INCLINOMETER COMPARISON

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1. INTRODUCTION

Although Hydrostatic Levelling Systems are remarkably precise, certain applications may be better served using high precision bi-axial inclinometers. Over the past two years two such systems have been tested for possible implementation in the long term monitoring of accelerator magnet support mechanisms. Three tests have been made at the ESRF. The first and second are long term tests of the behaviour of two different biaxial inclinometers. Two examples each of the Leica Level 20 and the Wyler Zeromatic 2/2 were tested on a metrological marble in our laboratory. The third test is the follow up of three level 20 inclinometers installed in the ESRF storage ring (SR) tunnel.

2. THE MAIN INTEREST

In a classical setup such as at the ESRF, a magnet support girder is equipped with three hydrostatic levelling system (HLS) sensors. This permits the measure of three degrees of freedom, the two tilts, pitch and roll, and the height with respect to another HLS or a reference. A dual axis inclinometer can replace two of these HLS sensors.

The most sensitive direction to tilt errors, at least at the ESRF, is across the magnet support. Taking advantage of the very short lever arm and the inclinometer angle precision, the roll of these supports, which are generally long and narrow, can be measured more accurately by a precise inclinometer than by an HLS. Naturally, the accuracy in the other direction is reduced with respect to that of the HLS. Nonetheless, this may be acceptable for most applications.

	Separation Distance		
	2 m	1 m	0.5 m
HLS with resolution of 1 µm	1 µm or ½ µradian	1 µm or 1 µradian	1 µm or 2 µradian
Inclinometer with a resolution of 1 µradian	2 µm or 1 µradian	1 µm or 1 µradian	½ µm or 1 µradian

3. THE MARBLE TEST

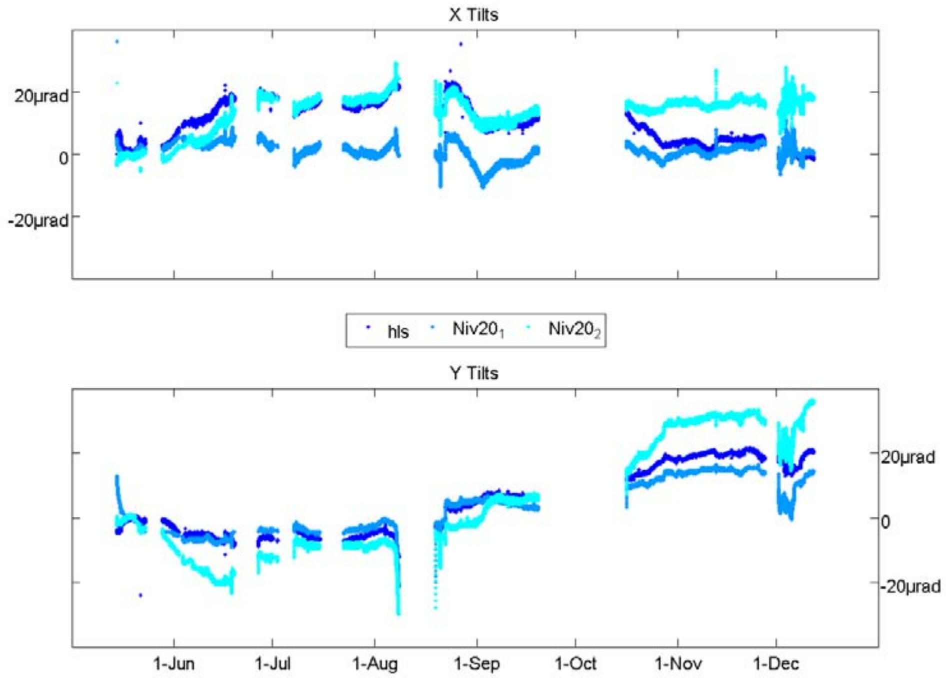

Figure 1 Long term test of the Level 20 Inclinometer lasting 8 months from May to December 2003 on the ESRF metrological marble.

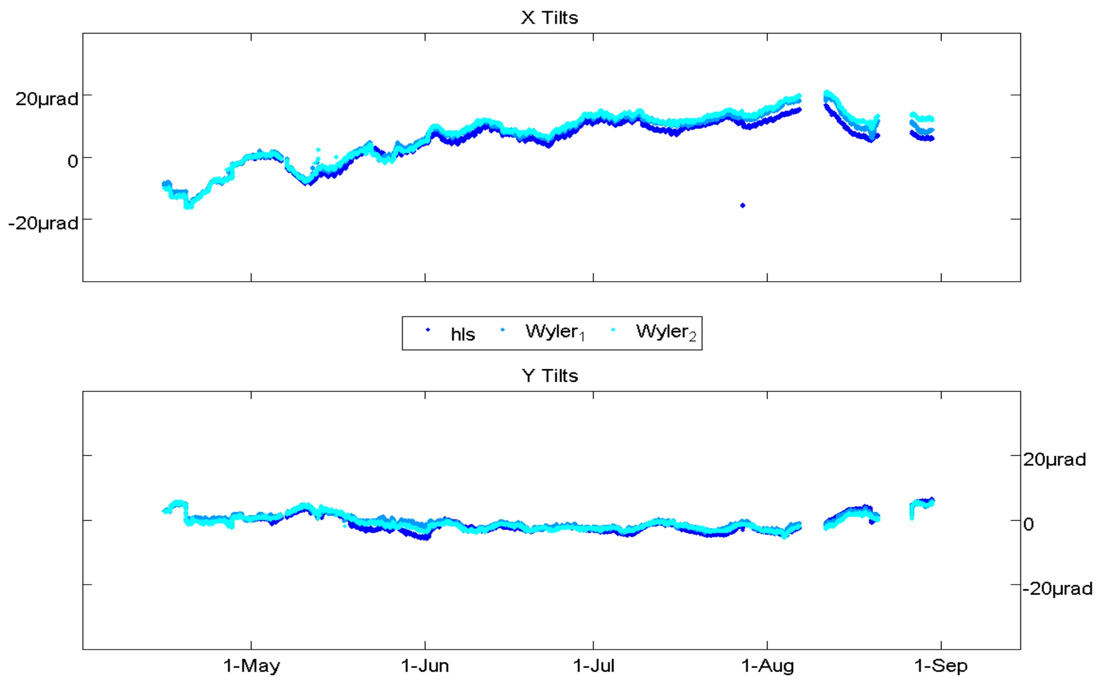

Figure 2 Long term test of the Wyler Zeromatic 2/2 biaxial inclinometer lasting five months between April and September 2004 on the ESRF metrological marble.

Figure 3 shows the experimental setup for this test. All results are the value of the tilt at given time minus the value at the origin. (i.e. $dT_{t=x} = tilt_{t=x} - tilt_{t=0}$)

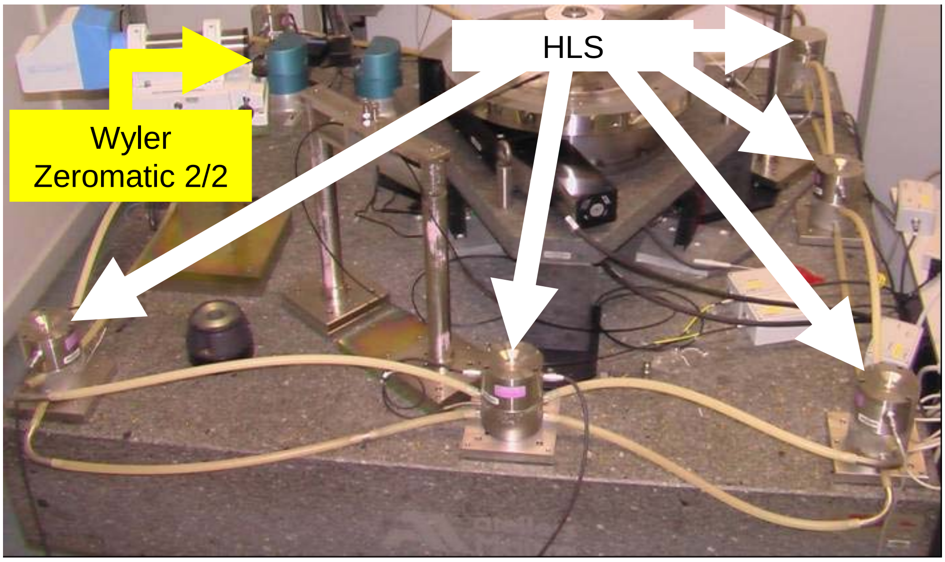

Figure 3 Inclinometer and HLS setup on the ESRF laboratory test marble. Pictured here are the two Wyler Zeromatic 2/2 inclinometers. One can see the layout of the 8 HLS around the periphery of the marble.

The results for these tests are shown in Figure 1 and Figure 2. Both instruments have a nominal resolution of 1 µradian. The Wyler Zeromatic 2/2 performs a reversal measurement and compensates any offset. One can see that the overall agreement between the HLS and the inclinometers and between the inclinometers themselves is generally quite good. This is particularly true of the Wyler Zeromatic 2/2.

4. THE SR TUNNEL TEST

Three Leica Level 20 inclinometers have been installed on three SR magnet supports since January 2004. They are compared with a HLS installed in parallel on the same support girders. The HLS is composed of 9 sensors, three each installed on the 3 magnet supports. A part of the installation is shown in Figure 4. Comparative results are given in Figure 5, Figure 7 and Figure 6.

These results show very good agreement between the Level 20 and the HLS. Comparisons are made during what is referred to as *calm days*. These are days during normal user service mode (USM) operations. Machine shutdown and machine dedicated time (MDT) shifts have been eliminated from the comparisons. Additionally, there was a long period between April and May when we had problems with the serial communication with the Level 20 inclinometer installed on the G20 magnet support. These problems were completely independent of the instrument itself. Nevertheless, data for this period and before it have been eliminated from the tests.

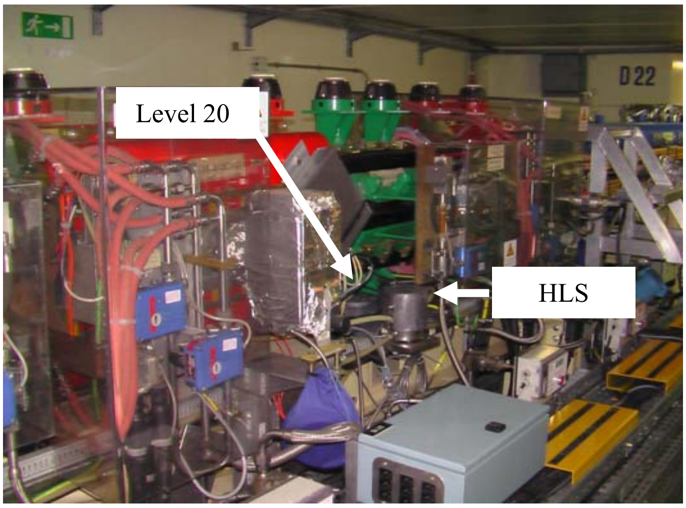

Figure 4 Position of HLS and Level 20 in SR tunnel test

Figure 6 shows the difference between the HLS and the level 20 tilts. We see there is a drift or gain in the differences associated with either the HLS and/or the Level 20. Eliminating the drift by passing a best fit line through the points gives a nominal agreement between the two systems of better than 6 μradians at 2σ significance level.

5. CONCLUSIONS

It has been proposed that a dual axis inclinometer with one HLS sensor can be used to monitor magnet support movements. In particular, it is proposed that the direction across the magnet support most sensitive to tilt errors can be more accurately measured by a precise inclinometer than by an HLS. This is done by taking advantage of the very short lever arm and the inclinometer angle precision. Long term tests both on a metrological marble in the laboratory and in the SR tunnel have shown this method is a viable alternative to the more classical 3 HLS sensor installation.

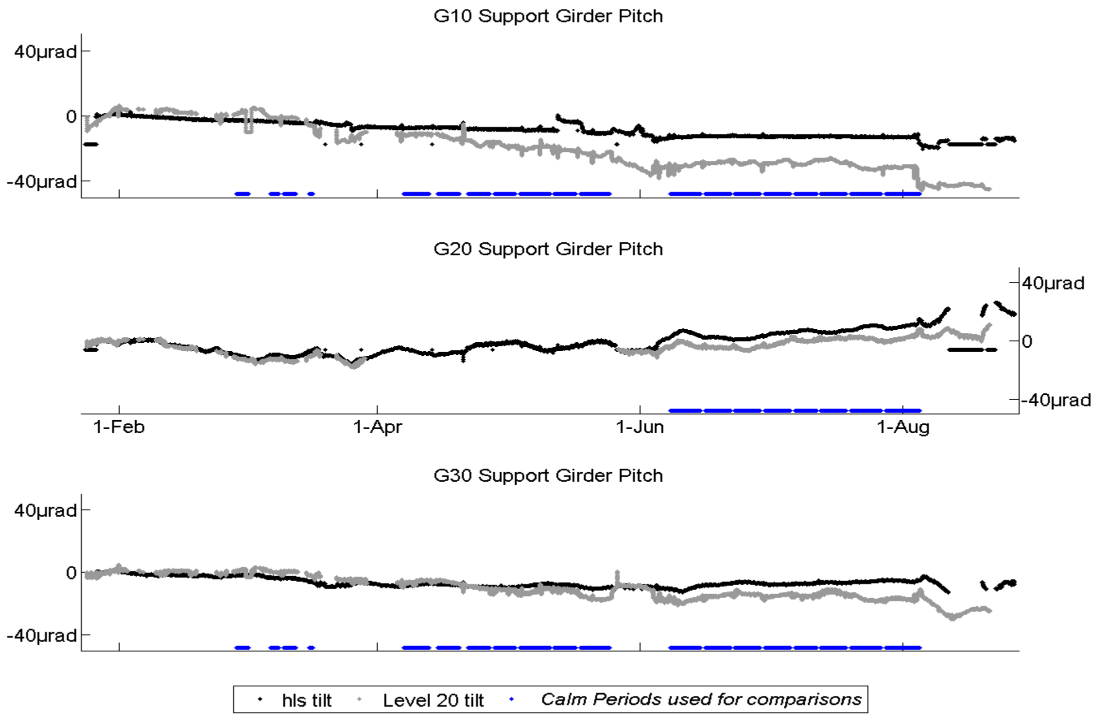

Figure 5 Level 20 SR tunnel test Pitch or longitudinal magnet support tilt January to August 2004 and the equivalent tilt determined by the HLS over the same period.

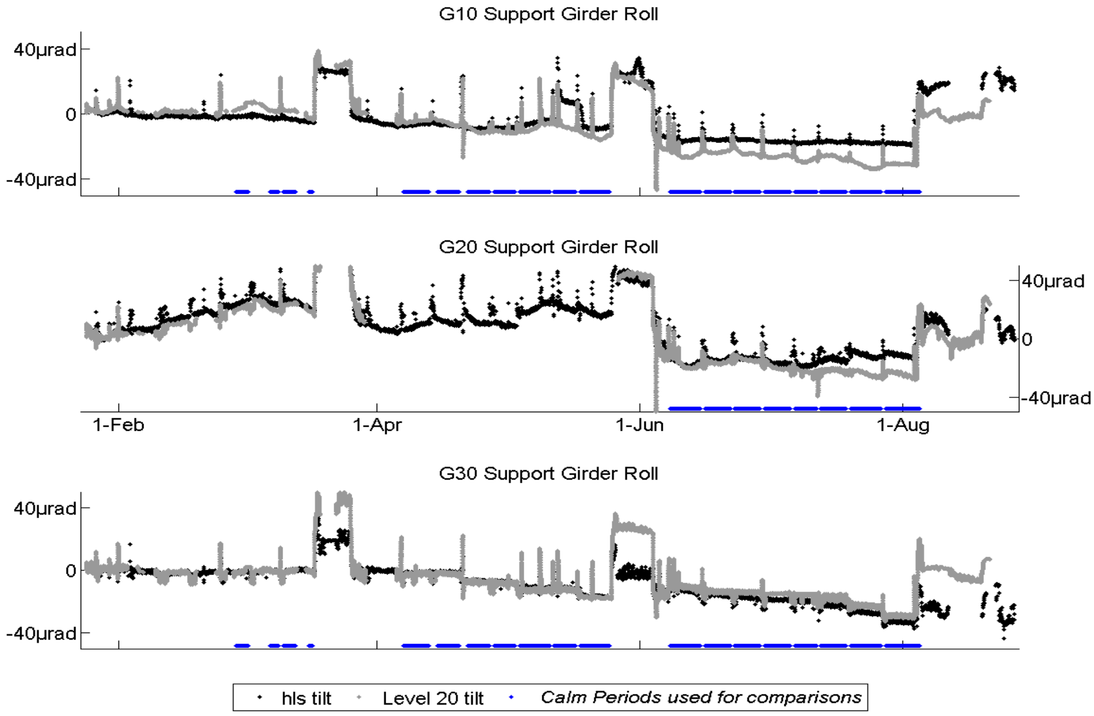

Figure 7 Level 20 SR tunnel test Roll or lateral (radial) magnet support tilt January to August 2004 and the equivalent tilt determined by the HLS over the same period.

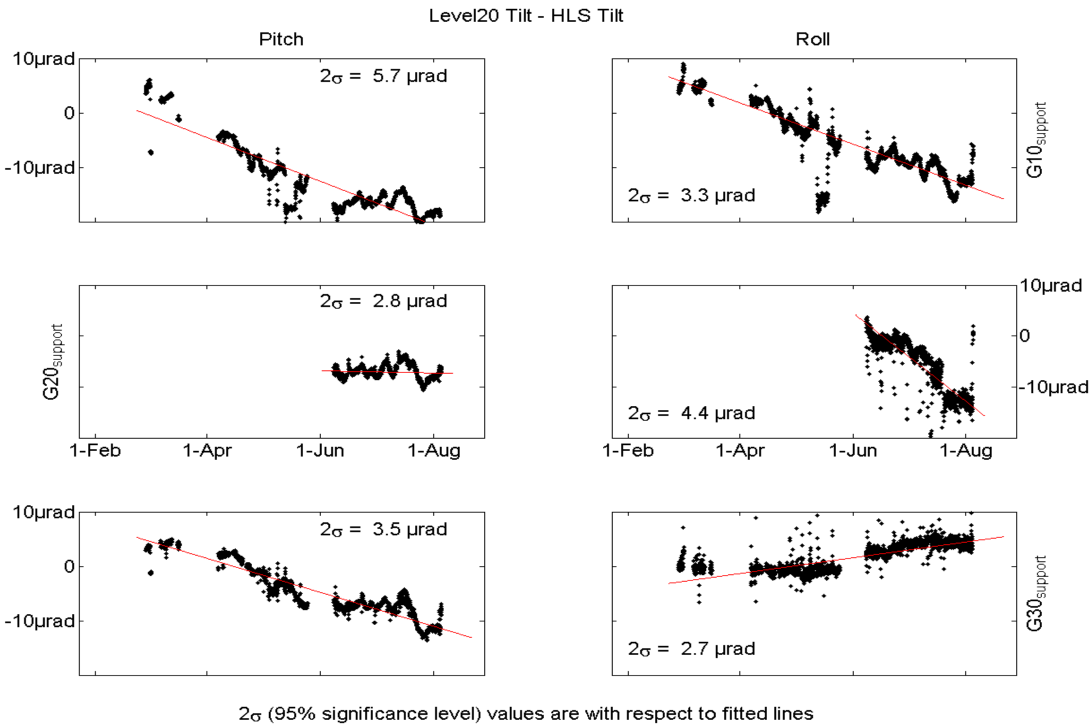

Figure 6 HLS tilt subtracted from the Level 20 tilt over the study period January to August 2004. We remark in these graphs that there is a drift component associated with this difference. The maximum error with respect to a best fit line through this data is 6 µradians.