin, et al[3].

In Fig. 2 the L_i dependences of the distortion parameter D are shown for the cases of the 6, 12 and 34 post couplers. It is seen that the stabilized region is reduced by decreasing the number of the post couplers. This will be one of disadvantages of saving the number of the posts. It is noted that the better stabilization effect (smaller D) was obtained by reducing the number of the post couplers. This suggests that the tuning method for case of 34 post couplers is not fine enough to compensate the variation of the couplings between the post couplers along a tank.

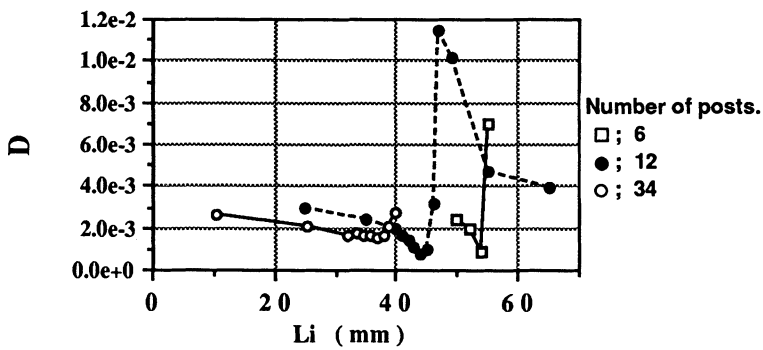

FIGURE 2 Distortion parameter D vs. distances L_i between i-th post coupler and drift tube. L_i is constant for 6 and 12 posts. Only L_i of the 18-th post coupler is shown for 34 posts.

A group velocity of the accelerating mode can be another measure of the stabilization effect of the post couplers[4]. The group velocity defined as a derivative of the measured dispersion curve (Fig. 3) at the accelerating mode is shown in Fig. 4 as a function of the number of the post couplers. It is seen that the group velocity with 34 post couplers is almost the same as one with 12 post couplers.

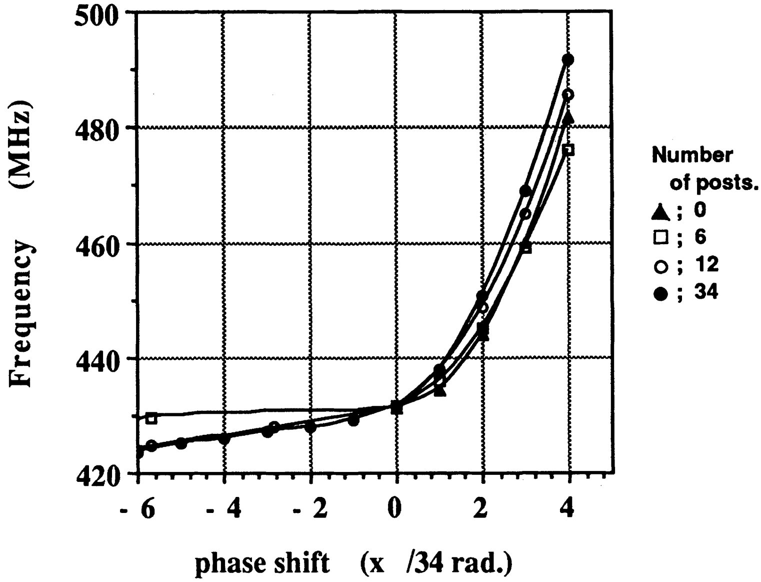

FIGURE 3 Dispersion relations of TM01n mode with 0,6,12 and 34 post couplers.

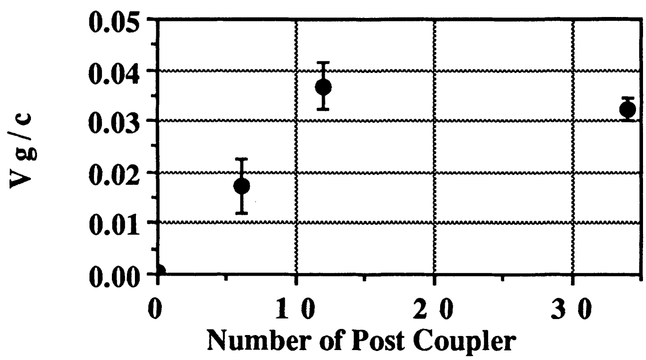

FIGURE 4 Group velocity of accelerating mode vs. number of post couplers.

The Q value of accelerating mode is shown in Fig. 5 as a function of the post couplers. Reduction of the Q value becomes about 7 percent by inserting 34 post couplers, which is not negligible small.

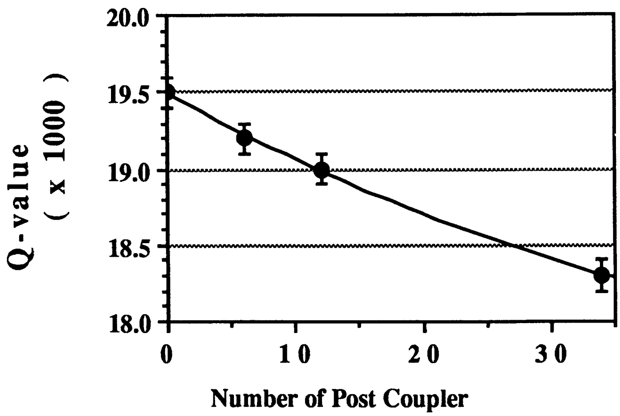

FIGURE 5 Q value of accelerating mode vs. number of post couplers. The line is just an eye guide.

CONCLUSION.

From our experimental results we conclude as follows;

1. Post couplers can stabilize the accelerating field in the low β region if we apply the fine tuning method of the distances between the post couplers and drift tubes.
2. Post couplers can also stabilize the field even if a number of post couplers is less than a number of total cell.

ACKNOWLEDGMENT

The authors would like to thank Prof. Kihara and the member of a 1 GeV Proton Linac group in KEK for their valuable discussions.

REFERENCES.

1. D. A. Swenson, E. A. Knapp, J. M. Potter and E. J. Schneider, " Stabilization of the Drift tube Linac. by Operation in the $\pi/2$ Cavity mode", Sixth Int. Conf. on High Energy Accelerator, Cambridge, Mass.,CEAL-2000 (1967) p.166
2. C. W. Owen and J. D. Wildenradt, " Experiences with Post Coupler Stabilized Structure in the NAL Linac", Proc. 1970 Proton Linac Conf. Batavia (1970) p.315
3. J. Ungrin, S. O. Schriber and R. A. Vokes, " Post coupler and Stem current measurement for High current CW drift tube Linac",IEEE Trans. Nucl. Sci. Vol. NS-30 NO.4 (1983) p.3013
4. M. Bell, " On Stabilization of Linac Cavities", Particle Accelerators Vol.3 1978) p.71