Measurement of Oscillatory Modes in the Recycler Gradient Magnet Hangers: First RGF at Location 628D

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Since the revolution frequency of the Recycler is approximately 90 kHz, the choice of betatron tune operating point means that the lowest betatron sideband frequency is approximately 40 kHz. At this frequency random magnet motion results in transverse emittance growth. Longitudinal oscillations in magnet placement will cause a slight beta-wave oscillation which can also cause transverse emittance growth. In this paper the frequency spectrum of the magnet is analyzed by measuring the vertical, radial, and longitudinal motion of a magnet stand.

1. Measurement Overview

Using a LeCroy 9354L digital oscilloscope connected to an accelerometer, the resonant frequencies of the proton upstream stand of the first Recycler gradient magnet installed at 628D was measured in the radial, vertical, and longitudinal directions. The accelerometer is an IRD Mechanalysis Vibration Pickup P/N 24957 Model 560. It has a velocity output which was connected directly to the oscilloscope. The ±10% amplitude bandwidth of the monitor is from 1 Hz to 4.5 kHz. The full specification sheet is attached to this note.

The accelerometer was attached to the stand instead of the magnet since the rigid body oscillation modes of the magnet would have made the measurement much more difficult. Since the vibration in the tunnel which drives the magnet motion is transmitted to the magnet from the magnet hangers, it was felt that by reciprocity the result of magnet motion excitation should also be viewed from the hangers.

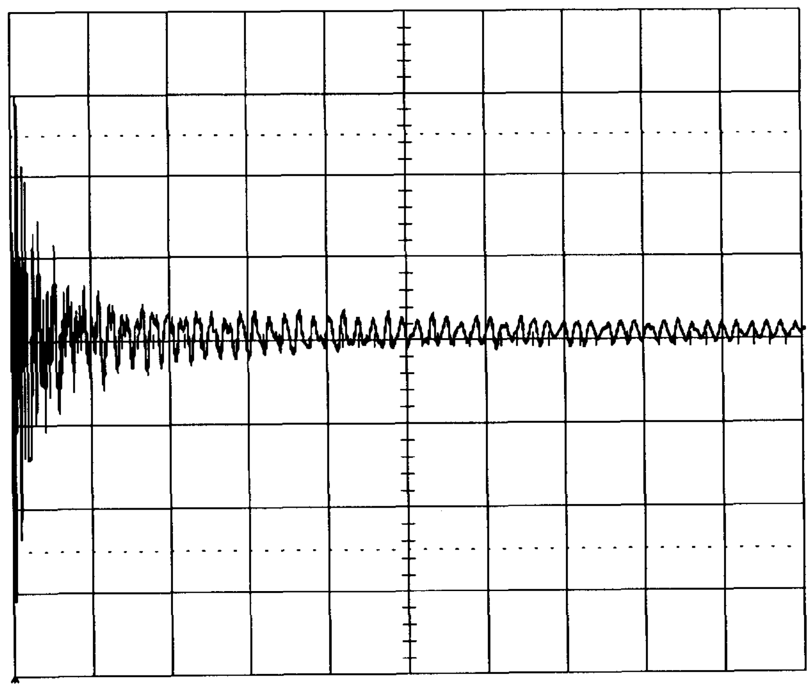
The measurements below were made in the time domain. An uncalibrated rubber hammer blow to the magnet was used to shock excite a radial, vertical, or longitudinal oscillation. The digital oscilloscope was triggered in order to record the oscillation signal from the accelerometer, which was moved into the appropriate orientation to measure the excited oscillation. The purpose of the measurement was to identify resonant frequencies and Q's.

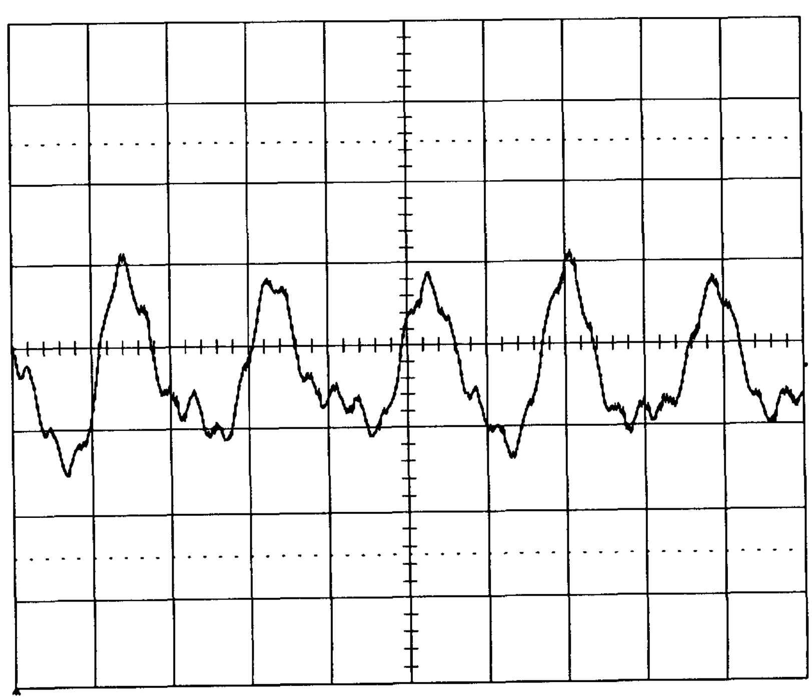
Below are the results of these measurements. In each case the resonant frequency and damping time of the mode is specified. Note that since each magnet will have an unique hanger configuration, each magnet will have a slightly different resonant frequency spectrum.

The conclusion of these measurements is that the resonant frequencies of the magnet/hanger system are very, VERY low compared to the betatron frequency. Given the relatively high Q of the oscillations, it is very unlikely that the magnets will begin to vibrate in position due to external noise excitations such as flow in the LCW system.

2. Radial

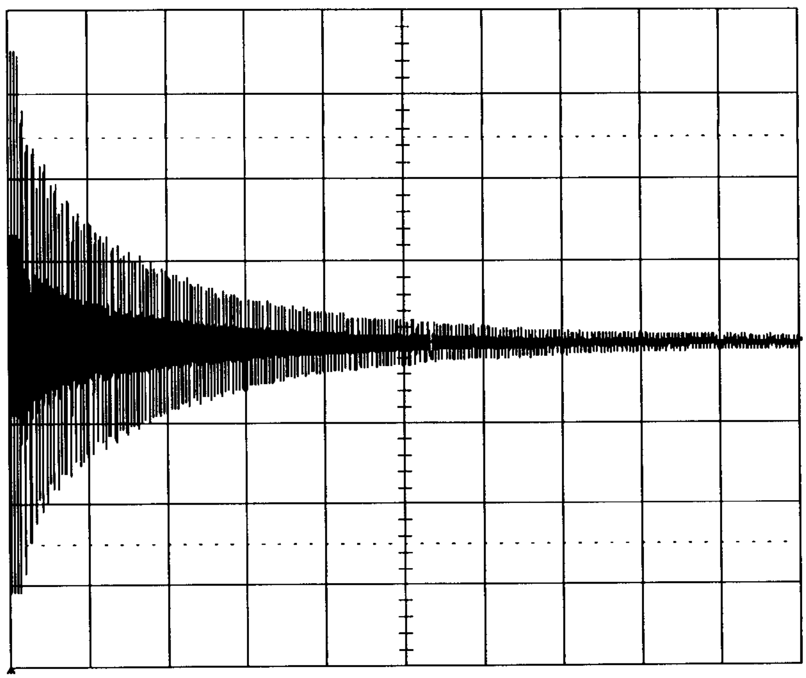
The resonant frequency is 9.6 Hz. For the top trace the horizontal scale was 0.5 sec/div, so the damping time is approximately 0.3 seconds. For the bottom trace the horizontal scale is 50 msec/div. It shows another higher frequency of much lower amplitude in the neighborhood of 70 Hz.

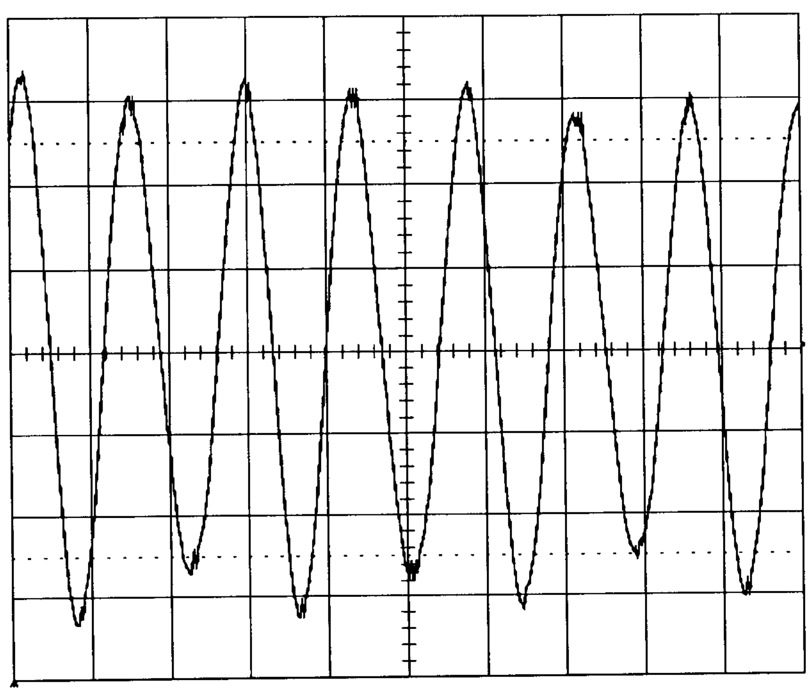




3. Vertical

The resonant frequency is 14.2 Hz. For the top trace the horizontal scale is 2 sec/div, so the damping time is approximately 3 seconds. For the bottom trace the horizontal scale is 50 msec/div.





4. Longitudinal

The resonant frequency was 7.5 Hz. The horizontal scale is 2 sec/div, so the damping time is approximately 5 seconds.