FLOOR LEVEL MOTION OBSERVED IN THE KEKB TUNNEL

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Abstract

The level of the KEKB tunnel floor has been monitored using tilt meters. A clear diurnal effect, which seems to have a strong correlation with the outside air temperature, has been seen. The tunnel level appears to be affected by atmospheric pressure as well. Simultaneous measurements in the basement floor and at four locations along the beam line were carried out. They show that the amplitude of the daily floor motion is largest on the basement floor of the experimental buildings and is reduced on the far side of the expansion joint away from the building. Measurement results are shown.

MEASUREMENT DURING BEAM OPERATION

KEKB is a two-ring collider with a circumference of 3016 m [1]. The tunnel lies about 11 m below the ground surface. There are four experimental buildings called TSUKUBA, OHO, FUJI and NIKKO (see Fig. 1). The 8 GeV electron ring (HER) and 3.5 GeV positron ring (LER) intersect at one interaction point (IP) in TSUKUBA.

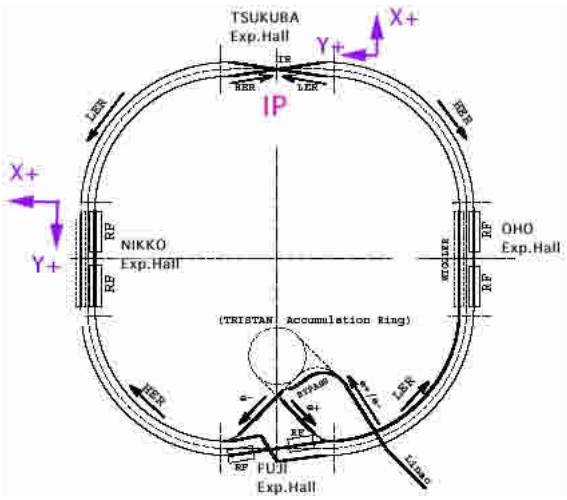

Figure 1: KEKB tunnel

Tilt meters (Leica NIVEL 20, digital output) were placed on the basement floor of the TSUKUBA experimental hall during the last 10 days of beam operation before the 2003 summer shut down. The floor level monitoring was undertaken in order to understand the day and night effect of the machine performance. Temperature was measured in three locations: the top of the TSUKUBA building roof, the ceiling of the TSUKUBA utility space, and the outside. These temperatures are plotted along with the luminosity in Fig. 2. The first two days were sunny and the roof temperature rose to 60 degrees Celsius. Luminosity tends to degrade more significantly on sunny and warm days than on cloudy days. It should be noted that the luminosity changes as a result of various machine tuning parameters, and it is difficult to compare the hour-to-hour machine performance. Daily luminosity does seem to have a correlation with the temperature.

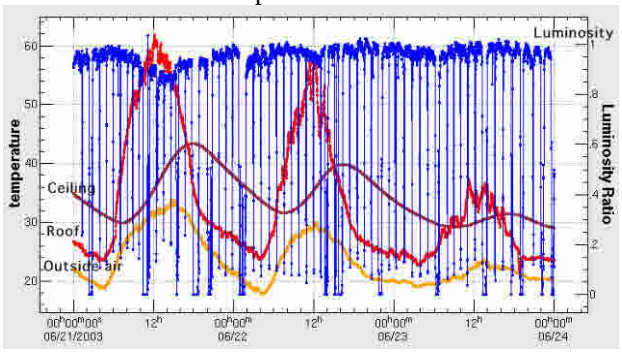

Figure 2: Machine performance for three days at the end of June.

Fig. 3 shows the floor motion for the same three-day period as in Fig. 2 The tilt meters were placed on the basement floor, on the left and right sides of the IP and on the BELLE detector [2] supports. The tilt meters were oriented with the x-axis pointing radially outwards from the ring, with the y-axis pointing along the beam-pipe and the z-axis pointing vertically upwards. An upward tilt of the outer edge of the ring registers as a positive Δx.

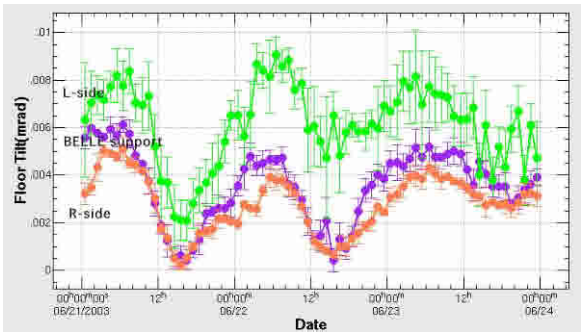

Figure 3: Floor tilt in x-direction at TSUKUBA experimental hall.

The tilt data were recorded every 60 seconds. The one-hour averages and their standard deviations are plotted. A diurnal effect is seen in the floor motion, with a peak to peak amplitude of several micro radians. The outside of the KEKB tunnel starts rising around 4 pm and starts sinking around 4 am. A longer-term motion is discussed later in this paper. There were no large differences in the floor motion among the three locations. The IP floor level shows a clear day and night effect though it is difficult to explain the luminosity degradation by the floor motion quantitatively. The diurnal effect in floor motion might explain the diurnal effect in the circumference of the KEKB tunnel described in a previous paper [3].

TUNNEL MOTION NEAR THE IP DURING THE SUMMER SHUTDOWN

More extensive floor motion monitoring was performed during the machine shutdown. The NIVEL 20 tilt meters were removed from the basement floor of the TSUKUBA building and placed in the right-side straight section of the tunnel. The locations of the tilt meters are indicated in Fig. 4. The definition of the xyz axes is the same as previously described.

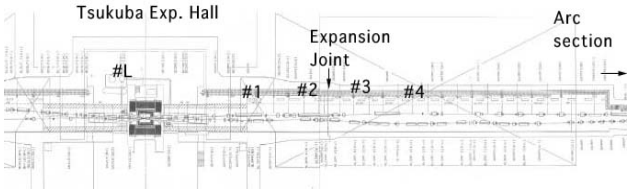

Figure 4: The tilt meter location in the tunnel. The tilt meters were spaced at 10 m intervals.

Fig. 5 shows the floor and tunnel level motion measured in August. A clear diurnal effect is seen. The effect in the x-direction is larger than that in the y-direction. The diurnal amplitude is larger for locations #1 and #2. Monitor #4 no longer presents a clear diurnal effect. The other interesting phenomenon seen is the correlation between the atmospheric pressure and the tunnel tilt. The outside of the tunnel started rising on Aug.9th when a strong Typhoon 10 moved across Japan. The temperature and the atmospheric pressure are plotted in Fig. 6. The tunnel level appears to be affected not only by the temperature but also by the atmospheric pressure.

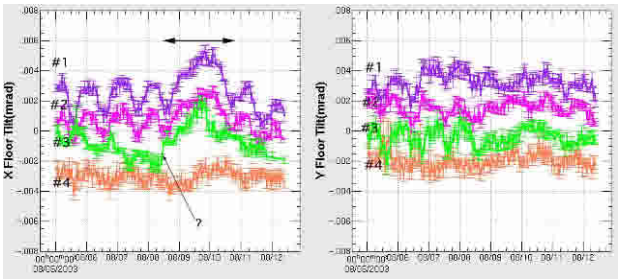

Figure 5: Tunnel floor motion in the x (left) and y (right) directions. The offsets in the tunnel level are subtracted in order to show all data on the same plots.

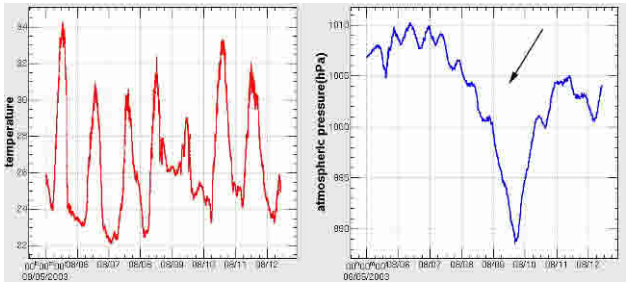

Figure 6: Outside temperature and atmospheric pressure.

An additional tilt meter (Applied Geomechanics inc., analog output) was placed on the left side of the Belle detector. Its location is indicated as #L in Fig.4. The basement floor data and the tunnel floor data are summarized in Fig. 7. The outside air temperature during the same period is shown in Fig. 8 along with the IP floor motion. Again the outside of the KEKB ring sinks in the afternoon and the amount of sinking has a correlation with the temperature maximum-minimum difference of that day. The amplitude of the daily floor motion is largest in the TSUKUBA basement and is reduced on the far side of the expansion joint.

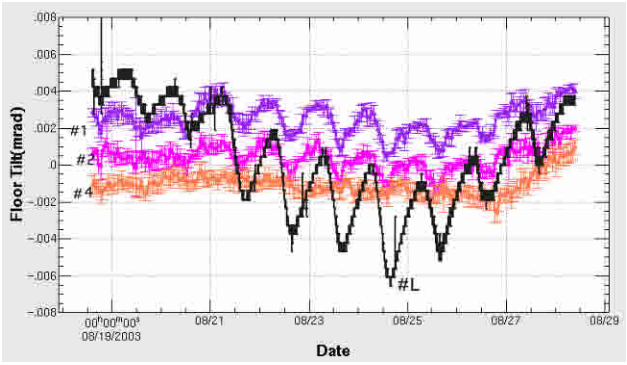

Figure 7: TSUKUBA building and tunnel motion for 10 days. Monitor #3 data had some problem and are not shown.

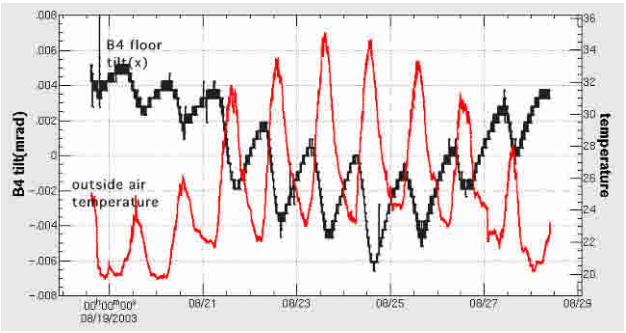

Figure 8: Outside air temperature and the IP floor motion. A strong correlation with the temperature is seen with some time lag.

FLOOR LEVEL MONITOR AT NIKKO STRAIGHT SECTION

The tilt meters were moved from TSUKUBA to the right side of the NIKKO experimental hall. The tilt meters were placed in the same way as in the TSUKUBA straight section. A diurnal effect is seen again as shown in Fig. 9. The tilt meter placed closer to NIKKO experimental hall, presents the clearest effect. The amplitude is on the order of several micron radians. This is similar to what has been seen at the TSUKUBA straight section. The damping of the amplitude across the expansion joint is somewhat smaller than in the TSUKUBA tunnel during this period. The outer side of the KEKB tunnel sinks in the afternoon as in the TSUKUBA tunnel.

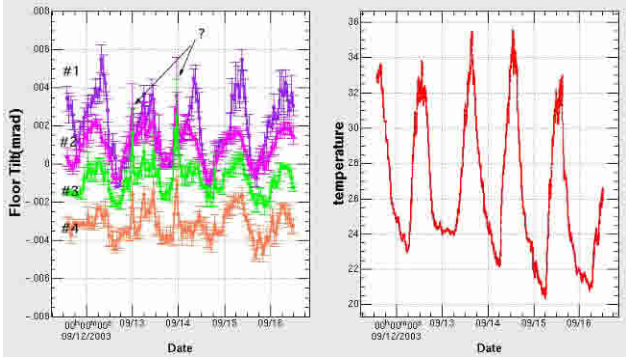

Figure 9: Tunnel floor motion observed at the NIKKO straight section.

LONG TERM MOTION

Longer term data are presented in this section. The floor level has been monitored by the tilt meter placed on the TSUKUBA basement floor (#L in Fig.4). Fig. 10 shows the floor motion in the x and y directions over a month. A diurnal effect appears in both directions, though the amplitude in the y-direction is several times smaller than that in the x-direction (see Fig. 11). There seems to be a longer-term (several-day) motion in both directions as well, which might be caused by changes in the atmospheric pressure system. The floor level has been tilting up in the past month. The reason for this is not clear at this point. The level changed rather abruptly in the last few days in the plot, which might be due to the fact the temperature went down during that period.

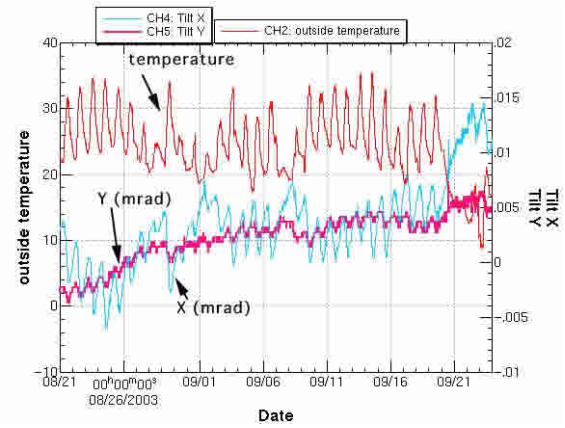

Figure 10: Longer term floor motion. The daily floor motion is smaller in the y-direction (thick line).

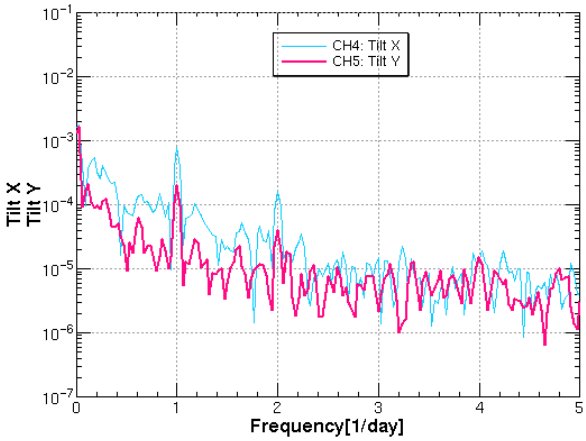

Figure 11: Fourier analysis of the floor tilt. The thicker line indicates the floor motion in the y direction. The diurnal component is clearly seen in both the x and y directions.

SUMMARY

The floor motion has been monitored in two straight sections of the KEKB tunnel. A diurnal effect has been seen during the beam operation and during the summer shutdown as well at TSUKUBA. The measurement at NIKKO showed a similar diurnal floor motion. The floor level has a strong correlation with the outside air temperature, with some time lag between the two. The floor level is also affected by the atmospheric pressure. These characteristics are very similar to what we saw in the circumference deviation [3]. The tunnel floor level motion is damped across the expansion joint, which indicates that the source of the diurnal motion is the experimental buildings. The floor level seems to have a long term component as well. This might be coming from the seasonal temperature drift. A longer term monitoring of the floor level is needed. The floor tilt may be implicated in the diurnal effect in luminosity.

REFERENCES

[1] KEKB B-Factory Design Report, KEK Report 95-7(1885)
[2] THE BELLE DETECTOR, NIM A479(2002) p117.
[3] M.Masuzawa,et.al., "CIRCUMFERENCE VARIATIONS OBSERVED AT KEKB," Proceedings of IWAA 2002, November, 2002.