INJECTION INTO INDUS-2

A. A. Fakhri*, A.D. Ghodke & G. Singh
Centre for Advanced Technology, Post CAT, Indore-452013

Abstract

A multi turn injection scheme employing a compensated bump generated by four kickers has been chosen for beam injection into INDUS-2, a 2.5 GeV synchrotron radiation source under construction at Centre for Advanced Technology Indore. Injection process is studied in the absence and in the presence of chromaticity sextupoles for a half sine wave kicker pulse of width 3μs. The effect of various parameters septum position, residual betatron oscillation, jitter, and asymmetric bump on injection efficiency is also studied.

INJECTION SCHEME

The injector for this ring will be a synchrotron with a peak energy of 700 MeV. The synchrotron will provide two bunches each one is around 1ns long and are separated from each other by nearly 30ns at the required energy at a repetition rate of 1-2 Hz. After injecting several pulses at 600-700 MeV, the beam will be accelerated to 2.5 GeV by slowly increasing the magnetic field of the bending magnets. The injected beam performs a coherent betatron oscillation inside the ring. These oscillations get damped due to synchrotron radiation in a fraction of a second and therefore when a next pulse is injected into the ring, earlier one will be sufficiently damped and will nearly be on the orbit. The injection is carried out in the radial plane from the outer side of the ring by using a compensated bump generated by four kicker magnets. During the first three turns, the kicker strength is modified according to:

$$\theta(n) = \theta_0 \cos(nT_r \pi / T_k) \qquad (1)$$

Where θ_0 : Maximum integrated strength, n : Number of turns of the stored particles in the ring, with n=0 at injection time , T_r : Revolution period of the ring, T_k : Pulse length =3μs

The bump strength (B) and the location of the septum from the designed orbit (L_s) can be approximately calculated from the following relation [1]

$$B = 4\sigma_{xi} + 2S_c + S_t \qquad (2)$$

$$L_s = B + 4\sigma_{xs} + S_c \qquad (3)$$

Where σ_{xi}: Beam size of the injected beam, σ_{xs} : Beam size of the stored beam, septum clearance S_c =2.0mm; septum thickness S_t =2.0mm, injected beam emittance ε_{xi} = 3.9*10-07mrad and stored beam emittance ε_{xs} = 2.5*10-08mrad are respectively at 600 MeV. The value of ε_{xs} has been arrived at by taking into consideration a blowup of emittance due to intrabeam scattering and bunch lengthening due to single bunch instabilities [2], for the injected beam also a blowup factor of two (2) has been assumed. In the case of Indus-2, above relations are only guidelines not exact due to sinusoidal nature of the kicker pulse having slow fall time(1.5μS). Tracking studies have been carried out with the computer code RACETRACK[3] for 80 particles over 50 turns. In studies, both bunches (coming from the synchrotron) are tracked.

METHOD OF OPTIMIZATION

The septum location, orbit bump and their shapes are optimized keeping into consideration that the injected and stored bunches should not hit the septum magnet or any other part of the vacuum chamber and residual betatron oscillation of the injected beam should be minimum. The Indus-2 lattice has the capability to operate at different values of β_{xs} in the insertion sections. To avail of this flexibility in the operation of the ring, optimized injection [1,5] has been planned. This will be facilitated by using a movable septum. It will help in minimizing the residual betatron oscillation and aperture requirement at the injection point. In this paper detailed study has been carried out for design operating tune ($\nu_x = 9.2$, $\nu_y = 5.2$) with the betatron functions at the centre of injection section $\beta_x = 14.0$ m and $\beta_y = 2.0$ m. Fig.1 for optimized beta & fig.2 for matched beta show that after one turn a part of the injected beam hits to the septum, as the oscillation amplitude of the injected beam is very large at septum location and the bump cannot be reduced fast due to initial slow fall time of the kicker pulse.

To obtain good injection efficiency, various parameters has to be optimized. It can be overcome by changing the operating tune value $\nu_x = 9.2$ to 9.3, as after one turn residual betatron oscillation amplitude is reduced at septum location. By providing a large bump, the injected beam can be cleared from the septum; it will lead to a very high value of the bump and a large septum distance from the designed orbit, which cannot be done. Injection efficiency can also be optimized by increasing residual betatron oscillation amplitude. It can be done [4] by increasing the septum distance (~5mm) without changing the bump. This solution has the drawback that the dynamic aperture requirement is larger and less space is available for closed orbit distortion. Another feasible way is to generate an asymmetric bump at the septum location and do parallel injection w. r. to the design orbit. The asymmetric bump method provides a reasonably good solution but injected beam is still not fully cleared from the septum. It can be overcome by providing a high value

* fakhri@cat.ernet.in

of the asymmetric bump (for 0.5mrad angle) with increasing septum distance. After optimizing both asymmetric bump and septum location, the tracking results are shown in the fig.3 & fig.4. In the optimized beta case the septum is located at ~19.2mm instead of ~16.7mm and the maximum asymmetric bump for 0.5mrad angle is given as ~14.8mm instead of a symmetric bump ~12.3mm. In the matched beta case, the septum distance is not changed however the bump should be asymmetric.

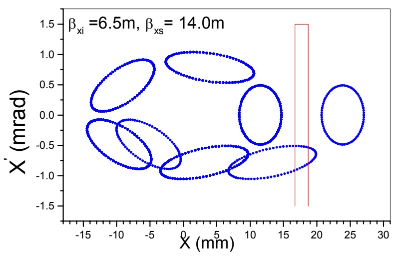

Fig.1 Optimized β

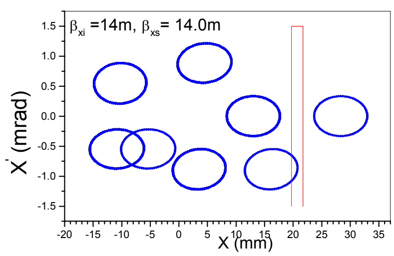

Fig.2 Matched β

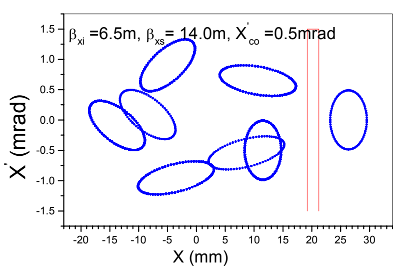

Fig. 3 Optimized β

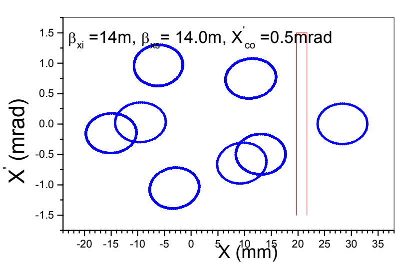

Fig.4 Matched β

EFFECT OF CHROMATICITY SEXTUPOLES

In the presence of chromaticity sextupoles, injection efficiency will further deteriorate. Sextupoles produce amplitude dependent tune shifts and thus will change the betatron tunes of these oscillating bunches. A significant change in tunes will change the results of tracking completely. Tune –shifts with amplitude calculated analytically [6] are:

$$\delta\nu_x = -10.02x^2 - 50.78y^2$$

These relation shows that amplitude –dependent tune shifts are significant, besides sextupoles also distort the phase space ellipse. In the fig. 5 & .6 tracking results with sextupoles are carried out. The results show that in the presence of sextupoles, the septum clearance is reduced and particle trajectory deformations are more severe in the matched β case compared to the optimized β case.

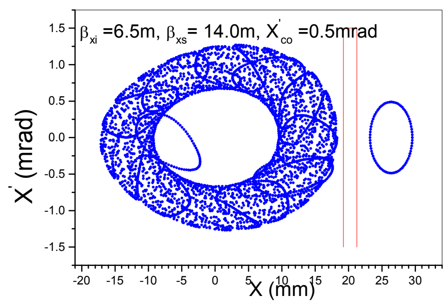

Fig.5 Optimized β

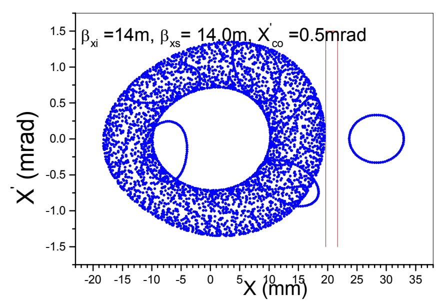

Fig.6 Matched β

This problem can be overcome by increasing the septum distance and bump strength as shown in fig. 7 & fig.8. In fig 3-8 $X_{co}^{/}$ =0.5mrad shows the slope of the asymmetric bump w.r.t design orbit. In the matched β-case maximum oscillation amplitude at $\beta_{x,max}$ is increased from 22.5 from 24mm. The new values of the septum location and bump strengths are summarized in table 1.

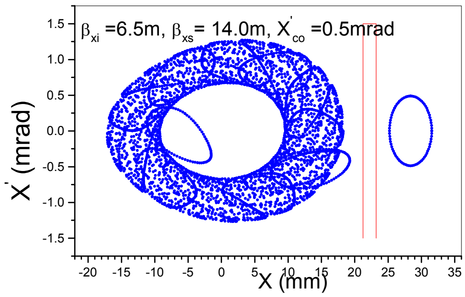

Fig.7 Optimized β

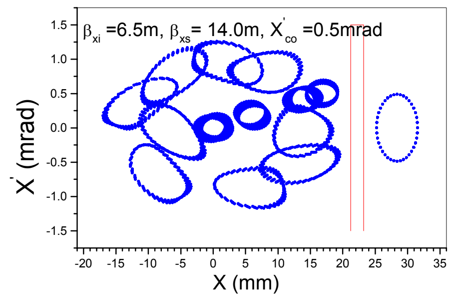

Fig.9 Optimized β

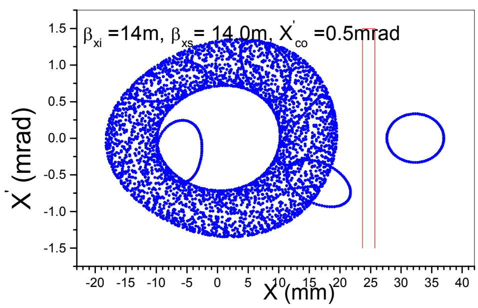

Fig.8 Matched β

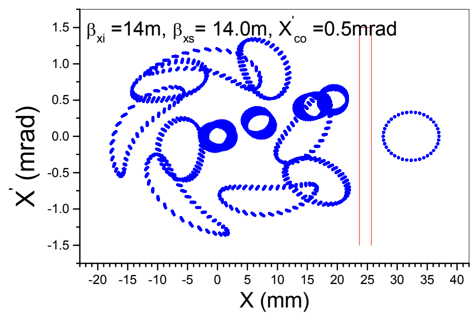

Fig. 10 Optimized β

Table 1:

1.1 Optimized Beta

	Without sextupoles	With sextupoles
Bump(mm)	14.8	16.8
Septum distance (mm)	19.2	21.2
Max. Oscillation at septum (mm)	17.3	19.3
Max. Oscillation at $\beta_{x,max}$ (mm)	22.5	22.5

1.2 Matched Beta

	Without sextupoles	With sextupoles
Bump(mm)	15.3	19.3
Septum distance (mm)	19.7	23.7
Max. Oscillation at septum (mm)	17.7	21.7
Max. Oscillation at $\beta_{x,max}$ (mm)	22.5	24.0

EFFECT OF JITTER

The effect is stringent during first turn for both injected and stored beam. It will reduce the beam from the septum for both injected and stored bunches. Its effect is estimated by tacking the injected and stored bunches with various possible combinations of the jitter. In our injection system the jitter will be around 20nS. In the fig. 9 & 10 tracking results are plotted for ten turns. From the fig. it is clear that the injected and stored bunches remain well separated from the septum.

CONCLUSIONS

Based on these calculation, it is recommended that for the design operating point (9.2,5.2) the normal position of the septum should be 22mm instead of 17mm and injection should be carried out parallel to the design with an asymmetric bump of 17mm having 0.5mrad angle w.r.t. design orbit instead of symmetric bump of 12mm. It is also recommended that in the presence of sextupoles optimized β-injection is preferable in comparison to matched β-injection.

REFERENCES

[1] B. Singh, G. Singh & S. S. Ramamurthi " Scheme of Injection for Indus-2" CAT/I/93-3 (1993)

[2] D Angal- Kalinin & G. Singh "Single bunch instabilities and beam lifetime in Indus-2", CAT/2000-11

[3] A. Wrulich, "RACETRACK; A computer code for the simulation of the nonlinear particle motion in accelerators", DESY 84-026 (1984)

[4] S. Tazzari, "Apertures for Injection", Internal report, ESRP-IRM-4/83 (1983)

[5] A.A. Fakhri & G. Singh "Injection studies for Indus-2", CAT/2003-26 (2003)

[6] Indus-2 Design Report –CAT (1998)