Magnetic Field Features of the Asymmetric Magnetic Circuit on the Sextupole Magnet

C. S. HWANG, C. H. CHANG, SHUTING YEH, M. H. HUANG
Synchrotron Radiation Research Center, Hsinchu, Taiwan
P. K. TSENG
Department of Physics, National Taiwan University, Taipei , Taiwan
G. J. HWANG
Department of Power Mechanical Engineering, National Tsing Hua University, Hsinchu, Taiwan

Abstract

Two adjacent poles have been partly cut from the sextupole magnet to accommodate the beam line chamber. The merit of this kind of yoke cutting of this kind is that it is much easier to control the mechanical accuracy. This cutting of the core of this yoke would create an asymmetric magnetic circuit that would induce some forbidden field. The fundamental field strength would also be less than the other sextupole magnet with the same power supply group in the storage ring. Those problems all come from the saturation effect in the york cutting side of magnet. Therefore there is an extra magnetic circuit across the cutting of the yoke from the two adjacent poles to compensate less core area of the yoke. This magnetic circuit can solve the saturation effect field. The field measurement for varied excitation current in these three magnetic circuits have been done to verify that the explanation of the phenomena is correct.

1. INTRODUCTION

A sextupole magnet was used to study the magnetic field behavior of an asymmetric magnetic circuit with part of the yoke cutting the yoke core at one side of two adjacent poles of the magnet. This part of yoke cutting (shown in Fig. 1) is used to accommodate the six-degree beam line chamber. This method makes much easier the assembly and the control of the mechanical accuracy than the total part cutting of the sextupole magnet. For this reason we selected yoke cutting of this type. The 14^{0} angle of the yoke core cutting tangential to the electron beam direction is enough to accommodate the bending vacuum chamber for the six degree beam line (This chamber includes the zero , three and six-degree beam ports). Three x-ray beam lines come from the same wiggler magnet are extracted from the zero-degree beam port.

The magnet core is constructed of a identical sextant. Laminations are glued and the sextants are assembled by means of bolts through the end plate. The sextants are aligned through usage of dowels. The core assembly consists of the upper and lower halves of the magnet. The core is machined by using the wire cutter to cut the edge part. The mechanical accuracy and reproducibility of the magnet assembly remain unaffected because a larger yoke is designed near the mating surface. Part of the inside mating surface is preserved for stable support of the magnet. An additional solid yoke extends across the horizontal midplane to compensate the asymmetric field as shown in Fig. 1. The outside yoke is designed to provide the same reluctance for more flux passage through it and is easy to assembly and to support the magnet. The top and bottom halves are fastened by means of bolts through stainless steel parts that extend to both sides.

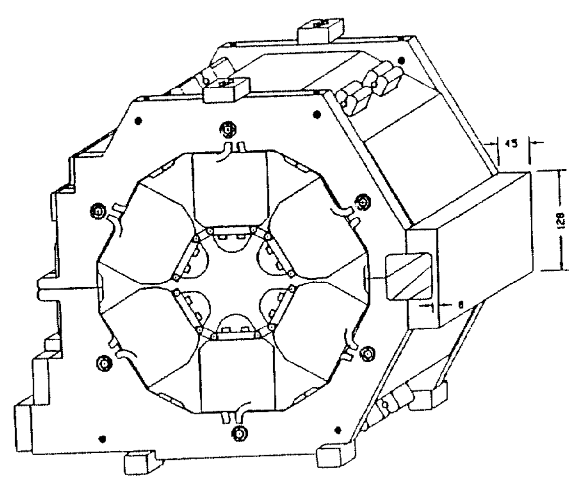


Fig. 1 Magnet structure with and without cutting of the one-side sextants.

The cut area is about 80% partially of the total area of the core between the two adjacent poles. Cutting this part of the core area would induce a stronger saturation field at the cut side of magnet. Hence an asymmetric magnetic field distribution would be created. Some forbidden terms of the harmonic field would also occur. There is 70% extra magnetic circuit area of the total area of the core across from the two adjacent poles to compensate the less yoke core area on the cut side of the magnet to solve the asymmetric magnetic circuit. After that, the field can obtain good quality again. In this paper we describe the field behavior of the asymmetric magnetic circuit. Each harmonic field measurement result with and without the cutting and after adding the extra magnetic circuit proved the argument correct.

2. FIELD MEASUREMENT AND DISCUSSION

On a normal sextupole magnet [1], the features of the sextupole field deviation Δ(∫Sds)/∫Sds as function of x (without cutting) are shown in Fig.2. The normalization of the forbidden field strength with respect to the fundamental field is revealed in Fig. 3. These results indicates that the sextupole field deviation Δ(∫Sds)/∫Sds is symmetric and the forbidden harmonic field is small. If the yoke core is cut fully at one side, the magnet circuit would become asymmetric and would induce an asymmetric sextupole field deviation Δ(∫Sds)/∫Sds.

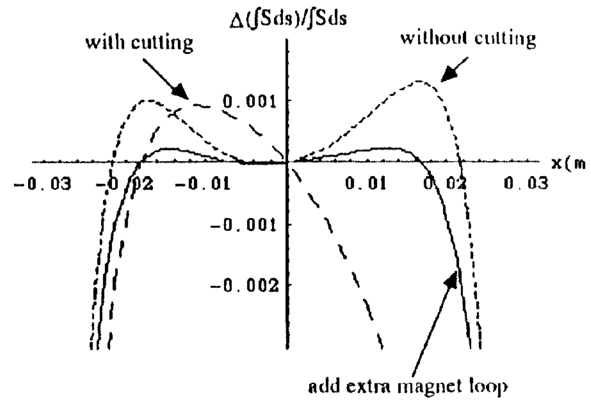
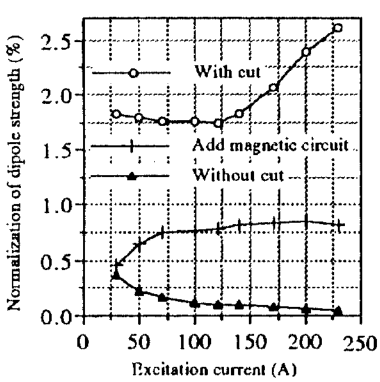
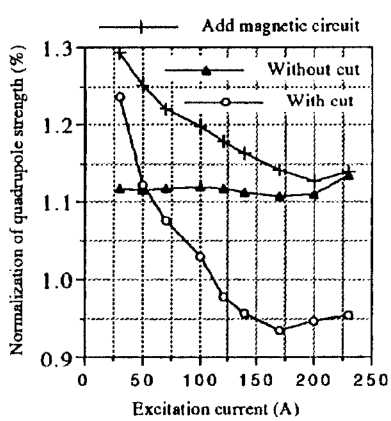


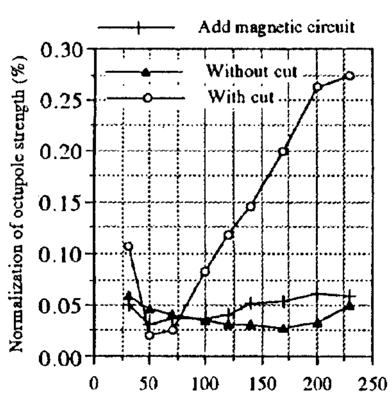
Fig. 2. Sextupole field deviation Δ(∫Sds)/∫Sds as a function of x with and without the cut as well as with an extra magnetic circuit added on cut side of the magnet yoke.



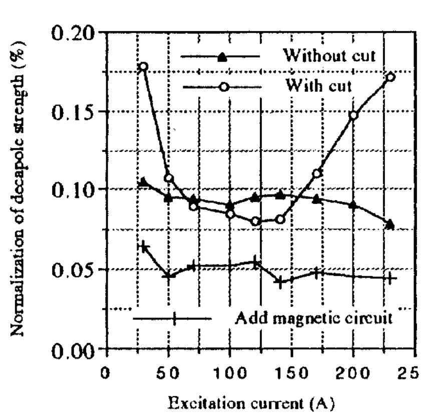
(a) Dipole strength



(b) Quadrupole strength



(c) Octupole strength



(d) Dectupole strength

Fig. 3. Forbidden field normalized with respect to the fundamental strength as a function of excitation current with and without cutting the york, and with an extra magnetic circuit added on the cut side of the magnet yoke.

At the same time, the forbidden field (e.g., the dipole, quadrupole, octupole and decapole etc.) become much larger than before. If the yoke core was cut partly along the 14-degree tangent to the electron beam direction, the magnetic circuit is still symmetric but saturation of the cut region would happen and also induce the forbidden magnetic field. Hence, the sextupole field deviation $\Delta(\int Sds)/\int Sds$ as a function of x become asymmetric as shown in Fig.2.

This asymmetric behavior is due to the saturation factor on the yoke cut side of magnet. For the same reason, the dipole, quadrupole, octupole and decapole etc. of these forbidden fields all occurred (shown in Fig. 3.). Normalization of these forbidden field strengths with respect to the fundamental field depend on the varied excitation current with yoke core cutting. These results reveal that there exists a greatly varied degree of saturation between the sides with and without cutting. The area at the cut side of the yoke core is one fifth that of the other side of the yoke without cutting. Therefore the saturation occurs seriously at the cut side when the field strength is beyond 0.15 T at the normal side (without cutting). At the same time, the fundamental component of the sextupole strength is 0.60% less than without the cutting at an excitation current 170 A (see Fig. 4).

Why does the octupole strength does not increase (Fig. 3) when the excitation current beyond 200 A and there exists a maximum octupole field strength at this excitation current. This effect is due to saturation phenomena[2] beginning to increase on the side of the magnet without cutting. So the ratio of saturation between with and without cutting would become small. Hence the octupole strength is inversely proportional to excitation current beyond 200 A.

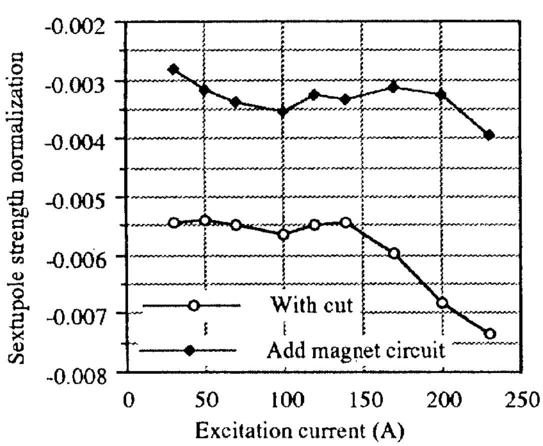


Fig. 4. Sextupole strength with cut and added magnetic circuit normalized to the sextupole strength of before the magnet cutting.

The asymmetric magnetic field would create the dipole, quadrupole, octupole and decapole field at the center. These forbidden fields all depend on the excitation current (Fig.3). These effects have also been explained as the cut side has a stronger saturation phenomenon than the uncut side of the magnet. Therefore for the purpose of solving the saturation behavior, a closed-loop magnetic circuit to cross pass the cut side of the yoke to compensate the core area is necessary. After the closed-loop magnetic circuit was added, the field measurement results are shown in Fig. 2 and 3. These results show that the asymmetric phenomenon has disappeared; at the same time, the forbidden fields are independent of the excitation current and become small. This work has solved the asymmetry and saturation behavior. Moreover, after the extra magnetic circuit is across from the two adjacent poles, the sextupole strength is compensated and is only 0.31% less than that without cutting at excitation current 170 A (see Fig. 4).

3. CONCLUSION

Partial cutting of the yoke is just to modify the original magnet, as it is unnecessary to design a new sextupole magnet. This method also makes it more convenient to assemble the sextupole magnet and easier to control the mechanical accuracy than cutting the full yoke.

After the yoke cutting, the forbidden field occurs and the sextupole strength become much less than without cutting. If the extra magnetic circuit is across from the two adjacent poles of the cut side of the magnet, the saturation behavior decreased much more than with yoke cutting, but the sextupole strength is remains 0.31% less than without cutting the yoke at the excitation current 170 A. Because of limited space, the yoke can't be complete but just 70% added to compensate the cut area. Hence, if there is enough space to compensate the core area, the field features should be the same as without cutting the york.

4. ACKNOWLEDGMENTS

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5. REFERENCES

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[2] K. Halback, " First order perturbation effects in iron dominated two dimensional symmetrical multipole ", Nucl. Instrum. Methods , vol.74 , 147 -164(1969).