COHERENT INSTABILITY THROUGH KICKER MAGNET IN KEK BOOSTER

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1. Introduction

With the increase of the beam intensity of the KEK booster a coherent transverse instability has been observed. The horizontal betatron amplitude rapidly increases coherently at some time during acceleration, which suffers serious beam losses. The instability was found to be induced by the interaction of the beam and kicker magnet for the beam extraction. When the supply current terminater of the magnet was removed the build up of the instability becomes rapid and always observed at about 17 msec after beam injection. The magnet is composed of LC distributed circuit and has some resonance frequencies without the terminater, which is believed to interact strongly with the circulating beam. An interesting feature is that the induced coherent oscillation quickly decreases coherently just after the build up, resulting in no emittance blow up. Here we show what field is induced in the magnet by circulating current and try to calculate how it affects the bunched beam.

2. Current Induced Field in Kicker Magnet

In the set up of Fig.1 induced voltage by AC current was measured as a function of the frequency and current position Δx. The magnitude and the phase of the voltage indicated that the secondary current was induced essentially by a mutual inductance with the flux path through magnet core. The flux distribution induced by the primary current at various position Δx was calculated with a computer program. The induced voltage and the field distribution give the same mutual inductance $M = \{10 - 1.6\Delta x(\mathrm{cm})\} \times 10^{-8}$ [Tm^2 /one ferrite core].

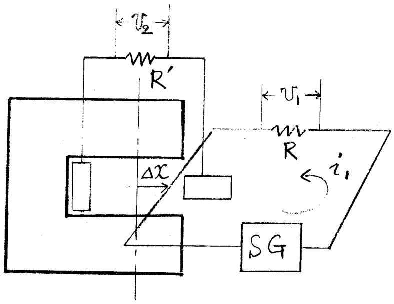

Fig.1 Setup of the measurement of induced voltage by a primary current.

Therefore an equivalent circuit of the magnet is expressed as shown in Fig.2. The current and voltage at the n-th mesh induced by a sinusoidal primary current was calculated. The magnitudes become large around the resonance frequencies of the distributed circuit and there the phase lag jumps by π radian. Fig.3 shows the induced voltage at the end mesh and the phase lag. The jump of the phase lag seems important for the coherent damping of the instability as shown later.

3. A Simple Model of the Instability

Fig.4 shows a simplified model of the bunched beam with betatron oscillation and density distribution. The induced current with this model was calculated using Fourier series expansion method. The current makes a magnetic field in the gap of the magnet and gives the Lorentz force. The electric field force is negligible.

Finally the motion of the bunched beam suffering the force was calculated and the build up or damping time is shown in Fig.5. We note in this figure that below the circulating frequency 5 MHz, the build up part ($1/\tau_\gamma > 0$) and damping part($1/\tau_\gamma < 0$) coexist between head and tail of the bunch, which suggests that by mixing of the head and tail particles through synchrotron oscillation the beam is overall stable. On the other hand all parts are instable in the region 5 ∿ 5.5 MHz and rapidly become stable above 5.5 MHz (17 ms). These features well agree with the observations as noted before. The build up and damping times around 17 msec are estimated to be ∿1 msec while the observed values are ∿0.5 msec.

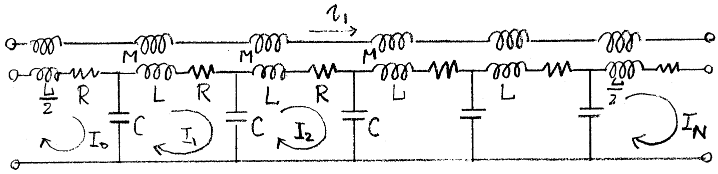

Fig.2 Equivalent circuit of the magnet with a primary current

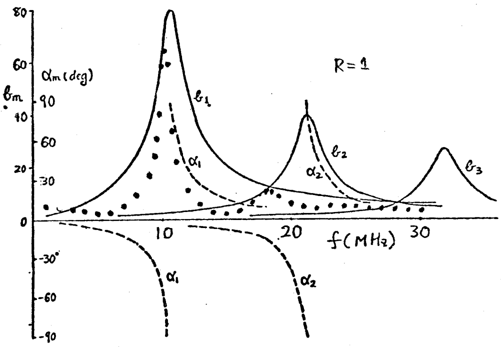

Fig.3 Induced voltage b_m and phase lag α_m. The dots in the figure is the measured.

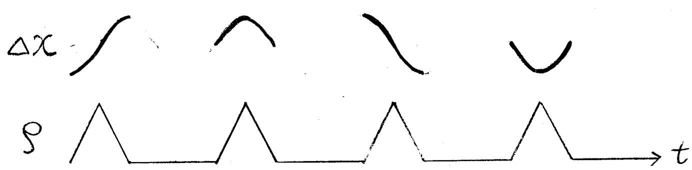

Fig.4 A simplfified model of the bunched beam.

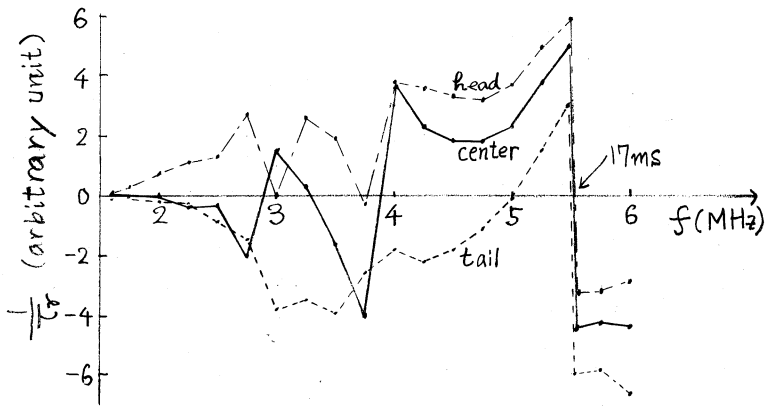

Fig.5 Build up or damping time during acceleration.