THE METHOD OF TEMPERATURE COMPENSATION FOR PERMANENT MAGNET FINAL FOCUS QUADRUPOLE.

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Abstract.

The method of temperature compensation for permanent magnet elements is proposed and applied to the permanent magnet final focus quadrupole design for linear collider. The possible advantages and disadvantages are discussed.

1. INTRODUCTION.

As it known the problem of temperature dependence of magnetic field for magnets based on using permanent magnet (PM) is one from the main problems for such type magnets. That is caused by strong temperature coefficient of remanence field (Br) of permanent magnet which is equal to -0.0003/degree for SmCo material and -0.0011/degree for NdFeB material. The final focus quadrupole for linear colliders requires the highest field stability among the other magnetic elements for accelerators. Typically it should be several units $\times 10^{-5}$ or less. That is reason that usually for final focus quadrupole the SmCo material is used as having lower temperature coefficient of Br. But even with this material the temperature stability about 2×10^{-5} , required for new linear colliders (JLC, NLC, CLIC), can not be achieved. In given paper the method of temperature compensation based on using two types of permanent magnet materials with different temperature coefficient of Br is described.

2. PRINCIPLE SCHEME OF TEMPERATURE COMPENSATED PM ELEMENT.

Fig. 1 shows the scheme of magnet element consisting of two materials - SmCo and NdFeB - which are placed in opposite directions of magnetization. Temperature caused changing magnetization of NdFeB material compensates changing magnetization of SmCo one due to their

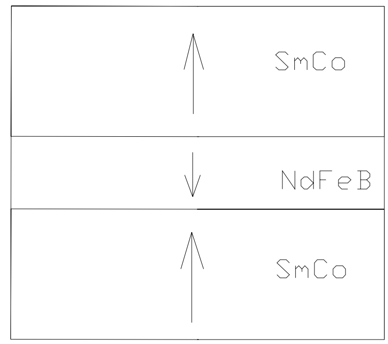

Fig. 1. Temperature compensated permanent magnet combined element.

opposite directions of magnetization. For full compensation of such combined element the following condition must be satisfied:

$$K_{SmCo} \times V_{SmCo} \times Br_{SmCo} = K_{NdFeB} \times V_{NdFeB} \times Br_{NdFeB},$$

where K and V are correspondently temperature coefficient and volume of PM material.

As temperature coefficient of NdFeB is essentially more than one of SmCo and Br is approximately same for both materials that volume of NdFeB has to be essentially less than volume of SmCo one. So it can be expected that gradient strength of SmCo quadrupole with addition of NdFeB does not reduce essentially.

3. FINAL FOCUS QUADRUPOLE WITH TEMPERATURE COMPENSATION.

Fig. 2 shows the cross section of PM quadrupole consisting of temperature compensated combined elements. Tables 1 and 2 present the main parameters of quadrupole and used single combined element correspondently.

As it was found out from calculation with FEM code the magnetic field

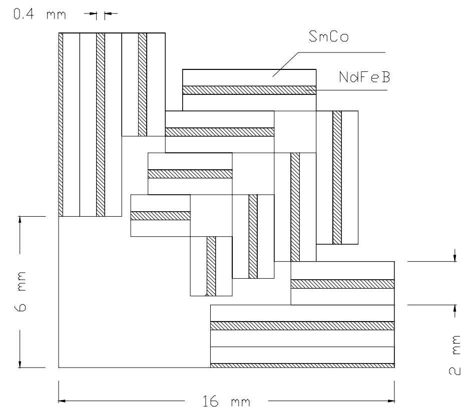

Fig. 2. Quadrupole lens consisted from combined permanent magnet elements. (only ¼ cross-section is shown)

changing at radius of 0.8 aperture for temperature changing of 10 degree is about 0.2 G. While field changing for same temperature changing for quadrupole without temperature compensation would be 15 G (that is G × R × temp. koef. × ΔT, where G is gradient and R is radius). Table 3 shows the difference in harmonic content between quadrupole fields for 20º C and 30º C temperatures at radius of 0.8 aperture.

Although the temperature compensation with such method is good enough but the possible disadvantages are as following:

- the gradient strength reduces due to presence the PM material with opposite magnetization direction (NdFeB) with respect to main PM material (SmCo). This reduces is about 30 % for described quadrupole design.
- sophisticated construction of quadrupole which requires a lot of combined elements of small thickness (2 mm in our case).

Table 1. General parameters of quadrupole.

Inner diameter	5 mm
Outer diameter	16 mm
Gradient	100 T/m

Table 2. Parameters of combined elements.

Thickness of SmCo material	1.6mm
Thickness of NdFeB material	0.4 mm
Br of SmCo material	1.1 T
Br of NdFeB material	1.2 T

Table 3. Changing harmonic content for temperature changing of 10 degree.
Radius=5 mm
By=An*cos(n*f)+Bn*sin(n*f)

n	An	Bn
0	0.000000	0.000000
1	0.000248359	0.000000
2	0.000000	0.000000
3	1.08754e-005	0.000000
4	0.000000	0.000000
5	0.000110083	0.000000
6	0.000000	0.000000
7	-3.14438e-005	0.000000
8	0.000000	0.000000
9	-5.48694e-005	0.000000
10	0.000000	0.000000
11	-2.56871e-005	0.000000
12	0.000000	0.000000
13	8.17931e-005	0.000000
14	0.000000	0.000000
15	1.22594e-005	0.000000
16	0.000000	0.000000
17	7.99828e-005	0.000000

4. CONCLUSIONS.

The method for temperature compensation of final focus quadrupole was suggested and shown the good stability of magnetic field provided design based on this method. The possible disadvantages are discussed.

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