HEAD-TAIL INSTABILITY IN KEK BOOSTER SYNCHROTRON

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Abstract

A transverse bunched beam instability has been observed for several years in the KEK booster. The general theory for the head-tail instability was given by Sacherer.[1] The remaining problem of his theory is the estimation of the coupling impedance. It was suppose that the kicker magnet for the fast beam extraction system was a good candidate for the instability found in the KEK booster synchrotron. Miyahara analyzed the instability induced by the kicker magnet with a free string model.[2,3] We observed this instability to make sure Miyahara's expectation. The head-tail mode was determined and the growth rate of the instability was observed quantitatively using a spectrum analyzer. We found that the growth rate of the instability decreased at a certain timing in the machine cycle. The decrease of the growth rate is well explained by the reflection of the current induced in the kicker at the end of the feeding cable.

1. Head- Tail Mode

The calculated frequency spectrum for the throbbing pattern of the bunch is shown in Fig.1. When the envelope of the line spectra of Δ R-signals appearing on the position monitor is measured, we can determine the head-tail mode number. We observed the line spectra with a spectrum analyzer. One of the results is shown in Fig.2. As there is only one peak in the envelope of the spectra, the head-tail mode m is zero. We observed the line spectra over the whole machine cycle, but we could not find any other modes except zero.

2. Growth Rate

We also used the spectrum analyzer to measure the growth rate of the instability. The growth rate can be obtained from the time differential of the amplitude. The amplitude of a certain line within the line spectra was measured at some timings in the machine cycle. The amplitude change in the machine cycle is shown in Fig.3. We found the decrease of the growth rate at about 10 msec after injection.

3. Effect of Reflection of Beam-Induced Current at End of Feeding Cable

As the feeding coaxial cable for the kicker is open-circuited equivalently at the pulse generator side, we can not neglect the effect of the reflection of the beam-induced current at the end of the coaxial cable. The real part of the transverse coupling impedance of the kicker with the open-circuited cable is

$$\mathrm{Re}\ Z_{tot} = (\ 1 - \cos\omega(\ \tau_c + \tau_o\ )/2\ )\ \mathrm{Re}\ Z - \sin\omega(\ \tau_c + \tau_o\ )\ \mathrm{Im}\ Z\ /2\ ,$$

where Z_{tot} and Z are the coupling impedances with and without the open-circuited coaxial cable respectively, and τ_c and τ_o are the travelling times of the induced current in the cable and in the kicker. The coupling impedance of the kicker with cable is shown in Fig.4. The pattern of the coupling impedance is oscillatory. When the peaks of the coupling impedance coincide with the betatron side bands, the growth rate is high, and when the valleys coincide with them, the growth rate becomes small. In Fig.4 the betatron side bands at about 10 msec after injection are shown by line spectra, and in this case the growth rate is very small. This explains the decrease of the growth rate at 10 msec after injection.

References

1) F.J. Sacherer: Proc. of 9-th Int. Conf. on High Energy Accelerators, Stanford (1974) 347.
2) Y. Miyahara: IEEE Trans. on Nucl. Sci. NS-26, No.3 (1979).
3) Y. Miyahara: Particle Accelerators, 10 (1980) 125.

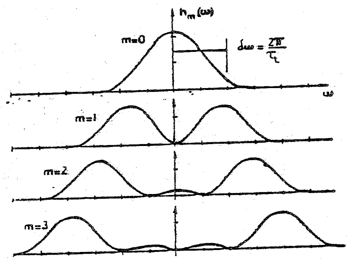

Fig.1

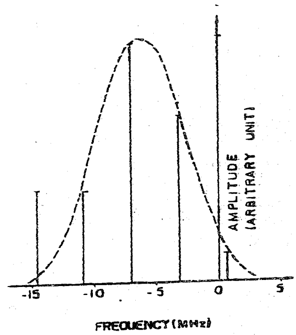

Fig.2

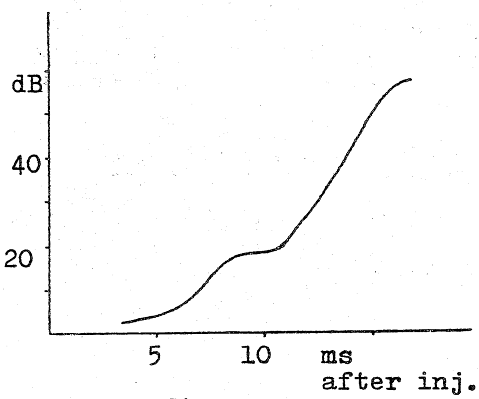

Fig.3

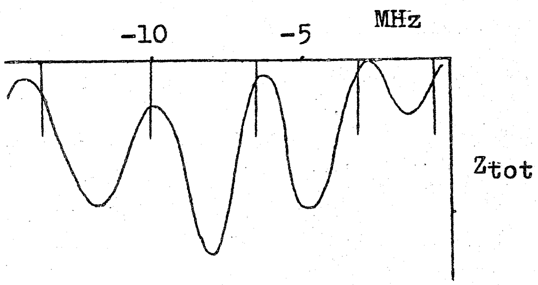

Fig.4