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BETATRON TUNES and the CURRENT in the QUADRUPOLE TRIM COIL

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Abstract

The current requirement in the quadrupole trim coil depends on both the current in the main power supply and the betatron tunes. A SYNCH program resides in the RHIC data base (BNLDAG::[RHIC.BOOSTER]BSTUNE.DAT) can be used to calculate the required trim current in the quadrupoles.

1. The Program and Discussion

Since a single power supply is used initially for the dipole and quadrupoles, the betatron tune of the machine can be adjusted by a power supply current int he quadrupole trim coil. A program is needed to calculate the trim current for a given betatron tune. This report shows an example of using the SYNCH to calculate the trim current requirement.

In the Appendix, the boxed region of the SYNCH input file can be viewed as a black-box. On the other hand, the first few lines should be changed according to the realistic data, where:

BOI	:	Transfer function in (Tesla/Amp)
IDIP	:	Current in the main dipole power supply in [Amp]
GLOI	:	Integrated transfer function of the short quadrupole in T/A
LDIP	:	Dipole effective length in [m] for QD
LQL	:	Long quadrupole length in [m] for QF
LQ£	:	Short quadrupole length in [m] for QF
QX	:	Horizontal betatron tune
QY	:	Vertical betatron tune

When you put in the number obtained from the magnet measurement data and the preferred betatron tunes, the SYNCH input file can be executed to obtain the current needed in the trim coil, called ITF and ITD in Amperes.

In the example (shown in the Appendix) we use 1000 Amp.

The SYNCH input file resides at:

BNLDAG::DUA3:[RHIC.BOOSTER]BSTUNE.DAT

To execute the program, you can COPY BSTUNE.DAT to your directory and work in the following procedure:

```
$ASSIGN    BSTUNE.DAT      FOR002
$ASSIGN    BSTUNE.OUT      FOR003
$RUN       DUA3:[RHIC.AP.SYNCH]SYNCH
```

The result of ITF and ITD currents are obtained in the BSTUNE.OUT file. If ITF and ITD are positive, they increase the quadrupole strength (shorter focal length).

Similar procedure can be worked out in the MAD input file. From the operational point of view, the trim coil should be calculated and parametized as a function of the current in the main power supply. The trim power supply function generation can be used to track the acceleration cycle.

Calculation based on the present Booster magnet measurement gives the trim current in the focusing and defocusing quads as:

$$I_{TF} = [0.807\ (Q_x - Q_x^{\circ}) + 0.256\ (Q_y - Q_y^{\circ})]\ I \qquad (1)$$

$$I_{TD} = [0.250\ (Q_x - Q_x^{\circ}) + 0.779\ (Q_y - Q_y^{\circ})]\ I \qquad (2)$$

where I in the main power supply current, Q_x° and Q_y° are the betatron tunes without trim power supply, i.e., $Q_x^{\circ} \approx 4.6$, $Q_y^{\circ} \approx 4.55$ obtained from the present magnet measurement. If the magnet measurement data are different, only Q_x° and Q_y° will be changed.

Note also that the accuracy of Eqs. (1) and (2) are about $1 \sim 2\%$. This is due to the fact that the relation between the tunes and the quadrupole strength is not linear. However, Eqs. (1) and (2) should be valid for obtaining the correct time to about $1 \sim 2\%$.

Equations (1) and (2) also gives the sensitivity of trim current in changing the tune. At I = 1000A, the tune of the machine will be changed by 0.01 if I_T is changed by 10A.

When I_T reaches the peak trim current of the trim power supply, the tunes of the machine will drift toward Q_x° and Q_y° as I in the main dipole supply is increased. The time dependence of Q_x and Q_y can also be obtained from Eq. (1) and (2), i.e.

$$Q_x = Q_x^{\circ} + 1.38\ I_{TF}/I - 0.443\ I_{TD}/I$$

$$Q_y = Q_y^{\circ} - 0.453\ I_{TF}/I + 1.43\ I_{TD}/I$$

Appendix BNLDAG :: DUA3 : [RHIC.BOOSTER] BSTUNE.DAT

```
$ TYPE BSTUNE.DAT
 BSTT  RUN          AGS BOOSTER TUNE CALCULATION
 BOI   =            .000243564                          ---- Transfer function in [T/A]
 GLOI  =            .0009123  *          0.994          ---- [GdL/I of F Quad in [T/A]
 IDIP  =            1000.                               ---- current in dipole in [A]
 LDIP  =            2.42                                ---- Length of dipole in [m]
 LQL   =            0.5064                              ---- " " D Quad in [m]
 LQS   =            0.4937                              ---- " " F Quad in [m]
 QX    =            3.755                               ---- Horizontal tune
 QY    =            4.775                               ---- Vertical tune
       NCPY
C=================================================================================
C THE FOLLOWING PART CAN BE VIEWED AS A BLACK BOX FOR THE TUNE CALCULATION
 B#OI  =            GLOI      /          .4937
 BI    =            BOI       *          IDIP
 B#B   =            B#OI      /          BOI
 BR    =            17.6
 BZ    =            1.27990812
 .BST  BML          QD   S30  BEND S100 QF   S30  BEND S100 QD   S370 QF
                    S30  BEND S100 QD   S30  BEND S100 QF   S370
                    QD   S30  BEND S100 QF   S30  BEND S100
 GF    =            9.83525219
 GD    =            -10.116755
 S30   DRF          .3
 S370  DRF          3.70
 S100  DRF          1.0
 BEND  MAG          2.4                 BR        BZ
 MUX   =            QX        /         6.
 MUY   =            QY        /         6.
 TUNE  SUB
 QF    MAG          .50375    GF        BR
 QD    MAG          .50375    GD        BR
 MP    MMM          .BST
       END
CBST   CYC        6 .BST
 FQ    FITQ         TUNE MP   GF   GD       1    1MUX       MUY
 LDR   =            2.4
 LQR   =            0.50375
 B#OI  CALC         RCL  B#B  RCL  BOI  *
 B#Q   CALC         RCL  B#B  RCL  BI   *
 B#F   CALC         RCL  GF   RCL  LQR  *    RCL  LQS  /
                    RCL  BI   *    RCL  BZ   /    RCL  LDIP *    RCL  LDR  /
 B#TF  CALC         RCL  B#Q  -
 ITF   CALC         RCL  B#OI /    5.   *
 B#D   CALC         RCL  GD   CHS  RCL  LQR  *    RCL  LQL  /
                    RCL  BI   *    RCL  BZ   /    RCL  LDIP *    RCL  LDR  /
 B#TD  CALC         RCL  B#Q  -
 ITD   CALC         RCL  B#OI /    5.   *
C      THE TRIM COIL CURRENT IS
       PRNT         ITF  ITD
C BST   CYC        6 .BST
       FIN
       STOP
```