THE NOVEL KICKER MAGNET IN HLS STORAGE RING

Lin.Wang, Xiangqi.Wang, Lei.Shang, Hongliang.Xu, Feng.Chao, Yuanji.Pei
NSRL, University of Science and Technology of China
Hefei, Anhui, 230029, P.R.China

Abstract

A new local-bump injection system consisting of four kicker magnets at one drift space is under construction in NSRL Project Phase II. The kickers actually used in HLS storage ring have been designed for the old lattice-dependent injection system and can't meet with the demand of new system due to its low kick strength and efficiency. New kicker with high kick strength and efficiency has therefore been developed, using half-sine excitation. High saturated magnetic flux density and resistivity are required both for new kicker while the standard NiZn ferrite material is not appropriate. Profiting from the characteristics of MnZn ferrite, the window-frame kicker is therefore built-up, employing 15mm thick laminations. Finally, the distribution of magnetic field in the aperture and inductance of kicker have been measured and the results showed the excellent performance of new kicker. This paper presents the new kicker design as well as the field simulation and measurement results.

1 INTRODUCTION

The main purpose of NSRL Project Phase II is to improve the performance of HLS storage ring. The actual local-bump injection system, in which kickers are installed on the curved segment of storage ring, is dependent on the lattice function and restricts the improvement of lattice. In the meantime, the impedance is large due to the enlargement of vacuum chamber since kickers are installed into the vacuum chamber [1]. A new lattice-independent injection system is therefore needed. Alternatively to the actually used kicker made by copper wire, new ferrite-dominated kickers are constructed. The new kickers offer several physical and technical advantages. First, the kickers with high kick strength can be installed on one drift line to obtain local bump, so that the bump is independent of lattice. Then, the high efficiency is helpful to lower operational cost. Again, the new kickers are installed out of vacuum chamber to improve continuity of vacuum chamber to lower impedance. Due to spatial limitation, the four kickers with two different sizes and similar property and structure were designed. To preserve the efficiency of injection and accumulation, the field homogeneity should be better than 10^{-2}/7cm and 10^{-2}/10cm respectively, and waveform distortion should be avoided [1]. In this paper kicker design of one specification was introduced.

2 MAGNET DESIGN

According to the requirement of injection of electron beam in HLS storage ring, the kicker design is to choose suitable material and reasonable structure to build best field distribution based on the internal conditions and economical consideration.

The window-frame structure was adopted for kicker due to economy and convenience to install. The aperture of kicker should be not less than 90×34mm^2 to install ceramic vacuum chamber. Limited by the installation space, the width of yoke can't exceed 15 mm. Then the conductor was built with 2mm thick copper. The crust of kicker is made by 316L nonmagnetic stainless steel and aluminum to reduce its effect on pulsed magnetic field. Other efforts of structure design are to avoid dimensional resonance and magnetic-force resonance. The structure of HLS kicker is shown in Fig.1.

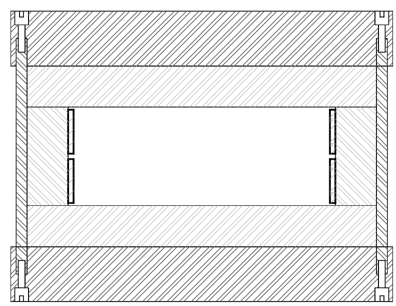

Figure 1 Cross section of new kicker

The magnetic field of kicker is pulsed dipole type in physical design of injection system. The kicker is driven by a half-sinusoidal current pulse with angular frequency of 0.9×10^6rad/s and attenuation factor of 0.3×10^6 /s.

The main parameters of the new kicker are given in Tab.1.

Table1: Main HLS kicker parameters at 200MeV/c

Parameter	Unit	Value
Aperture	mm×mm	98×36
Length	Mm	270
Peak field	T	0.13
Kick angle	Mrad	52.55
Integral field	mT·m	~35
Pulse duration	µs	~3.5
Raise time	µs	~1.4
Peak current	A	3740
Efficiency	Gauss/A	~0.33
Inductance	µH	1.1
1% good field area width	Mm	~80

The distinctive feature of new kicker is that yoke is built from MnZn ferrite. The disadvantage of thin yoke is that the maximum magnetic flux density in yoke is higher than 0.5T. The conventional material to build kicker is NiZn standard material or steel laminations [2]. The advantages of NiZn ferrite material are high permeability and resistivity and high cutoff frequency while its saturated magnetic flux density is about 0.3T. The saturated field of steel is highest but the techniques of thin laminations are difficult and its time response is slow [3]. To meet the demand to yoke material, the MnZn ferrite is one of the best options. The MnZn ferrite has several features comparing with NiZn ferrite, so that higher field in the yoke is acceptable [4]. First, MnZn ferrite is more suitable to the case with low application frequency. The spectrum of complex permeability of MnZn ferrite shows that its cutoff frequency is up to several MHz and is enough high for the application in HLS, and its power loss at low frequency is small while power loss of NiZn ferrite at high frequency is low. Then, the resistivity of MnZn is enough high to minimize the eddy-current effect on field distribution and to reduce eddy-current loss to acceptable level although it is much less than that of NiZn. Again, its relative permeability is sufficiently high to neglect in first approximation the reluctance of the yoke with respect to that of the beam aperture. Last, its saturated magnetic flux density is higher than 0.5T. The main parameters of MnZn yoke material in HLS kicker are given in Tab.2.

Table2 Main parameters of MnZn ferrite

Parameter	Unit	Value
Relative permeability μ	μ_0	4000
Saturated field B_s	T	>0.55
Cutoff frequency f_c	MHz	3
Resistivity ρ	Ω·m	>100
Coercive force H_c	kA/m	<0.012
Courier temperature	°C	180
Power loss (at 0.15T, 150kHz)	mW/g	<10

All these are helpful to obtain high kick strength and high efficiency. In the experiment of prototype kicker whose yoke width is 30mm four years ago, the field obtained in the kicker aperture was 0.3T limited by power supply and its efficiency obtained was 0.35Gauss/A. Due to the thin yoke, the highest magnetic flux density in the aperture of present kicker is about 0.25T when there hasn't distortion of magnetic field waveform and homogeneity is better than 10^{-2}/7cm.

3 MAGNET MANUFACTURING TECHNIQUES

The manufacturing techniques are very important to assure the similarity of two kickers with same specification. First, the electro-magnetic property of individual ferrite lamination was measured. According to the results, some laminations with similar property were picked out from all laminations and grouped into two teams. Then, 18 laminations are stacked longitudinally to produce a yoke of 0.27 m length. Finally, the yoke was put into a box produced with 316L stainless steel and aluminum.

4 PULSED MAGNETIC FIELD SIMULATION

The characteristics of the kicker have been analyzed and optimized mainly by means of the finite element package OPERA-3D, transient field option. The field simulations with different resistivity of yoke were performed and its results showed that the resistivity with value of 100Ωm(typical value for MnZn ferrite) is enough high to neglect eddy-current effect on the magnetic field distribution and waveform distortion. Also, the simulation results shows that the highest field in the yoke of window-frame structure is above 0.5T and the field homogeneity is better than 10^{-2}/8cm. The field distribution pattern at middle plane is shown as Fig.2. These results showed the resonality of the design of the MnZn ferrite-dominated kicker.

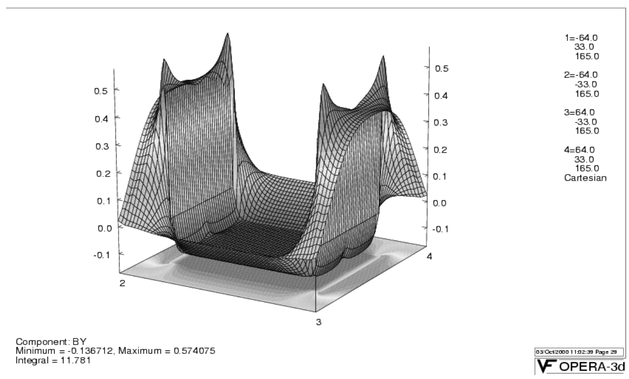

Figure 2 the magnetic field pattern at middle plane

5 MEASUREMENT RESULTS

The electro-magnetic properties of kicker were measured. Firstly, the field distribution in the aperture was measured with a point three-turns pick-up coil whose diameter is 6mm, mounted on a motor driven scanning machine. The maximum output voltage is proportional to the magnetic field in the aperture and displayed on an oscilloscope with precision of 5×10^{-3}. The solid curve in the Fig.3 is the measured curve while doted curve comes from computation results.

Then, the relation between magnetic field at central point of kicker and pulsed current was measured and the magnetization curve was shown in Fig.4. The maximum magnetic field in the aperture is above 0.22T and efficiency is about 0.33Gauss/A.

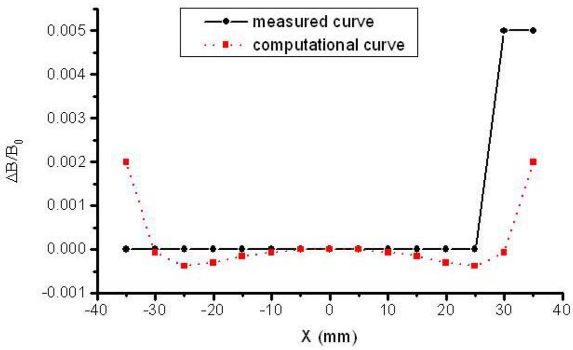

Figure 3 Field distribution measurement result

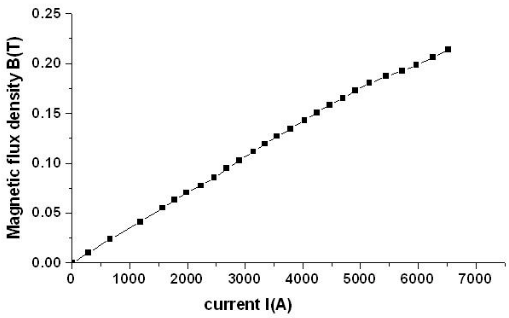

Figure 4 the magnetization curve of kicker

Additionally the inductance of kicker was measured. Its inductance is about 1.1μH and its difference between two kickers is less than 1%.

Finally, the longitudinal field was measured. The effective length of kicker is 272mm while its real length is 272 mm.

The measurements of electro-magnetic properties demonstrated the excellent performance of the new kicker magnet in field homogeneity and similarity of inductance.

6 CONCLUSION AND OUTLOOK

During the last year, the new kickers made of MnZn ferrite for HLS Project Phase II were finished and measured, and will be installed on the storage ring depending on overall evaluation. MnZn ferrite is more suitable for application at low frequency range such as kicker magnet of HLS storage ring. According to the properties of MnZn ferrite and experiment of prototype kicker, higher field level is hopeful by optimization of kicker structure.

7 REFERENCES

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