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INVESTIGATION OF THE ACCELERATING STRUCTURE FOR THE SECOND PART OF THE MESON FACTORY LINAC

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Introduction

In accordance with the project of meson factory linac[1], 108 accelerating sections with intermediate focusing magnets are used in the second part of the linac to accelerate protons from 100 to 600 MeV. The sections are grouped forming 27 cavities each of them including 4 sections and being fed by one radio-frequency generator. The sections are joint by means of bridge couplers which pass over the focusing regions[2]. An accelerating disk-and-washer structure was developed at the Radiotechnical Institute for use in meson factory linac[3,4]. Main results of theoretical and experimental studies of the accelerating structure and preliminary results of high power tests of full-scale experimental cavity are presented below.

Accelerating Structure Parameters

Cross section of accelerating structure is shown in Fig.1. It is a cylindrical cavity with conducting washers and disks where the sign-variable accelerating field is excited in the π/2-mode. Each washer is attached to the nearest disk by three stems; the washer and two stems have bores to pass a cooling water. The disk-and-washer structure may be presented as a chain of cells of two shapes: an accelerating cell is an axial region between two washers and a coupling cell is a peripheral region between two disks. Theoretical analysis has shown that in order to receive the necessary resonant frequency and unbroken dispersion curve, two unit segments should be tuned to operating frequency[3]. They are parts of the structure volume between two planes passing through the centers of two adjacent disks (Fig.2a) or the centers of washers (Fig.2b). This transition from the cavity to separate segments was used when the tuning procedure had been developed and structure parameters calculated. An optimal shape of the structure has been determined using a digital computer program which calculates the resonant frequencies and electromagnetic fields of both unit segments and varies dimensions $2r_o$ and 2R to adjust their frequencies to an operating frequency 991 MHz. The curves of shunt impedance versus an accelerating gap $2b_1$, thickness of disks $2t_2$ and the other dimensions have been obtained, and now all dimensions have been chosen to optimize the shunt impedance and to provide electrical reliability of the structure.

Fig.3 shows calculated values of the effective shunt impedance ZT^2 and quality factor Q versus particle velocity. Breaks of the curve ZT^2 are caused by the changes of the aperture diameter which accordingly is 3.4, 3.6, 3.8 cm. The real values ZT^2 and Q are less by 5-7% because the actual RF loss in copper is greater than the theoretical one. Fig.4 shows values of the cavity diameter 2R and the washer diameter $2r_o$ vs β. These values include the tuning margin and the corrections for the stems effect which has been left out of account in the course of computation. The stems effect has been defined for seven values of β : 0.43, 0.46, 0.505, 0.55, 0.60, 0.70 and 0.79, using 1/3-size models of the accelerating sections. With these models, the dispersion properties of the accelerating structure have been studied, since the computation of dispersion properties is very difficult. Fig.5 shows the dispersion curves of two models. Each of them is linear and symmetric near by π/2-mode. Coupling factor between cells of the structure is very great: K_c= 46-48%. As a consequence of extremely strong coupling the accelerating field distribution is insensitive to fabrication and tuning errors and beam loading. Maximum deviations of the electric field distribution along the models were within 1%. Each model has been tuned as a whole without separate cells tuning-up.

High Power Tests of Full-Scale Cavity

In December 1974, fabrication and installation of the experimental full-scale cavity including two sections was completed. Each section consists of 20 accelerating cells with sizes equal to the first cavity sizes of the linac's second part. The sections are joined by means of a bridge coupler in the form of a rectangular waveguide segment the length of which is 3.5 times the wave length of the H_{10}-mode. The bridge coupler with this length provides the phase shift π between fields in the last gap of the first section and the first gap of the second section. The second bridge coupler is joined with the second section exit and shorted on the free end. The cavity has been fed by the waveguide connected to the bridge coupler on the narrow wall.

Initial cavity excitation procedure began with pulse length of 140 μs while pulse repetition frequency was gradually increased from 1 to 100 pulses per second. Multipactoring appeared at low power level and continued till the rated one, leading to the rise of pressure. Therefore, the power level was gradually raised as the vacuum in the cavity had been improved and pulse distortions had been disappeared. Initial excitation procedure took about 15 hours and came to the end when nominal field 36 kV/cm had been obtained. Nominal peak power was about 1 MW and average power was 14 kW. Separate high-voltage discharges occured; a number of them had been gradually reduced as RF training being proceeded. After 15 hours of RF training daily switching on had been realized by leap without procedure of gradual raising of the level, and operation was stable without any discharges. After an exposure to air the excitation procedure took about 1.5 hours.

During operation peak power was increased to 1.5 MW. As power was raising some high-voltage discharges were being observed. In the course of RF training a number of discharges had gradually been reducing. After 1.5 hours training one discharge might be observed in every 2-3 minutes.

The phase and amplitude differences between the most distant cells of the cavity were measured. They seem to be invariable during the steady state and transient processes caused by power switching on or change of the section temperature. The cavity is cooled by means of water which runs inside the washers. Therefore, thermal transient time is small. After power switching on frequency equilibrium time is 3-4 minutes and a fall of the resonant frequency is about 90 kHz while cooling water expenditure is 3 m^3/hr for every section. Fig.6 shows resonant frequency plotted vs cooling water expenditure.

A vacuum set up includes two sputter ion pumps which are joint to the bridge couplers. Initially summary pumping rate was 350 litres per second. Vacuum 1.10^{-7} Torr had been obtained before RF power was applied. As consequence of a good vacuum conduction of the structure the pressure overall along the section is small ($<15\%$). Raising of the resonant frequency due to pumping is 290 kHz. The basic components of residual gas are hydrogen (50%), nitrogen and carbon monoxide (25%), water vapors (8%). A mass spectrum is free of hydrocarbon peaks (C_mH_n). Heavy components which can recharge H^- ions have not been found except argon (10%). While applying the RF power a substantial increase of the hydrogen component (to 65%) due to hydrogen deposition from the copper surface has been observed. As RF training has proceeded hydrogen deposition has reduced and vacuum has become better. After RF training power switching on does not cause raising of pressure. Recently the pumping rate has been increased to 500 litres per second and pressure 3.10^{-8} Torr has been obtained.

References

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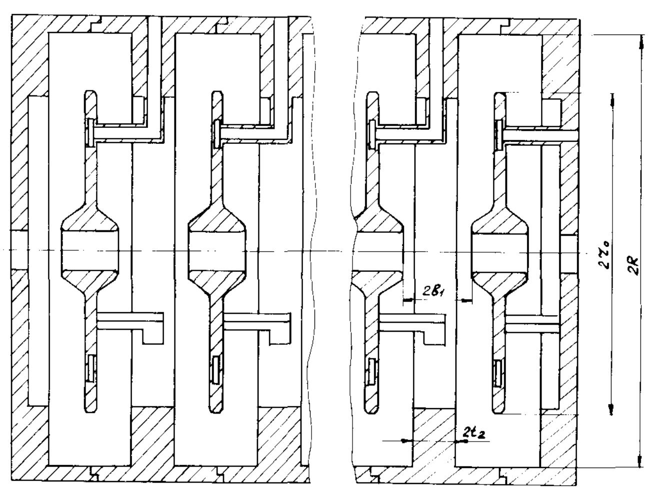

Fig. 1 Cross section of the disk-and-washer structure.

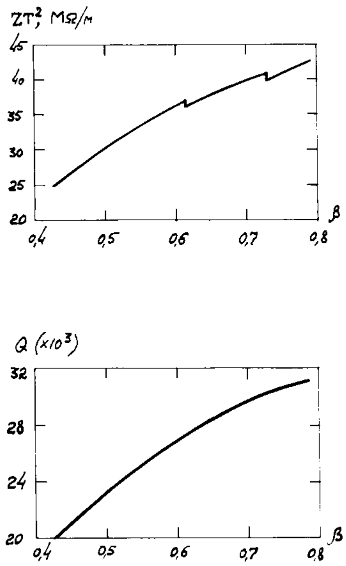

Fig. 3 Calculated values of the effective shunt impedance ZT^2 and quality factor Q.

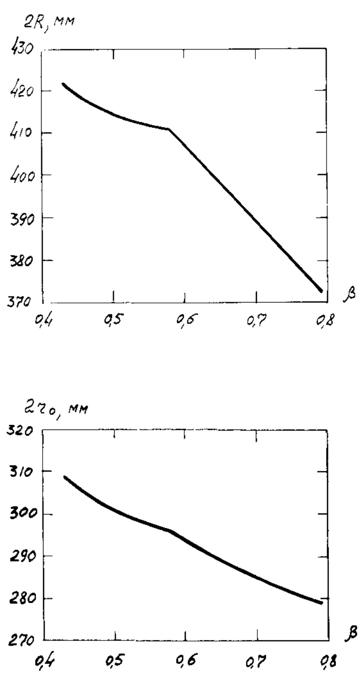

Fig. 4 The structure diameter 2R and the washer diameter $2r_o$.

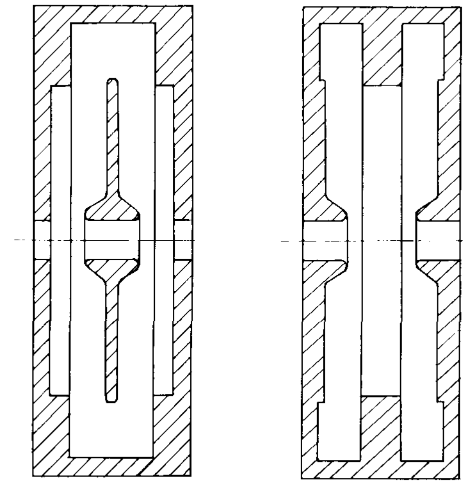

Fig. 2 Cross section of unit segments:
a) segment with a washer
b) segment with a disk

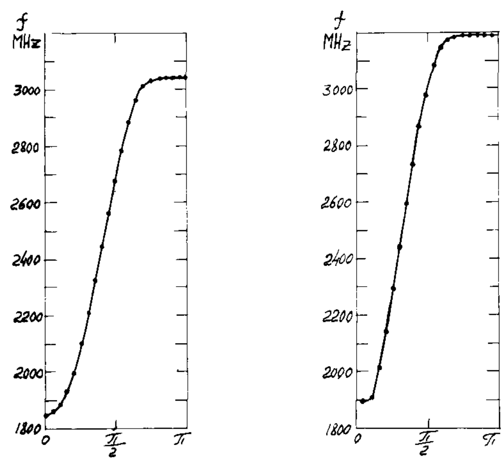

Fig. 5 Dispersion curves of models of the accelerating sections:
a) β = 0.70 b) β = 0.46

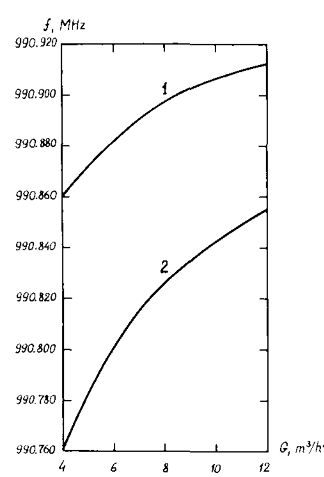

Fig. 6 Resonant frequency vs cooling water expenditure. Curve 1 - average power is 12 kW, curve 2 - 22 kW.