POSITION SENSORS FOR MONITORING ACCELERATOR MAGNET MOTION AT DELTA

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Abstract

The Dortmund Electron Accelerator (DELTA) is a 1.5 GeV synchrotron light source. Magnet movements were identified as the main source of closed orbit drifts. A monitoring system to survey the magnet movement based on commercially available position sensors was installed. Results of the measurement and first steps to improve the magnet stability will be presented.

1 INTRODUCTION

The DELTA Storage Ring is a 1.5 GeV 3rd generation storage ring for synchrotron radiation production (see figure 1) [1]. A large amount of heat load from synchrotron radiation must be dissipated from the vacuum chamber. In the DELTA storage ring the synchrotron radiation hits the outer chamber wall and leads to a bending of the vacuum chamber.

Due to the fact that the beam position monitors (BPMs) are attached to the vacuum chamber, they start to move with increasing heat load onto the vacuum chamber. With an ill-defined orbit the vacuum chamber was heated up at several points to around 200 centigrade. Sometimes even the complete stored beam was lost.

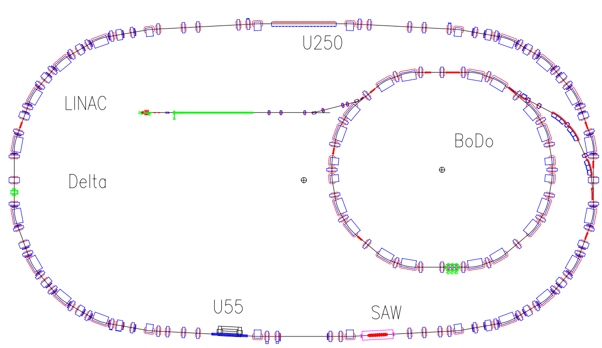

Figure 1: Overview of the DELTA accelerator complex

The stability and reproducibility of the storage ring, especially the beam orbit, is crucial for the operation as synchrotron light source. The stability of the measured beam orbit itself depends on the position stability of the beam position monitors and the focusing magnets. Therefore the position stability of quadrupole magnets and beam position monitors was measured.

2 POSITION SENSORS

To allow the monitoring of the large amount of components with sufficient resolution an inexpensive commercially available solution was searched, which allows the direct position measurement of the components. As a good compromise between cost, sensitivity and ease of use, Linear Variable Differential Transformers (LVDTs) with integrated electronics were chosen. 20 sensors from TWK [2], [3] have been installed to monitor quadrupole magnets and BPMs in one quarter of the DELTA storage ring (figure 2). This allows to study, to survey and to improve the mechanical stability of the components.

Figure 2: Installation of sensors before quadrupole magnets.

3 LINEAR VARIABLE DIFFERENTIAL TRANSFORMERS (LVDTS)

The position sensor works as an inductive half bridge.

A position change of a Mu-Metall cylinder inside two solenoids induces an inductance change inside the two solenoids, which is transferred into an electrical signal proportional to the position.

A standard measurement range of 5 mm was used. The sensor has a linearity of 0.25 % (10 µm).

The output signal is connected to the DELTA control system via standard ADC modules.

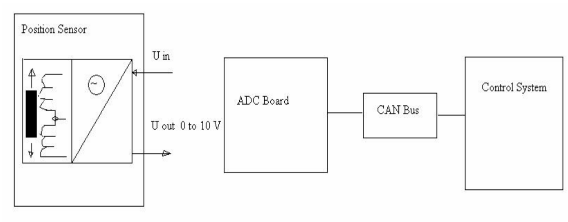

Figure 3: Working principle of the Linear Variable Differential Transformer (LVDT).

4 MEASUREMENTS AND RESULTS

The source of the thermal movement of the magnets can be separated into three different effects.

- Rise of cooling water temperature after starting the accelerator.
- Changes in the hall air temperature.
- Heat-load from synchrotron light.

4.1 Cooling water and hall temperature

DELTA is operated during the week from Monday morning to Friday afternoon. Especially on Mondays the reproducibility of the machine was difficult. The position monitoring of magnets showed a large movement of magnets during the Monday morning shift (see Fig. 4). To distinguish between the heat load from synchrotron radiation and other sources of heat load the measurement was done at low beam energy.

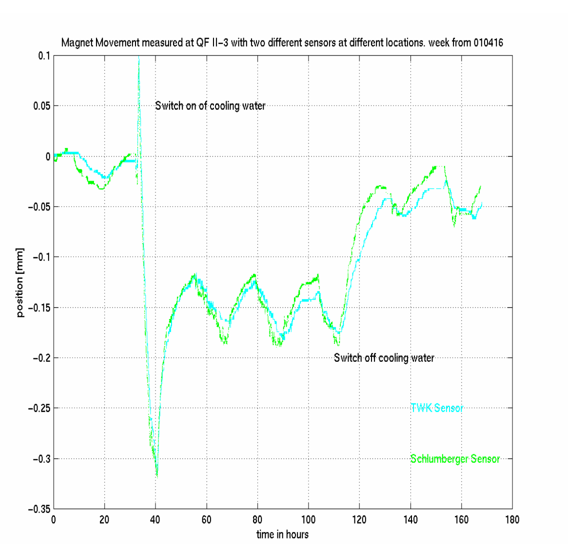

Figure 4: Quadrupole Position measured during one week with beam stored at low energy (750 MeV) (no influence due to synchrotron radiation). Start-up of the machine and daily changes are visible. The x-axis starts at Monday 0:00.

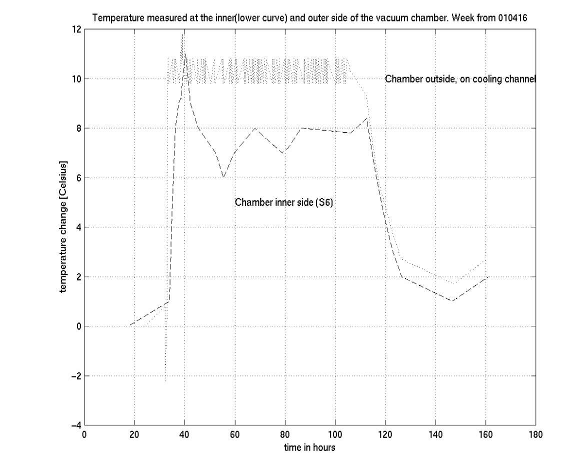

Figure 5: Temperature development during the same week with low beam energy (750 MeV) (no heat load due to synchrotron radiation).

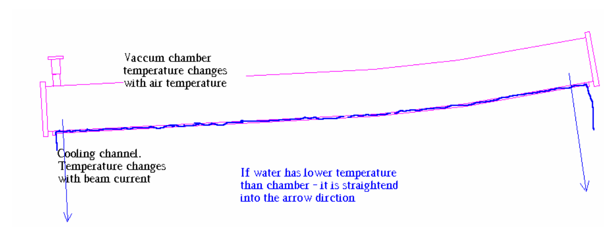

Figure 6: DELTA vacuum chamber with cooling channel

The magnet movement visible in figure 4 can be explained by the rise of the cooling water temperature during the start-up of the machine (see Fig. 5).

The cooling channel is welded to the outside of the stainless steel vacuum chamber to dissipate the heat load from synchrotron radiation (figure 6). During the start-up of DELTA the cooling water temperature increases. The outside of the vacuum chamber in the cooling channel becomes more than 10 centigrade warmer. This leads to a bending of the chamber because the inner chamber part follows with a delay. The temperature sensor reading shows that it takes more than 4 hours to establish an equilibrium between inner and outer side of the chamber.

The vacuum chamber very often has contact to the quadrupole magnets and therefore moves them with the bending of the chamber. The position of the quadrupole magnets follows this bending of the chamber (see Fig. 4 and 5).

In addition a daily change of the temperature in the hall leads to a temperature change at the inner side of the chamber whereas the outer chamber temperature due to the cooling stays constant. This leads to a bending of the chamber and to a movement of quadrupole magnets (see Figure 4 and 5). The data were recorded during a low energy run of DELTA so that the influence of synchrotron radiation can be neglected.

4.2 Heat load from synchrotron radiation

The third thermal effect is the heat load from synchrotron radiation. As a function of beam current the cooling water temperature changes. This again bends the chamber and moves quadrupole magnets as visible in figure 7 and 8.

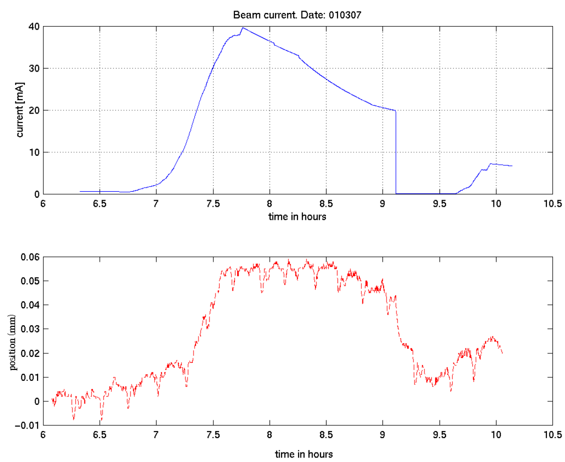

Figure 7: Magnet movement with beam current at 1.5 GeV beam energy.

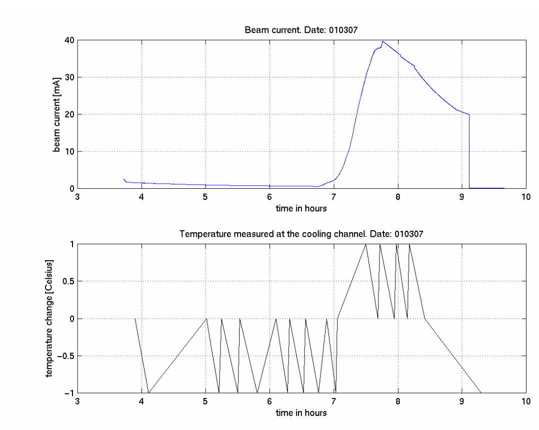

Figure 8: Chamber temperature as function of the beam current at 1.5 GeV beam energy. Synchrotron radiation changes the cooling water temperature.

The influence of a quadrupole magnet onto the equilibrium beam orbit depends on the amplitude of the position movement and the local betatron function. Only some quadrupole magnets show a strong effect on the orbit. To stabilise the beam orbit only these quadrupole magnets will be disconnected from the vacuum chamber.

By reducing the cooling water temperature and the stabilisation of the air temperature the magnet movement was already reduced (figure 9). The separation of the vacuum chamber cooling from only four independent to now 20 sectors reduced the temperature increase with the stored beam current and therefore the current dependent magnet drift.

The next step will be to stabilise the quadrupole magnets by de-coupling of magnet and vacuum chamber.

Finally the position sensors will be used to monitor the position of BPMs and quadrupole magnets to include this information into the orbit correction scheme.

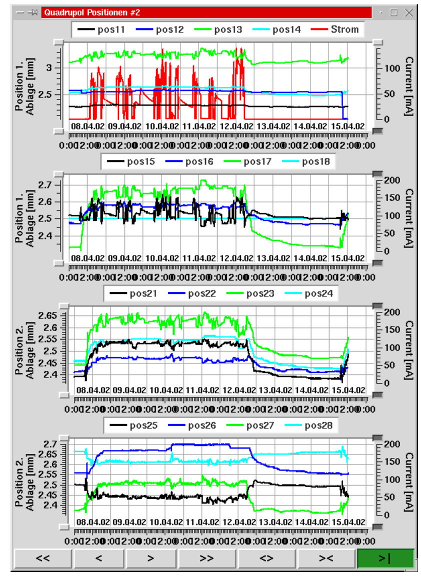

Figure 9: Orbit drift of magnets during a complete week. Data taken after hall cooling was installed. (Beam current-red curve, first graph)

5 SUMMARY

An inexpensive and precise method to monitor this movement has been installed at DELTA. Commercially available Linear Variable Differential Transformers (LVDTs) have been used. The low cost and industrial availability allows to use a large number of position sensors.

The use of position sensors in combination with temperature sensors has allowed to understand the behaviour of the DELTA orbit stability problems.

Based on these measurements it was possible to improve the stability of the storage ring.

Some quadrupole magnets have been identified which have a significant position movement and influence on the equilibrium beam orbit.

ACKNOWLEGEMENT

Thanks to O. Kaul, B. Sarau, from DESY Hamburg who made position sensors available, to allow us first tests.

The authors would like to express their gratitude towards the university of Dortmund for the funding of the cooling system.

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