DECREASING TRANSIENT BEAM LOADING IN RF CAVITIES OF U-70 ACCELERATOR

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Abstract

The U-70 RF system was worked out to operate with the injector - linac at 100 MeV energy. A wide RF range was (2.6-6.1) MHz. For the U-70 injector Booster the wide RF range decreased and now it is (5.5-6.1) MHz. This fact and simplest method of changing the parameters in RF ferrite dominated cavities allow one to increase of the equivalent value of the cavity capacitance for the main frequency by about a factor of 2.7 and increase of the value of the cavity gap capacitance by about a factor of 5 [1]. The experimental investigation of the U-70 RF cavities due to the injection of bunches from the Booster into the U-70 orbit, near transition and on main flat-top is presented.

I. EXPERIMENTAL RESULTS

When a bunch charge crosses the cavity, it leaves behind a voltage. This voltage will decrease with an increase of an accelerating gap capacity (fundamental theorem of beam loading [2]). The equivalent circuit of a resonator is shown in Fig.1.

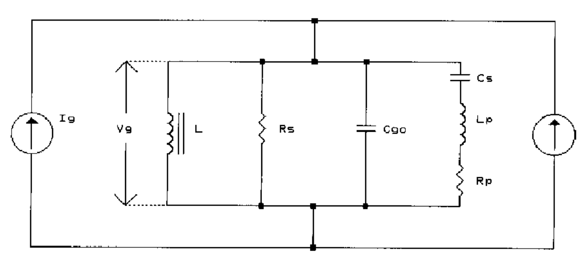

Figure. 1. The equivalent circuit of a resonator.

Here L - inductance of the cavity, C_{g0} - capacity of the accelerating gap, R_s - shunt impedance of the cavity on main working frequency in which the exciting amplifier output impedance, transformed to the cavity gap, is included in R_s as well as the cavity loss. I_g, I_b - current RF generators of the exciting amplifier and bunch accordingly, C_s - capacity of tube, L_p - inductance of a connecting plug-in, it connect the gap to the anode of the final tube, V_g - voltage on the accelerating gap.

Below in the article the experimental characteristics for two cavities will be resulted:

- A - old design,
- B - new design.

In table 1 control parameters of cavities for initial frequency of accelerating field $f_0 = 5,500 MHz$, measured in the test cavity without a beam on method [3] are shown.

Table 1.

cavity	$C_g(pF)$	$C_{g0}(pF)$	$L(\mu H)$	$R_s(kOhm)$	Q_0
A-old	253	89	3,31	7,4	65
B-new	672	480	1.25	6,4	148

C_g - total capacity, indicated to an accelerating gap on main working frequency of a resonator. Q_0 - quality of resonator non-loaded by beam.

On Booster flat-top of U-70, ξ -value of the ratio for beam induced voltage in an idle cavities A, B and a quality Q were measured. The accelerating cavities in test were used resonant of a wall-current monitors. The resonant frequency of cavities was established by change of a bias field current and corresponded to frequency of a accelerating field.

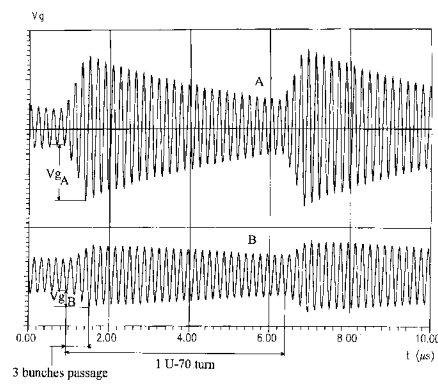

Figure. 2. Beam induced voltage in cavities.

On Fig.2 are shown the voltages in gap of cavities, developed at the passage of three circulating bunches following in succession. The value ξ is equal

$$\xi = \frac{V_{gA}}{V_{gB}} = \frac{C_{gB}}{C_{gA}}, \qquad (1)$$

where V_{gA}, V_{gB} - induced voltage of bunches at the passage old and new of cavities accordingly. The measured value was $\xi = V_{gA}/V_{gB} \simeq 2{,}7$. The ratio C_{gB}/C_{gA} is 2,66 (see table 1).

After passage bunches in cavities free oscillations with frequency of set-up f are made. The constant time of cavity τ_f is connected with a quality Q by a ratio

$$\tau_f = \frac{2Q}{\omega}, \qquad (2)$$

where $\omega = 2\pi f$. If a constant time of the cavity to express through number of RF periods during which the amplitude of

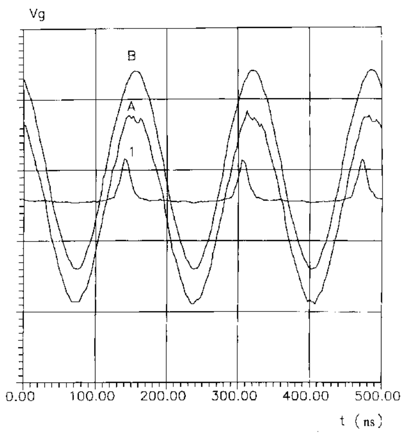

Figure. 3. Accelerating voltage in cavities near transition.

free oscillations will decrease in e time, then a quality can be determined as

$$Q = \pi m \ , \qquad (3)$$

where m - number of RF periods f. The measured values were m_A=21, m_B=44 and then Q_A=66, Q_B=138. The results of control measurements a quality listed in table by 1 well coincide with experimental made on a beam.

A study of transient beam loading of the U-70 accelerating cavities due to the injection of bunches from the Booster into the U-70 orbit. The theoretical aspects of a problem are described in work [4]. For new U-70 cavities the measurement value of phase shift of a accelerating wave of a electrical field after injection bunch in free bucket makes about 3 degrees at bunch intensity $N_b = 10^{12}$ protons. This value is by a factor 3 less than in case of old cavities because of a increase cavity capacity of a on such value. It should remind, that in U-70 can be injected 30 bunches.

The transients in the cavity U-70 about transition called by passage the bunches high density are displayed maximally. Excitation of a harmful resonance in old cavity at $42MHz$ from a circuit plug-in of inductance L_p and output final tube of capacity C_p of a connecting tube with the cavity gap is observed. The similar problem was resolved in PS CERN by installation special a high pass damper connected to the anode of the final tube [5]. In modernized variant of a cavity the suppression of the harmful resonance occurs on self.

On a Fig.3 are shown: 1 - bunches (5×10^{11} protons/bunch), A- accelerating voltage on the gap of the old cavity, B- accelerating voltage on the gap of the new cavity. Peak amplitude of a voltage on gap was equally $V_g = 10kV$. The appreciable distortion of a accelerating wave for the cavity A is stipulated by L_p, C_{g0}, C_s of a circuit with the resonant frequency $f_{pA} \simeq 42MHz$ and a quality $Q_{pA} \simeq 6$. A impedance on this frequency made $Z_{sA} \simeq 400Ohm$. In the cavity B after a increase of capacity C_{g0} the frequency of the harmful cavity resonance has made $f_{pB} \simeq 27MHz$, the impedance was $Z_{sB} \simeq 25Ohm$. The reduction of the impedance was stipulated almost by equal frequencies of parallel and serial resonances. In serial circuit L_p, C_s the resonant frequency was $f_{sB} \simeq 24MHz$.

In summary some words about stationary interaction of the beam with cavities on main flat-top of U-70. The most of physical experiments on main flat-top are carried out with a coasting beam. By virtue of technical difficulties the gaps of cavities can not be short connected on a time of the beam circulation. Interaction of cavities with a circulating beam is observed. It is expressed in a grouping of beam on the tune frequency of cavities. The reduction an absolute value for the impedance of RF system divided by harmonic number Z_k/k causes a increase of threshold a coasting beam instability in U-70 accelerator (Keil-Schnell criterion [6]).

In our case change of initial frequency of tune RF system with $2.6MHz$ to $5.35MHz$ (at absence of a bias field current in cavities) results in the reduction Z_k/k. The value frequency $f = 5.35MHz$ corresponds to a condition of a finding precisely between k=26 and k=27 by harmonics of revolution frequency on flat-top. The revolution frequency is $F_0 = 202kHz$. The reduction of impedance Z_k occurs because of a increase of ferrite losses in cavities on higher frequency. So now we have the reduction Z_k/k on main flat-top of U-70 more than by a factor 5.

References

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