

# THE CHARACTERISTICS OF DIFFERENT MAGNETIC MATERIAL FOR RF CAVITY UNDER PERPENDICULAR MAGNETIZATION

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## Abstract

In recent years, a technology of perpendicular magnetization for ferrite loaded cavities is developed. Yttrium Garnet ferrite is generally used for that case with higher frequency range from 30-60 MHz. An attempt is taken to measure the characteristics of different new materials such as FINEMET, METGLAS and NiZn ferrite under the condition of perpendicular magnetization. The results are summarized in this paper.

## 1 INTRODUCTION

Ferrite loaded cavity is usually used in Proton Synchrotron with a magnetic biasing field which is in parallel direction with the RF magnetic field. The resonant frequency of the cavity is tuned by varying the biasing field hence the permeability of the ferrite. Recently, it is found if the direction of the biasing field is changed to perpendicular with the RF magnetic field, the RF losses of the ferrite will be greatly reduced [1]. The principle has been explained elsewhere for example in [2]; it is because if the material is magnetized to saturation beyond the gyromagnetic resonance field, there is no longer any possibility of resonance occur. Yttrium Garnet ferrite are available with very low saturation magnetization fields, so it is widely used for cavities with perpendicular biasing [3]. But now, some new materials of magnetic alloy such as FINEMET, METGLAS are developed and to be used for RF cavity instead of ferrite because of their special advantages [4], also some NiZn ferrite with low saturation biasing field are developed. What the characteristics of these materials under perpendicular magnetization are of great interest. An attempt to measure their characteristics were carried out and the results are presented in this paper.

## 2 MEASUREMENT APPARATUS

The main purpose of this measurement is to know the tendency of the characteristics of those materials under perpendicular magnetization biasing, the precision of measurement is of second importance. A small dipole magnet with the pole diameter 10.4 cm and gap width 3.9 cm and a  $hp$  4285 LCR meter are used for measurement.

The ring of the material will be as a 1 turn coil, then the  $L_p$ ,  $R_p$  and  $Q$  are measured. Here,  $L_p$  is proportional to  $\mu$  and  $R_p$  is proportional to  $\mu QF$ . The magnet field is measured by a gauss meter. The relation of the field to the

current of the magnet can be fitted as  $B = 0.38987 + 0.24953 I R$ , where  $B$  in kgauss,  $I$  in Amp. and  $R = 0.9933$ . At 10A the magnetic field is about 3 kgauss. In order to examine the effects of perpendicular magnetization, the ratio of the measured values with different biasing fields at same frequency is introduced.

## 3 RESULTS OF MEASUREMENT

### 3.1 FINEMET

FINEMET is a new material developed by HITACHI METAL. It is made with the thin isolated tape of the Fe-based alloy consisted of amorphous and crystal with the size of nano-meter. It has a very high permeability and rather low  $Q$  but still high  $\mu QF$  value. The main advantages of this material are:

- \* It can work at more high  $B_{rf}$  and high temperature than ferrite and still keep the characteristics stable.
- \* Because of low  $Q$ , the cavity can be a wide-band cavity, no tuning system is needed;
- \* High Curie temperature (570°C).

Three types as FT-3M, FT-3L and FT-3H of FINEMET cores are measured. The dimension of them is : O.D.=70mm, I.D.=32mm and thickness  $t=25$ mm. The thickness of the tape is 18  $\mu$ m. They have different heat processing under magnetic field with different direction as is listed in Table 1.

Table 1

name	direction of magnetic field
FT-3M	no magnetic field
FT-3L	axial
FT-3H	azimuthal

The direction of  $B_{rf}$  in cavity is along the tape of the material, so axial means the magnetic field is perpendicular to the  $B_{rf}$ , azimuthal is parallel.

The results of measurement shows the characteristics of FINEMET have only a little improvement. Taking FT-3M as an example, the ratio of  $R_p$  and  $Q$  at 10MHz are:

$$R_p(10A)/R_p(0A) = 1.45$$

$$Q(10A)/Q(0A) = 1.6$$

The conclusion is, there is very small increase of  $R_p$  and  $Q$ , so does for FT-3L and FT-3H. But it is interesting to point out ; the  $L_p$  of FT-3H is little increased with increase of bias field and the  $R_p$  of FT-3L is decreased with increase of bias field. These phenomena are in contrast with the common knowledge of conventional materials.

### 3.2 METGLAS

Two types as AM-no1 and AM-no6 of METGLAS as an amorphous core of Fe and PF as an alloy of Fe and Ni composed of amorphousness are measured. All of them are rolled by thin tape, the thickness of the tape of PF and AM-no1 is 16  $\mu\text{m}$  and 23 $\mu\text{m}$  of AM-no6. Only AM-no6 has been treated by heat process. The dimension is: O.D.=70mm, I.D.=34mm and t=25mm. The results of measurement for AM is less of interest because of less improvement. But PF is quite different, both the Q and the  $R_p$  are greatly increased with increase of perpendicular magnetic biasing. The ratio of Q and  $R_p$  reach about 100 and 20. The results are shown in Fig 1,2 and 3.

### 3.3 NiZn ferrite

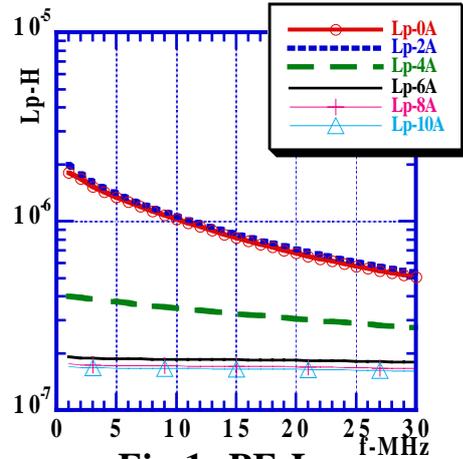
Usually, people think NiZn ferrite is not suitable for perpendicular magnetization biasing because of their very high saturation magnetization field. But S-6 and S-7 manufactured by TDK have lower saturation value. Both the Q and  $R_p$  are greatly increased under the perpendicular magnetization biasing. The ratio of Q is little more than 100 and the ratio of  $R_p$  more than 50. The results are shown in Fig.4,5,6 and Fig.7,8,9 respectively. The dimension of them is O.D.=31mm, I.D.=23mm and t=10mm. As it is well known, the characteristics of ferrites are deteriorated at higher  $B_{rf}$ , though the  $\mu QF$  at small  $B_{rf}$  is higher than magnetic alloy in this measurement.

## 4 CONCLUSION

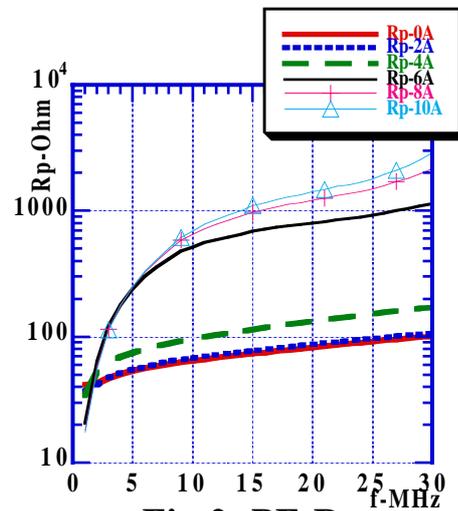
Some new magnetic materials for RF cavity under perpendicular magnetization field are measured. PF shows great improvement in  $R_p$  and Q. NiZn S-6, 7 have lower saturation field, they can be used in practice under reasonable biasing field. It is shown that the Q and  $R_p$  are still keeping increasing with increase of frequency. For practical use, the characteristics dependence on  $B_{rf}$  and temperature and the measurement of real dimension must be carried out in further works.

### References:

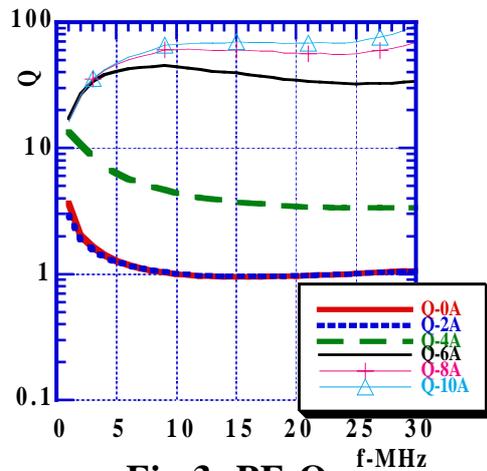
- [1] W.R. Smythe IEEE NS-30, P2173, (1983)
- [2] R.L. Poirier IEEE Particle Acc. Conf. P753, (1993)
- [3] W.R.Smythe et al., IEEE Particle Acc. Conf. P2951,(1985)
- [4] C.Ohmori et al., Proceeding of Particle Acc. Conf. Vancouver,Canada (1997)



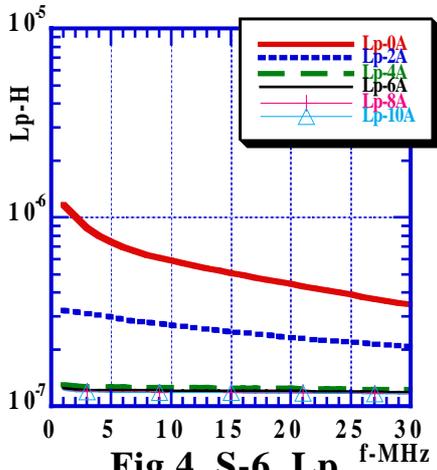
**Fig.1 PF-Lp**



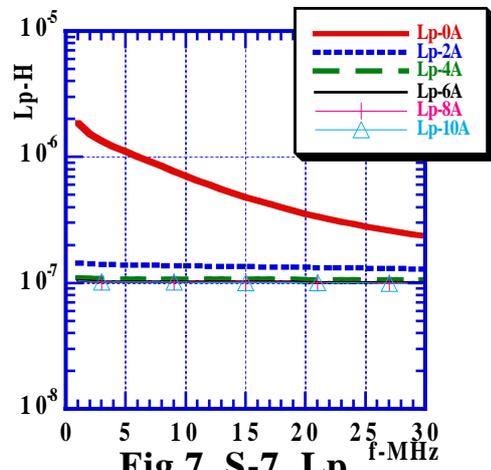
**Fig.2 PF-Rp**



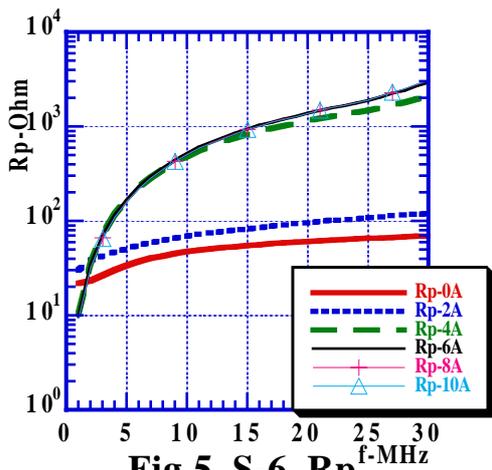
**Fig.3 PF-Q**



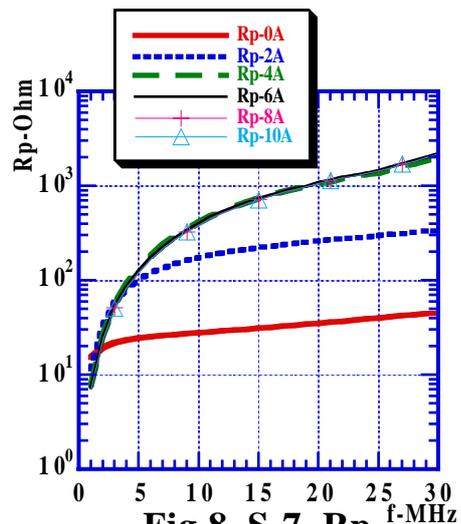
**Fig.4 S-6 Lp**



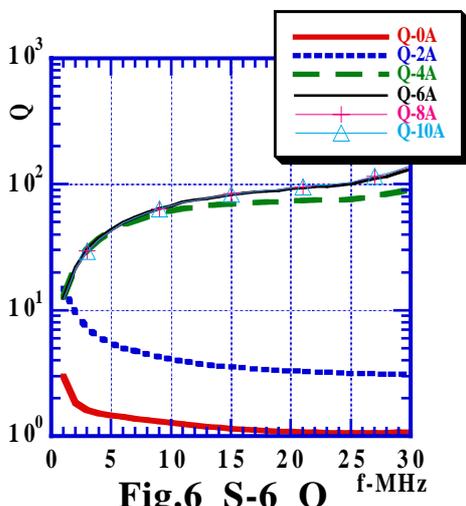
**Fig.7 S-7 Lp**



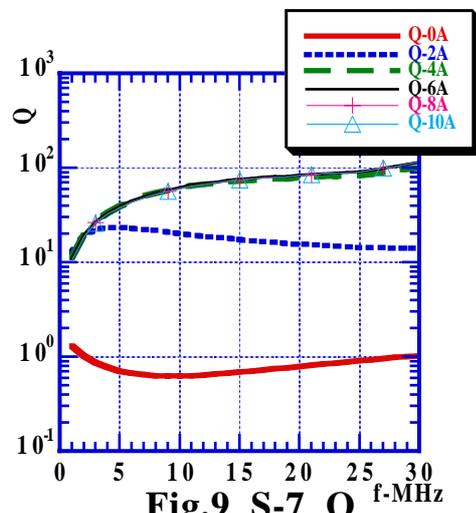
**Fig.5 S-6 Rp**



**Fig.8 S-7 Rp**



**Fig.6 S-6 Q**



**Fig.9 S-7 Q**