Ferromagnetic Cores Made from Amorphous Material for Broad-band Accelerating System

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Amorphous ferromagnetic ribbons are considered as a material for ferromagnetic cores for unresonant accelerating structures of 100...200-MeV ion accelerators. The manufacturing of the cores using this material are cheaper and easier than that of the cores made from common-used ferrites. Calculated and experimental characteristics of the ferromagnetic cores made from these ribbons (permeability and tangent loss) for a coaxial broad-band accelerating system are presented. These characteristics over the frequency range from 1 to 10 MHz are in good agreement taking into account skin-effect. Possible versions of coaxial accelerating systems for medical synchrotrones with above mentioned cores are considered.

I. METHOD OF CALCULATION

The coaxial cavity with toroidal ferromagnetic cores is shown in Fig.1.

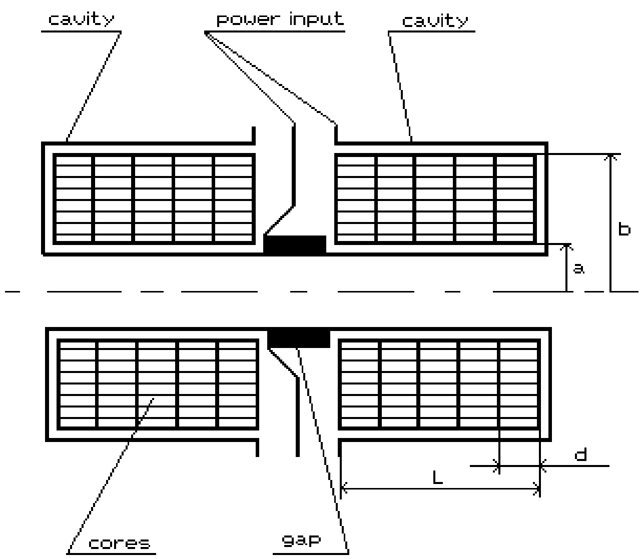

Figure 1. Accelerating system.

At small electric and magnetic fields without saturation and for a narrouw hysteresis cycle someresults presented in [1] may be used to calculate parameters of such system. The paper [1] generalizes results described in [2] in case of foliated cores. In this case the dominant role is played by skin-effect which limits the magnetic field penetration in to the ribbon and creates power dissipation.The complex input impedance of the left or right part of the cavity may be calculated using the following equation:

$$Z = j\frac{\ln(b/a)}{2\pi}\sqrt{<\mu>/<\varepsilon>}\,\mathrm{tg}(KL) + (j2\pi fC)^{-1}, \qquad (1)$$

where $(\varepsilon) = \varepsilon_1(\Delta_1+\Delta_2)/\Delta_1$, $(\mu) = [\mu]e^{-j\delta}$, $\mathrm{tg}\,\delta = (\mathrm{sh}P - \sin P)(\mathrm{sh}P + \sin P)^{-1}$, $P = \Delta_2\sqrt{\mu_2 \pi f/\rho}$, $K = 2\pi f\sqrt{(\varepsilon)(\mu)}$, $[\mu] = \dfrac{\Delta_2\mu_2(\mathrm{sh}P+\sin P)}{(\Delta_1+\Delta_2)P(\mathrm{ch}P+\cos P)\cos\delta}$.

In these formulas (ε) is the resulting dielectric permeability, (μ) is the resulting complex magnetic permeability of the foliated cores, ε_1 is the dielectric permeability of the insulation between the ribbons, μ_2 is the magnetic permeability of the ribbon at the zero frequency, Δ_1 is the thickness of the insulation between the ribbons, Δ_2 is the thickness of the ribbon, ρ is the ohmic resistance of the ribbon material, C is the equivalent capacity of the accelerating gap, f is the frequency.

II. CALCULATED AND EXPERIMENTAL RESULTS

In order to develop one of the versions of the coaxial accelerating system for the medical H-minus synchrotron with the energy of 250 MeV the amorphous material 9KCP (Metglas 2605) with the following characteristics was used: $\mu_2/\mu_\bullet=4000$, $\rho=1,3\bullet10^{-6}$ Ohm•m $\Delta_2=25\bullet10^{-6}$m, $\Delta_1=8\bullet10^{-6}$m, d=0,02m, a=0,117m, b=0,21m. Experimental and calculated characteristics for this material are shown in Fig. 2 also.

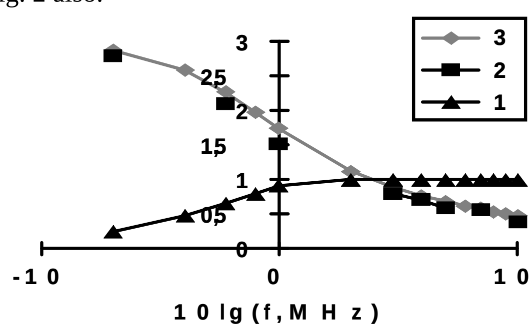

Figure2. Characteristics of the cores: 1 is $\mathrm{tg}\delta$ (calculated), 2 is $[\mu]/1000\mu_\bullet$ (experimental), 3 is $[\mu]/1000\mu_\bullet$ (calculated).

The accelerating system consists of two simmetrical left and right parts (Fig.1). Its frequency range is 3,8-14,7 MHz, the maximum accelerating voltage supplied to the gap is 600 V, L= 0,1m, C= 60 pF, the total number of the cores is 10. There are four cavities of this type in the accelerator. The experimental and calculated absolute values of the input impedance [Z] for the left or right part of the accelerating system calculated with the use of (1) are shown in Fig.3.

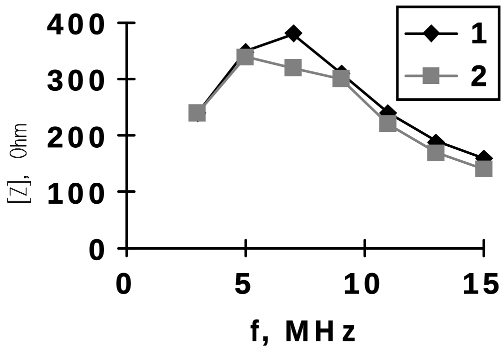

Figure 3 . Input impedance of the cavity : 1 is [Z] (calculated) , 2 is [Z] (experimental) .

According to these results the system is unresonant and it is analogous to the systems presented in [3, 4]. The advantage of the system is the small variation of its input impedance in a wide frequency range. The analysis of different versions of this type of accelerating systems shows that such systems are suitable for lower frequencies of the accelerating voltage. For example the accelerating system of the medical proton synhrotron with the energy of 220 MeV, the frequency range is 0,8 - 3,6 MHz, L=0,18 m, a= 0,07m, b= 0,21m, has the impedance changing between 500 Ohm and 700 Ohm.

III. REFERENCES

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