A Study of Thermally Induced Movement in SRS Storage Ring Quadrupole Magnets.

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Abstract

Significant drifts in the horizontal beam orbit in the SRS over a period of many months necessitate occasional re-alignment of quadrupole magnets, based on optimising correcting algorithms. A study has been made of the stability of the F-Quadrupole magnets both over the duration of a single stored beam and over longer periods of SRS operations. Of particular interest is the behaviour of the magnets induced by the thermal cycling arising from the repeated energy ramping from injection at 600 MeV to the final 2 GeV operating level. Among the parameters studied are precise position measurements on the magnets, together with variations in cooling water temperature and ambient conditions. Such data can be used to assist the understanding of the electron beam orbit changes that have been observed both long and short term.

1. INTRODUCTION

An experiment has been set up to monitor positional and temperature variations in the SRS F-Quadrupole magnets over an extended period. The hope is that these results will help explain continual drifts which are seen in the unsteered electron beam orbit in the horizontal plane over many months [1]. Position detectors have been placed in contact with the magnet, along with temperature sensors on the magnet and on inlet and outlet cooling water supplies. The ring tunnel ambient is also monitored. Initial experiments were concerned with expansion and contraction, correlated to variations in cooling water and ambient temperature. This paper reports some of the data gathered so far, as different aspects of the effect of thermal variations on the SRS are investigated.

2. EXPERIMENTAL SET-UP

Movement in magnet faces is monitored through a set of Sylvac displacement transducers which are placed in contact with the magnet. The probes have a nominal resolution of 1μm and give increasing readings as the plunger length increases. A commercial multiplexer allows data to be taken from up to 8 probes. Control is obtained through a PC via RS232. The duration of the experiment, reading interval and number of readings can be specified by the user. K-Type thermocouples are used to make temperature measurements.

A square section aluminium mounting frame is used to hold the probes in proximity to the magnet. The frame is bolted to the concrete floor of the ring tunnel.

A control has been set up consisting of a probe mounted close to but not touching the magnet. This probe is subject to the same variations in temperature and magnetic fields as the measurement probes. A typical arrangement of sensors and thermocouples around the quadrupole is shown in figure 1.

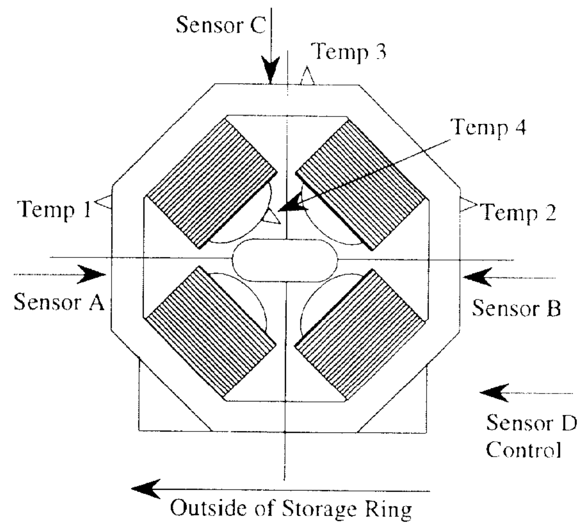

Fig 1 Typical Arrangement of Sensors for Quadrupole Movement Monitoring.

3. TEMPERATURE VARIATIONS

Temperature variation of inlet and outlet cooling water temperature has been monitored, and the average magnet temperature computed from the mean of several thermocouples attached to the magnet laminations. The cyclic behaviour is as would be expected from the sequence of beam dump, magnet cycle and refill, including energy ramp from 600 MeV to 2 GeV. During the period in question this was carried out on a daily basis. The cooling water temperature shows a strong correlation with magnet current. The temperature profile over 6 days is shown in figure 2. This data is typical of that which has been seen throughout the experiment.

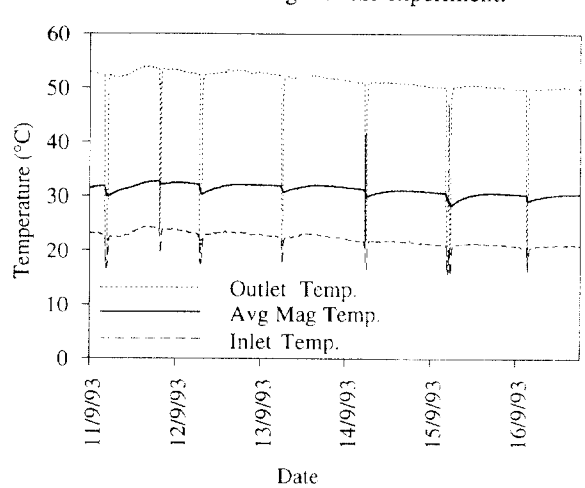

Fig 2 Typical temperature profile of F-Quadrupole magnet.

4. EXPANSION AND CONTRACTION OF MAGNETS

Measurements have been made of the expansion and contraction of a number of F-Quadrupoles. The correlation with magnet average temperature was investigated. The sum of movements as measured on inner and outer sensors is assumed to be equivalent to a horizontal expansion. The assumption is also made that the probe mounting assembly is stable. Figure 3 shows the measurements as recorded over a 7 day period.

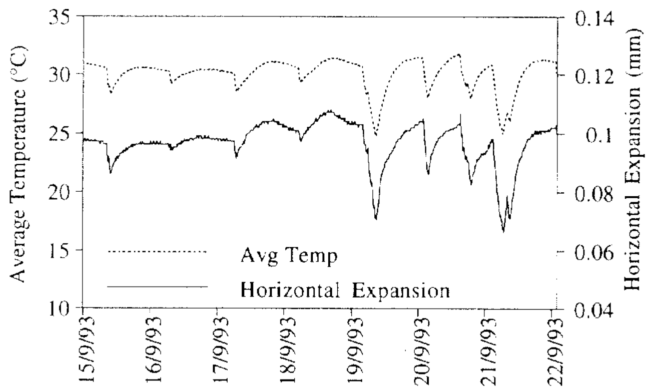

Fig 3. Horizontal expansion of FQ11 and correlation with magnet average temperature.

Further analysis of these results allowed an assessment of the cumulative displacement of the magnet centre due to many expansion-contraction cycles. Horizontal movement ΔH is defined as half the difference in inner and outer sensor reading;

$$\Delta H = \frac{(\Delta inner - \Delta outer)}{2} \quad (1)$$

Measurements recorded over an extended period - 16 days from 25th September - 11th October shows a progressive displacement of the magnet centre. As the magnet expands and contracts under the influence of temperature it clearly 'walks' off centre. A shift of over 0.06mm is estimated from the data, as shown in figure 4.

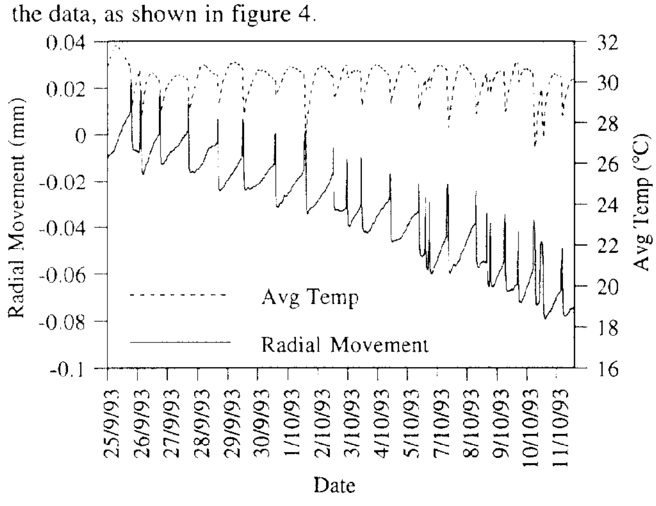

Fig 4. Horizontal movement of the magnet centre

It is interesting to note the form of the radial movement. Spikes indicating an increased rate of movement at the time of beam dump and refill. An expanded graph of one such event is shown in fig 5. Raw sensor data is shown for inner and outer sensors along with the magnet outlet water temperature as this correlates with magnet current.

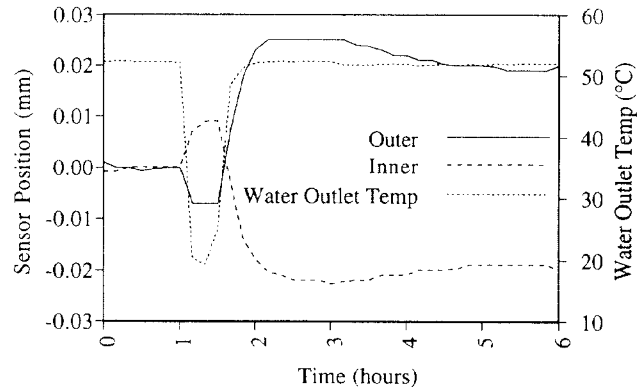

Fig 5 Magnet behaviour during beam dump and refill.

The equal and opposite readings for inner and outer sensors indicate a pure outward movement when magnet current is set to zero during beam dump and cycle. The lack of such spikes from the expansion data indicate that this could be a magnetic rather than a temperature induced effect.

Effects such as this can help to explain the progressive horizontal orbit changes seen in the SRS. It has been postulated that orbit changes are not due to one magnet error, but an accumulation of many errors around the storage ring. Clearly thermal variations will effect all the magnets in the lattice, and over a period of time could give rise to many errors in this way.

As would be expected, data recorded in the vertical plane shows similar expansion characteristics, though clearly there can be no progressive movement here.

5. MONITORING OF VACUUM VESSEL BEHAVIOUR

The magnitude of the horizontal movement of the quadrupole magnets raised the issue of whether a similar effect would be seen at the vacuum vessel, and hence at the BPMs which in the case of the horizontal monitors, are located close to the F-Quadrupoles. The vacuum vessel is a touch fit within the quadrupole, and is fixed to the F Quadrupole mounting platform at the upstream end less than 1m from the BPM.

Further experiments were carried out to monitor movements of the vacuum vessels in the same way as for the quadrupole magnets. Thermocouples were attached to the vacuum chamber and to the magnet platform. Displacement probes were mounted either side of the vessel in the horizontal plane, in the vicinity of the H BPM. A schematic diagram of the layout of the experiment is shown in figure 6.

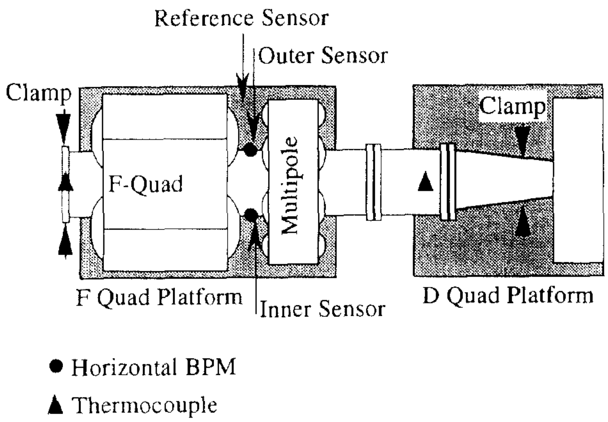

Fig 6 Layout of sensors for vessel monitoring

Initial results implied that significant movement of the vacuum vessel takes place during the course of a stored beam. A similar correlation is seen with vessel temperature as before. The exact cause of such vessel movements is not yet clear and further investigations are required. Figure 7 shows the movement of the vessel as measured between 22nd and 24th January 1994.

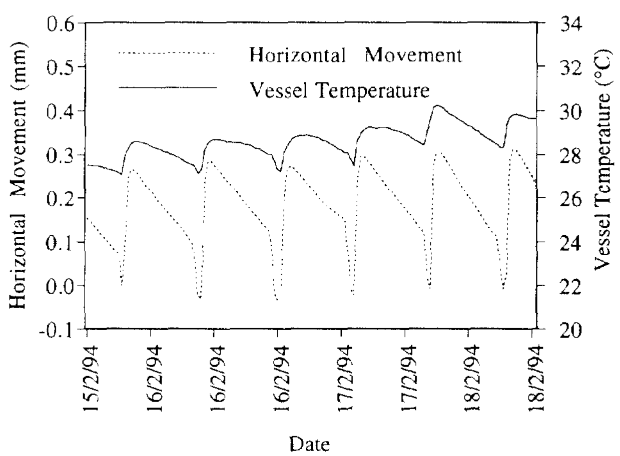

Fig 7 Horizontal vessel movement at H BPM

The result is typical of those seen. The vessel temperature varies by less than 4°C, in contrast to the 20°C variations seen in the quadrupole laminations. The physical clamping arrangements of the vessel may play a part in the results seen here, as may the vessel proximity to the magnet. The positioning of the probes in the restricted space close to the BPM was found to be particularly difficult, and further experiments are being carried out with a modified clamping arrangement for the Sylvac probes. Vessels in different straight sections of the SRS will be assessed.

6. CONCLUSIONS

A study has been made on the effects of thermal variation on the SRS F Quadrupole magnets and vacuum chambers. Sylvac displacement transducers are used to measure movement of components. Temperature is measured with K Type thermocouples. Significant expansion and contraction behaviour is seen, which correlates strongly with the periodic beam dump and refill during SRS operations. Furthermore, progressive displacement of quadrupoles is seen due to continued expansion and contractions. Such movement goes a long way toward explaining long term drifts seen in the electron beam orbit. There is also evidence to suggest that the quadrupoles are subject magnetic as well as thermal effects.

Preliminary measurements of vessel movement have indicated a similar cyclic pattern to that seen in the magnets. The small temperature changes in the vessel itself imply that any movement could be in part caused by contact with the actual magnet.

Further experiments are being carried out to monitor more closely the vessel movement at the BPI buttons, so that the validity of positional information at the BPM can be verified. This is of particular importance with a view to positional correction of the beam through a global servo mechanism [2]. A more stable support mechanism for the displacement probes has been designed and implemented for the next set of experiments. Positional measurements of quadrupole magnets are continuing, with assessments being made of different magnets in turn. It is hoped that results would correlate with quadrupole magnets which have required re-alignment for correction of the horizontal orbit on repeated occasions in the past.

7. REFERENCES

1. L A Welbourne. Long Term Drifts and Correction of the SRS Closed Orbit, these Proceedings.

2. B G Martlew, R J Smith and S L Smith, Development of Global Feedback for Beam Position Control in the Daresbury SRS Storage Ring, these proceedings.