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# 1 GeV リ ニ ア ッ ク 検 討 資 料

## 1 GeV LINAC DESIGN NOTE

題目 ( TITLE) 四極電磁石の概念設計プログラム

著者 (AUTHOR) 加藤隆夫

概要 (ABSTRACT)

高崎メモによる四極電磁石の概念設計の計算部分をマックで簡単に出来るようにしたので、紹介する(TRUE BASIC 使用)。

KEY WORDS:

Ion source, RFQ, DTL, CCL, Magnet, Monitor, Beam Dynamics,
Transport, Vacuum, Cooling
Klystron, Low level rf, High power rf, Modulator
Control, Operation, Radiation, Others

高エネルギー物理学研究所 *KEK*

# 四極電磁石の概念設計プログラム

911113　加藤隆夫

高崎メモによる四極電磁石の概念設計の計算部分をマックで簡単に出来るようにしたので、紹介する。

基本式

NI = G r*r / (2*mu)　[ A T ]
flux = G r*r ( 1 + x ) / 2 [ Tm ] :  x is about 0.5
pole tip surface mag. field  Bs = G r <= 1 T
MORE length = r /2　（漏れ磁場の長さ）

入力
1　r　bore radius in mm
2　G　field gradient in T/m
3　Lq　Q-mag length along z-axis
used for computer beam simulation
Rmore = r/2　by Takasaki memo
4　Felength　real pole length along z-axis
flux: B in the pole is assumed 1 T ---> mag.half width (width)が決まる

Bs is smaller than 1T
space between two coils > 6 mm　by T.K
coil space = SPACE

冷却条件
NI = i * S * f
s = SPACE * LL　コイル断面積、f = packing factor
空冷　電流密度　i　1 A/mm$^2$ or 2 A/mm$^2$
packing factor =0.8
水冷　電流密度　i　10 A/mm$^2$ or 20 A/mm$^2$
packing factor =0.5

コイル断面の形　SPACE * LL
LL = NI / (i * f)　-----> 半径方向の長さをチェックする

水冷の場合

入力　5　　　t,w　　　ホローコンダクターの断面形、 w // r 方向

入力　6　　　thick　　ホローコンダクターの肉厚

ホロコンの銅断面積　　Cuarea

ホロコンの水流部面積　areaWater

ホロコンの電流　　　　I = i * Cuarea

ホロコンのターン数　　N = NI / I per pole

２層巻を仮定する（宿題：この部分をＮ巻にして、汎用にして下さい）

絶縁物とコーナーの出っ張りを仮定して全ホロコンの断面積を計算する

全ホロコンの断面積 = wid * leng

磁石の断面を取り巻く全ホロコンの長さを計算する　Leng1turn　per pole

抵抗をを計算する　resis

電力をを計算する　power

４ポールの抵抗　Rtot

４ポールの電圧　Vtot

４ポールの電力　Ptot

発熱と温度上昇

水温上昇は　１０度とする

4.2*V(cc/sec)*deltaT= P(Watt)

流速

# Example of Qmagdesign program

(Below is copy of the output on the screen, Script **bold** is input data)

( This view is not the same as the screen)

ELECTRO Q-MAGNET DESIGN 911112 T. Kato with Takasaki formula and memo
Fundamental equations used for design are
NI = G r*r / (2*mu) [ A T ]
flux = G r*r ( 1 + x ) / 2 : [ T m ] x is about 0.5
pole tip surface mag. field Bs = G r <= 1 T
MORE length = r /2
Please input radius in mm
? **17.5**
-------------------- radius in m = .0175
---------------- MORE length = R/2 = .00875
Please input mag.field gradient in T/m
? **45**
------------------ gradient in T/m = 45
----- pole-tip surface mag. field in T= .7875
------ Bs is smaller than 1T, --------- OK
-------------------------- fai in Tm = 1.03359e-2
flux : B in the pole is assumed 1 T
------ thus, magnet half-width W in mm = 10.3359
Do you change width? no change =0 else enter in mm
? **17.5**
new width (mm) = 17.5
------------------- Required NI in AT = 5483.39
Please enter effective Q-magnet length in mm
? **40**
------------- effective Q-length in m = .04
-------------------- MORE length in m = .00875
-------------- Felength=Lq-Rmore in m = .03125
Do you agree with Felength? If O.K return 0, else enter in mm
? **35**
------------------- new Felength in m = .035
half SPACE BETWEEN TWO MAGNET PIECES in mm = 17.5
------allowed width of coil is (above-3mm) = 14.5
-------------- COIL AND COOLING DESIGN -------------------
air cooling current dennsity = 1 A/mm2
water cooling current density = 10 - 20 A/mm2
N*I = I*S*f f is packing factor = 0.8 is assumed air cooling
N*I = I*S*f f is packing factor = 0.5 is assumed water cooling
s is coil cross area

------------- COIL AND COOLING DESIGN-1 WITH AIR -------------------
--- 1 A/mm2 current density ----
AIR cooling coil cross area is in mm2 = 6854.23
coil width and length in mm= 14.5 472.706
length of coil is too long > 100 mm !!!!!!!
--- 2 A/mm2 current density ----
AIR cooling coil cross area is in mm2 = 3427.12
coil width and length in mm= 14.5 236.353
length of coil is too long > 100 mm !!!!!!!
-------------- COIL AND COOLING DESIGN-2 WITH WATER ------------------
water cooling current density = 10 - 20 A/mm2
N*I = I*S*f f is packing factor = 0.5 is assumed water cooling
s is coil cross area

-- 10 A/mm2 WATER cooling coil total cross area is in mm2 = 1096.68
coil width and length in mm= 14.5 75.6329
-- 20 A/mm2 WATER cooling coil total cross area is in mm2 = 548.339
coil width and length in mm= 14.5 37.8165
ENTER HOLOCON YOKO(t),TATE(w) IN mm
? **3.5,6.5**
enter thickness in mm
? **1**
--- holo conductor design --------
CU-AREA IS IN MM**2= 16.
FOR 10A/mm**2 TOTAL CURRENT/ one holocon IN A = 160.
TURN NUMBER = 34.2712
TURN NUMBER = 34
FOR 20A/mm**2 TOTAL CURRENT/ one holocon IN A = 320.
TURN NUMBER = 17.1356
TURN NUMBER = 18
TWO LAYER WINDING IS ASSUMED, then 2*t is azumuthal width
10A/mm**2 two layer wid*Len in mm = 12.5 120.5
20A/mm**2 two layer wid*Len in mm = 12.5 64.5
Fe pole cross section Felength and half width = 35 17.5
Holocon total length/pole in m= 7.43036 3.93372

| total resistance | current | voltage | power |
|---|---|---|---|
| .031579 | 160. | 5.05264 | 808.423 |
| 1.67183e-2 | 320. | 5.34986 | 1711.95 |

Increase in water temperature is assumed 10 degrees
4.2*V(cc/sec)*deltaT= P(Watt) is used
Then, required amount of water cc/min = 1154.89 2445.65
Water velocity in m/sec = 2.85158 6.03864
Do you want sum of the result? If yes, enter 1
? **1**

***** ----- Summary of the electro-quadrupole magnet design ----- *****

boreradius (mm) = 17.5

gradient (T/m) = 45 Bs (T) = .7875 Half flux (T) = 1.03359e-2

B in the pole is assumed 1 T

magnet half-width W (mm) = 17.5

Required NI (AT) = 5483.39

effective Q-length (mm) = 40

MORE length (mm) = 8.75 Felength=Lq-Rmore (mm) = 35

allowed width of coil(mm)= 14.5

------------- COIL AND COOLING DESIGN-1 WITH AIR -------------------

| current density | 1 A/mm2 | 2 A/mm2 |
|---|---|---|
| Total coil cross area (mm2) | 6854.23 | 1713.56 |
| coil width (mm) | 14.50 | 14.50 |
| coil length (mm) | 472.71 | 236.35 |

-------------- COIL AND COOLING DESIGN-2 WITH WATER -------------------

| current density | 10 A/mm2 | 20 A/mm2 |
|---|---|---|
| Total cooling coil area (mm2) | 1096.68 | 548.34 |
| coil width (mm) | 14.50 | 14.50 |
| coil length (mm) | 75.63 | 37.82 |

width and length mean cross section of one side of Fe

--------------HOLOCON and Power design--------------------------------

Holocon geometry (t w) and thickness (mm) 3.50 6.50 1.00

Cu area and water area of a holocon (mm2) 16.000 6.75

| | turn/pole | width | length | length/turn | Tot.coil length/pole |
|---|---|---|---|---|---|
| | | mm | mm | m | m |
| 10A/mm2 | 34 | 12.50 | 120.50 | .22 | 7.43 |
| 20A/mm2 | 18 | 12.50 | 64.50 | .22 | 3.93 |

7.43036

| | total resist | current | voltage | power | water volume | velocity |
|---|---|---|---|---|---|---|
| | ohm | A | V | W | cc/min | m/sec |
| 10A/mm2 | .0315790 | 160 | 5.05 | 808.42 | 1154.89 | 2.85 |
| 20A/mm2 | .0167183 | 320 | 5.35 | 1711.95 | 2445.65 | 6.04 |