Simulations of the MAX-II Storage Ring Using the Computer Code, DIMAD[1]

Greg LeBlanc, MAX-lab, Lund, Sweden

Abstract

The magnetic elements of the MAX-II[2] ring have been measured carefully prior to installation[3], enabling a very precise model to be constructed using the computer code DIMAD. Simulations of the machine have been helpful during the commissioning procedure and have aided in discovering magnet misalignments and evaluation of the beam position monitors. The simulations are compared to the measurements made on the storage ring and the correlation is evaluated.

1 Creating the Model

1.1 The MAX-II Lattice

The MAX-II lattice has a ten fold periodicity with each period containing, disregarding the corrector magnets and injection kickers, five distinct magnet types:

- Q1: A 0.283 meter long combined focusing quadrupole/sextupole magnet.
- Q2. A 0.233 meter long combined defocusing quadrupole/sextupole magnet.
- Q3. A 0.213 meter long combined defocusing quadrupole/sextupole magnet.
- Q4: A 0.533 meter long combined focusing quadrupole/sextupole magnet.
- DIP: A 1.0574 meter long rectangular 18 degree dipole magnet.

One period of the lattice is built up with these elements in the order (Q1, Q2, DIP, Q3, Q4, Q3, DIP, Q2, Q1) with drift tubes of varying lengths between each of the magnet so that the length of one such cell is approximately 9 meters.

1.2 Magnetic Measurements

Accurate magnetic measurements are necessary in order to build a computer model of an accelerator that is as close to the actual machine as possible. The magnets that make up the MAX-II storage ring were measured carefully prior to installation and the computer model is based on these measurements.

The multipole magnets were measured using a Hall probe and a rotating coil. The Hall probe measures the magnetic length and the gradient in the center of the magnets while the rotating coil measures the relative strength of the higher order multipoles.

1.3 Calibration of the Magnet Currents

The currents in the magnet coils were calibrated to the set values used by the control system to steer the digital-to-analog converters. These calibrations, together with the Hall probe measurements, established the relationship between the set values and the magnetic fields.

2 DIMAD

The program DIMAD is used for the simulations of the MAX-II storage ring. The fact that there are specific combined quadrupole/sextupole magnet elements make the program particularly useful for simulating MAX-II.

Combining all of the magnetic measurements and current calibrations makes it possible to create conversion routines which take the set values of the ring elements and create input files for DIMAD.

The model that is created using this procedure, while fairly accurate, still differs from the actual machine. Some sort of fitting routine is necessary in order to refine the model and more accurately predict the performance of the machine under different operating conditions.

3 Fitting Procedures

There are different ways of fitting the model to the measured data acquired from the storage ring. The program DIMAD has a built in least square fit routine that can be used. This has been used to fit the quadrupole and sextupole strengths to the measured tunes and chromaticities. In order to do this, it is necessary to couple certain parameters so that the eight magnet strengths, four quadrupole fields and four sextupole fields, can be fitted to the four measurements. This has been done for a number of different lattice settings and has given an indication of how accurate the conversion from set values to model is. The relationship between the sextupole and quadrupole components in the multipole magnets , while it has been measured, is an uncertainty. This is particularly evident when the chromaticity correcting back-leg windings are used.

The average deviations in the quadrupole strengths after evaluating a number of different settings of the magnets was found to be a few tenths of a percent for the focusing quadrupoles and a couple percent for the defocusing quadrupoles.

This was improved upon when it was noticed that the end field measurements for the dipole magnets, which designed as rectangular bends, indicated that the entrance angle should be 7 degrees instead of the 9 degrees that is expected in an 18 degree bend. There is some tapering of the poles which might explain the discrepency.

4 EVALUATION OF THE MODEL

4.1 Simulating the injection process

The efforts to create an accurate model of the ring have been fruitful.Particularly during the early stages of the commissioning of the ring, an accurate model is a valuable tool which can be used to improve the performance of the ring and give indications of properties which are not easily measured. MAX-II is injected in bursts from the MAX-I storage ring which must be cycled, filled, and ramped between each shot[4][5]. The optimum repetion rate for this process is of the order of one shot per minute. This makes it imperative to optimize the injection process in order to avoid lengthy commisioning periods. It is difficult to measure the closed orbit of a stored beam during the injection bump, which lasts about 4μs. With an accurate model, it was possible to create injection bumps that were then confirmed by checking if a calculated bump that would theoretically scrape off some of the beam did just that when it was implemented in the machine.

The sextupole fields result in a nonlinear relation between the three injection kickers and the bump amplitude. The bump is also tune dependant. Without an accurate model, it would be time consuming to find the optimum injection kicker settings for the various lattice settings that are inevitable during commisioning.

4.2 LATTICE ERRORS

The initial uncorrected closed orbit indicated that there were larger errors than expected. The uncorrected orbit was studied and the fitted model was used to attempt to find possible sources of closed orbit deviations in agreement with the pattern and amplitudeof the orbit that was measured. It became apparent that the closed orbit error could be due, in part to a longitudinal shift of the dipoles in relation to the ideal position. A subsequent measurement showed that this , indeed, was the case. The device used to place the magnets on the girders proved to be faulty introducing a systematic error in the position of the dipoles. Furthermore there were individual magnets with deviations in position relative the systematic error.

4.3 Comparison of model and machine

Figures 1 and 2 show the response of the beam to correctors for the machine and a model. There are three horizontal correctors per cell and these are two of the positions in one cell. They show the closed orbit when horizontal correctors of one cell in the ring are changed corresponding to a kick of approximately 1 mrad. It is hoped that response measurements such as this will become a tool for evaluating the machine[6][7] and some work has been done in this area.

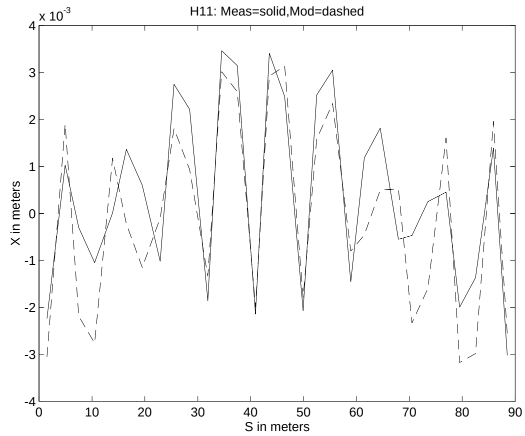

Figure 1: The response to a corrector in position 1.

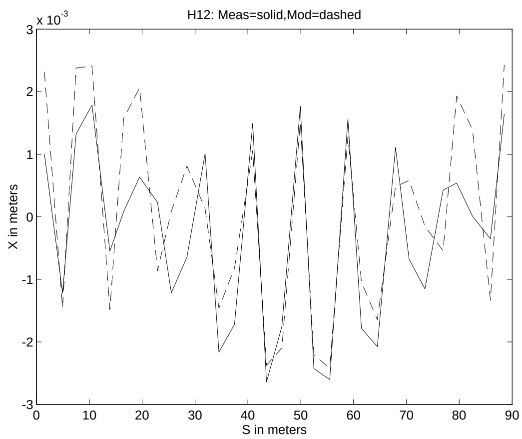

Figure 2: The response to a corrector in position 2.

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