Instrumentation for Low Frequency Motion in Synchrotron Facility

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Abstract

Many commercial accelerometers and tilting sensors for monitoring the vibration or drift at low amplitude (micron order) and low frequency (below 1 Hz) were compared. A piezoelectric-driven shaker in micron range was used to calibrate the instruments. A new design of a low frequency accelerometer is presented. The accelerometer includes a constant force device, a high sensitivity displacement sensor and an appropriate mechanism. Some applications of these instruments in the beamline and storage ring are also presented.

Keywords: low frequency vibration

1. Introduction

Beam stability is inevitably influenced by the vibration or drift of mechanical parts in the frequency range below 1 Hz and amplitude in the order of micron. For example, in the ring, quadrupole magnets and beam position monitor are position sensitive components, the thermal induced deformation of girder were studied in SRRC [1]; in the beamline, the slit is sensitive to the position change, the mirror is sensitive to the angle variation [2]. For the diagnostics of beam stability some instruments in the low frequency range are needed. But the stability, precision, and frequency response of different instruments have to be considered. In this paper we present some experiences in the instrumentation of the low frequency range.

2. Classification of Instrument

Studying the mechanical motion in the synchrotron facility, the first thing is to know the position or angle changes of the components. Reference point of the motion has to be defined first. Generally the Earth is a good reference. It is convenient to compare the data everywhere. For example, accelerometer and tilt meter use the reference to the Earth, but the sensitivity or stability of the instrument may have some limits. If the reference is to a specific point, instruments for length measurement in high resolution and precision are available. Such as, mechanical, reluctance, capacitance or optical types are available. Stability, resolution, and measurement range are the major concern

2.1 Accelerometer

Accelerometer is based on the measurement of the acceleration or velocity change of a mass and converts this change to electronic output. It has the advantage that the reference is the Earth. Piezoelectric type accelerometer has low limit around 1 Hz and low sensitivity by the leakage current of the electronic circuit [3]. Servo type accelerometer can extend frequency range to DC, but sensitivity is governed by the proof mass. For sinusoidal vibration at 0.1 Hz and 1 μm the acceleration is corresponding to 40 ng maximum. It exceeded the detecting level of our selected accelerometers. To test the sensitivity and useful frequency range we design a piezoelectric shaker to calibrate and test of some accelerometers in the following section.

Table 1. The Specifications of Some Instruments for Low Frequency Motion

	PCB 393B12	**Rion LS 20C**	**Sprengnether FBX-28**	**LVDT Tesa**	**Nivel 20**
Measuring range	0.5 g	0.2 g	1 g	2 mm	±1.5 mrad
Resolution	8 μg	1 μg	0.1 μg	0.1 μm	0.001 mrad
Stability				~0.1 μm/day	0.005 mrad/°C
Error				0.01 um	0.002 mrad
Freq range	~1 Hz	0.1-100 Hz	DC-50 Hz	DC-115 Hz	2-10 sec
Weight	200 g	2100 g	20 g	100 g	850 g
Noise		1 μV/√Hz	5 μV		

2.2 Tiltmeter

A spirit level is a typical product in the measurement of tilting. Its reference is also to the Earth. Based on electro-optical technology the instrument can attain very high resolution and stability. For example Nivel 20 from Leica, resolution is 1 μrad, equipoise time is about 2-10 seconds. It is almost exclusion of temperature influence by optimized design. For the slow change of tilt in minute Nivel 20 is a good choice. We used Nivel 20 to monitor the deformation mirror chamber in the beamline.

2.3 LVDT

LVDT (linear variable differential transformer) is based on the technology of reluctance to measure the relative distance between the probe and target. It can provide the resolution down to 0.1 micron, stability is good, and repeatability is 0.01 micron. We use LVDT with quartz rod fixture to measure the girder deformation relative to ground.

2.4 Laser Interferometer

Laser interferometer is known to have high precision down to 10 nm or less. But it is sensitive to the temperature and pressure change. Although some temperature compensation software is available, the stability issue is not easily controlled in the working area.

3. Test Result

3.1 Frequency from 0.5 Hz to 1 Hz

Because the vibration frequency above 1 Hz can be easily detected by the accelerometer, we focus on the studying of frequency below 1 Hz. A piezoelectric shaker as shown in Fig. 1 was designed to calibrate the accelerometers. We shook the stage with a sine wave at 1 Hz and 3 μm amplitude and compared the response among three different accelerometers. The above-mentioned shaking corresponds to the sinusoidal acceleration change from 12 μg to zero. We found only FBX- 28 can respond correctly. Switching to 0.5 Hz and 3 μm sine motion, the acceleration is sinusoidal change from 3 μg to zero. None of the above three accelerometers can respond correctly.

Fig. 1: The piezoelectric shaker and its amplifier and function generator.

It seemed that the signal was smeared by the noise level of the accelerometers. It can be definitely said that the 3 μm at 1 Hz vibration in the ring or beamline would induce beam perturbation [1-2]. To fulfill the need in this frequency range we designed a new accelerometer as in Fig. 2. The accelerometer includes a constant force device, a high sensitivity displacement sensor and an appropriate mechanism. A proof mass sensed the acceleration variation and converted the signal to a displacement sensor. Figure 3 show the response of the FBX-28 and this new accelerometer. It is clear to find that this new device has better sensitivity than FBX- 28.

3.2 Frequency Lower than 0.5 Hz

Figure 4 shows the deformation of a mirror chamber by the beam heating. We used the Nivel 20 to measure the variation of tilting. In case we need to know the position change, LVDT with quartz rod fixture was successful adopted.

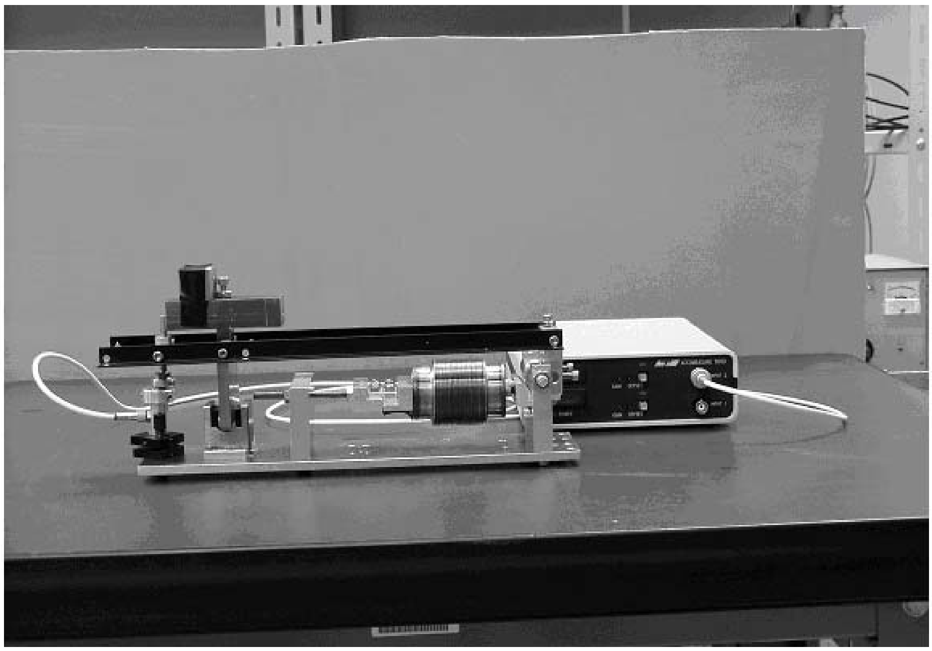

Fig. 2: The photo of the new accelerometer.

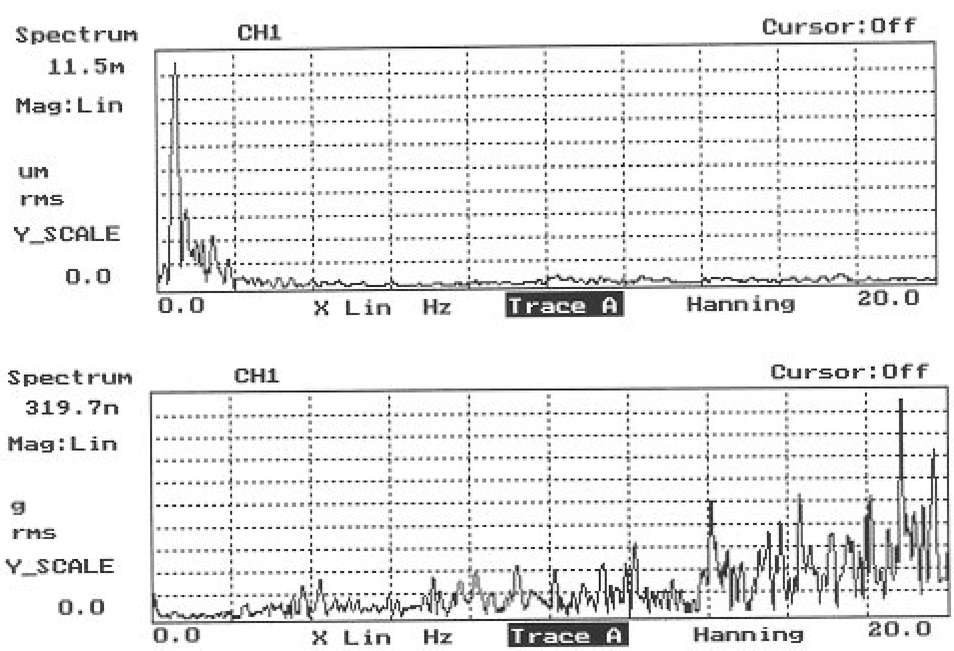

Fig. 3: Upper figure, the response of the new accelerometer; lower figure, the response of FX-28 accelerometer by 0.5 Hz and 3 μm amplitude shaking.

3.3 Fixture and Stabilization Time

From the experience in the optical laboratory, we find some stabilization time is needed after we adjust the fixture [4]. It may be the time lag of redistributing of the force equilibrium after adjusting.

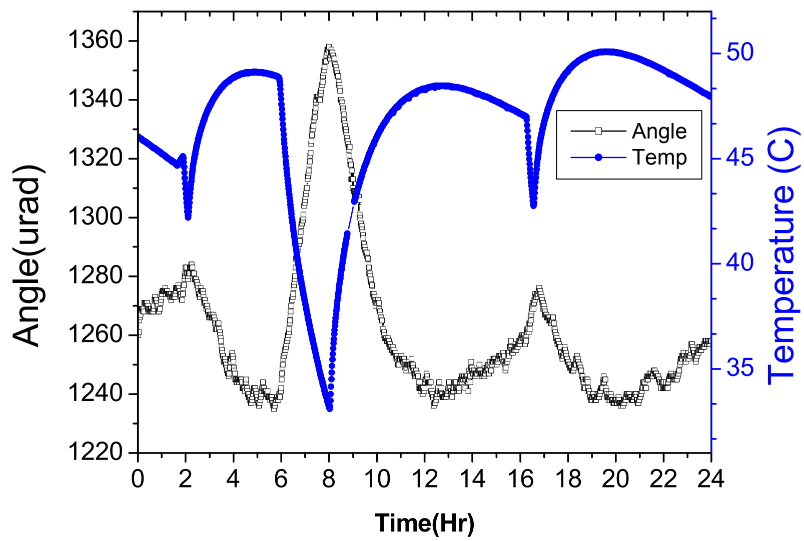

Fig. 4: The angle variation of mirror chamber by beam heating.

4. Conclusion

For the diagnostics of beam stability, different kinds of instrumentations for low frequency motion adopted in the synchrotron facility were introduced. A piezoelectric shaker was used to calibrate the accelerometers and converted the shaking acceleration to displacement. To investigate the motion precisely more advanced instrument will be needed in the future.

5. References

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