DEVELOPMENTS OF MAGNETIC ALLOY CORES WITH HIGHER IMPEDANCE FOR J-PARC UPGRADE

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Abstract

Magnetic alloy cavities are successfully used for J-PARC synchrotrons [1]. These cavities generate much higher RF voltage than ordinary ferrite cavities. For future upgrades of J-PARC facilities, a higher field gradient is necessary. It was found that the characteristics of magnetic alloy are improved by a new annealing scheme under magnetic field. A large production system using an old cyclotron magnet is under construction for the J-PARC upgrade. The status of core development will be reported.

INTRODUCTION

The J-PARC 3GeV RCS, Rapid Cycling Synchrotron, has started the high power user operation of 120 kW and 300 kW beam was delivered for one hour on target [2]. After modification of the neutron target, it is planned to deliver 200 kW beam in this fall. RCS was designed as a compact ring based on the technology using a high gradient cavity. The total length of the long straight sections, 44 m is optimized to obtain the required RF voltage using Magnetic Alloy-loaded cavities. As the field gradient of an ordinary ferrite-loaded cavity is limited and below 10 kV for an RCS with a large beam aperture, about 100 m-straight section would be necessary. However, the experiment users using neutrons require a short beam bunch. Long bunch of large ring bunch does not match with their requirement. The MA cavity was a solution to solve this problem.

The J-PARC MR, Main Ring, is operated with a repetition period of 3.52 sec for fast extraction mode. It is planned to increase the rate up to 1 Hz as shown in Fig. 1. Main parameters of the RF systems are listed in Table 1. However, the spaces to install the RF systems are limited and only twelve systems can be installed. It is quite necessary to increase the field gradient of the RF cavities to achieve the repetition rate of 1Hz. As the field gradients of J-PARC cavities are already high, there will be many problems to increase the power dissipation in MA cores [3]

Improvements of the MA materials are reported [4]. It is shown that the characteristics of it will be increased by factor of two by applying a magnetic field during the crystallization process in the production. An RF system design for the MR based on a new material is also shown. The field gradient will be about two times higher without increasing power dissipation in MA cores. It is also reported [5] that short bunches will be formed by applying it for the RCS cavities.

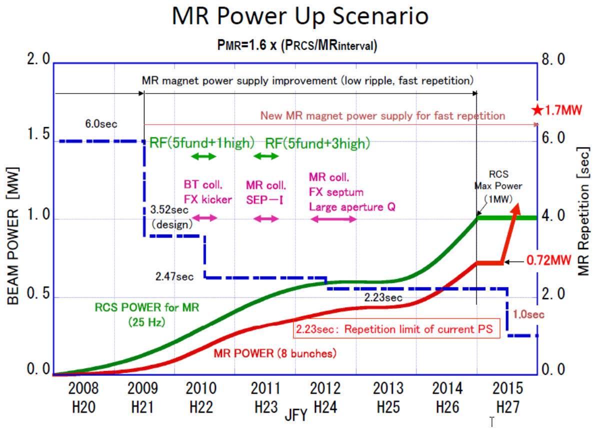

Figure 1: Beam Power Upgrade Scenario of J-PARC MR [6].

Table 1: Main Parameter of RF for 1Hz operation

Magnet pattern	Sinusoidal wave (during acceleration)
Injection time	120 ms
Acceleration time	500 ms
Magnet ramp down	$\leq$ 380 ms
RF voltage	540 kV
Maximum Δp/p	0.67 %
Filing factor	70 %
Maximu ϕ_S	61°
Effective duty	70 %
2nd harmonics	200 kV
Number RF cavities	12 (9 for H=9, 3 for H=18)

It is also investigated to study the mechanism to improve the characteristics of the materials [5]. With the collaboration with Material and Life Science Facility of J-PARC, μSR experiments were performed for the materials [4]. It clearly showed the effects on magnetic properties by apply-

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ing the magnetic field during the crystallization process in production. It suggests that the magnetic axes of nanoscale crystalline in FT3L are aligned to the direction of the magnetic field during the annealing process. The collaboration to study the magnetic alloy is still continuing.

PRODUCTION OF LARGE SIZE MA CORE

So far, the size of MA cores using FT3L technology was limited. Recently, a large production facility has been operated in the company to supply more FT3L materials for industrial uses. We have produced 27 cm-size FT3L core with a cooperation with Hitachi Metal Co. as a test production of larger size one. Figure 2 shows the product $\mu'_p Qf$ of MA cores by this test production. The result shows that it has a large shunt impedance as small core samples. The size-effects were not seen from this production, fortunately. $\mu'_p Qf$ is given by

$$R_p = \mu_0(\mu'_p Qf)t \ln \frac{\text{O.D.}}{\text{I.D.}}, \qquad (1)$$

where O.D., I.D., and t are the outer diameter, inner diameter, and the thickness of toroidal core. The product $\mu'_p Qf$ is independent of the size and shape of the magnetic core and is used to evaluate magnetic materials. Figure 3 shows the Q-value of the materials. It shows that the improvement on $\mu'_p Qf$ is mainly caused by increasing the Q-value.

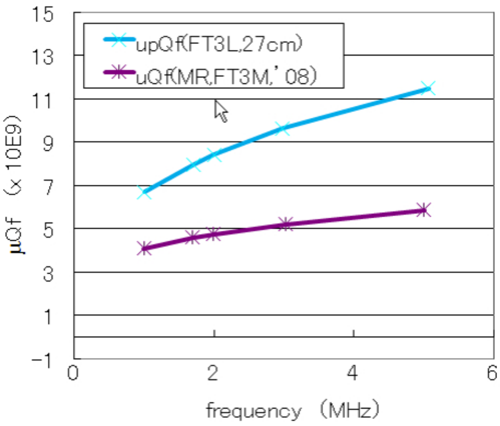

Figure 2: Characteristics of MA cores. The product $\mu'_p Qf$ for the test production (blue line) and that for ordinary MA cores (violet line) which is used for J-PARC MR are shown.

LARGE PRODUCTION SYSTEM

Although the commercially available new production line can make an MA core up to 30 cm diameter, it is not enough to produce the MA core for accelerator use. By the cooperation with the Institute of Particle and Nuclear Studies in KEK, a large size cyclotron magnet will be rent for production of the large size core, in this fall (see Fig. 4). The magnet has been modified as a large aperture one for a spectrometer magnet and it fits to install an annealing system of the FT3L materials for accelerator use. Figures 4 also shows an oven to anneal the core after winding. The gap height of the magnet is 60 cm and diameter of pole piece is 1.8 m. It can generate a good magnetic field to produce a large size MA core. The inner size of the oven is 1.1 m(W) X 1.4 m(L) X 30 cm(H). As the outer diameter of J-PARC MA core is 85 cm for the RCS, the inner size of the oven is enough for production. The oven will be installed in the magnet in this fall. The production of a large FT3L cores will be started in this year.

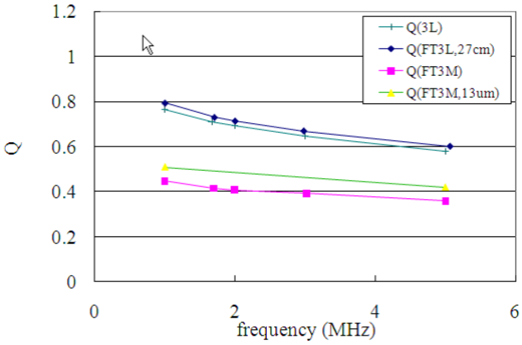

Figure 3: Q-value of MA cores. Q-values for FT3L's (small core sample and the 27 cm test production, blue lines) and for ordinary MA cores, FT3M, of standard thickness (18 μm, red line) and thinner one (13 μm, green line) are shown. The Q-value is increased by reducing the thickness of ribbon. However, it is increased more by applying magnetic field while crystallization.

DESIGN OF RF CAVITY

Figure 5 shows the required voltage for 1 Hz operation. As the number of the cavities for acceleration is 9, each caviy will generate 60 kV. For the second harmonic RF, 70 kV is necessary. The present 3-gap cavity will be modified to 4-gap structure.[5] The length of the cavity will be almost same as that of the present one to fit to the space in MR. The core thickness is reduced to 2.0 (or 2.5) cm instead of 3.5 cm. Because the μQf product of the FT3L is 2 times larger than the present FT3M, the resulting core impedance is still higher. The 4-gap cavity will be driven by the present amplifier and power supplies.

The field gradient of the new RF system is shown in Fig. 6 with other RF systems and present ones.

CONCLUSIONS

We prepare to produce large MA cores for accelerator use to increase the beam power of J-PARC MR and to improve the beam quality of the RCS.

Figure 4: Top: FM Cyclotron Magnet, Middle:Oven to anneal FT3L material for J-PARC accelerators, Bottom:The oven will be installed in the FM Cyclotron magnet in this fall.

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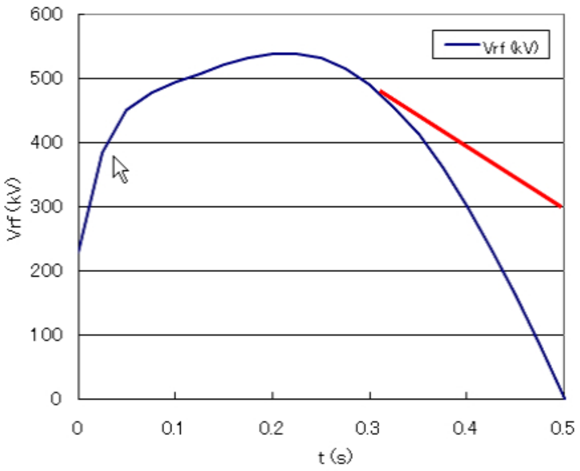

Figure 5: Required RF voltage for 1 Hz operation. We assume the filling factor will be constant and the voltage is reducing gradually. For the stable acceleration under heavy beam loading, the voltage will be kept higher level (red line).

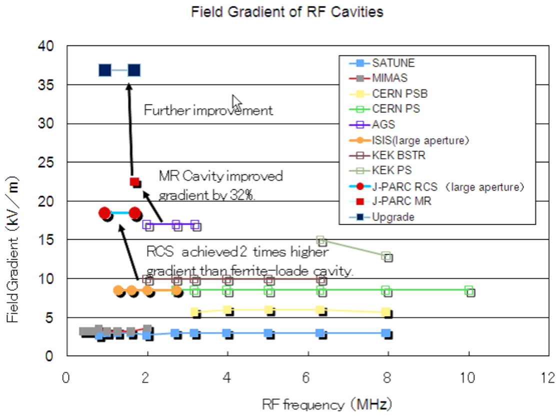

Figure 6: Field gradient of RF cavities.

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