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Roll Measurement of Tevatron Dipoles and Quadrupoles

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In 2003 a simple digital level system was developed to allow for rapid roll measurements of all dipoles and quadrupoles in the Tevatron. The system uses a Mitutoyo digital level and a PC running MS WINDOWS XP and LAB VIEW to acquire data on the upstream and downstream roll of each magnet. The system is sufficiently simple that all 1,000 magnets in the Tevatron can be measured in less than 3 days. The data can be quickly processed allowing for correction of rolled magnets by the Fermilab alignment group. Data will be presented showing the state of the Tevatron in 2003 and the changes in rolls as measured in each shutdown since then.

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1. MOTIVATION FOR ROLL MEASUREMENTS

During the Tevatron Run II it was observed that currents for corrector magnets were running at a high value. It was determined that one of the reasons was excessive roll in the dipoles and quadrupoles magnets. When the Tevatron was installed in 1982-83 all dipoles and quadrupoles were installed to a tolerance of ± 1 milli-radian. Measurements made in 2003 determined that some magnets had rolls as large as 10 milli-radians. Since the Tevatron was built on glacial till and crossed several areas of wet soil, ground motion and rusting of stands were attributed for the rolling of the magnets and the increase in corrector current.

2. ALIGNMENT OF MAGNETS

2.1. Survey lugs

When the Tevatron dipoles and quadruples were first manufactured field measurements were made at the Fermilab Magnet Test Facility. Four survey lugs were attached to the outside of each magnet two on either side of the upstream and two on either side of the downstream end of the magnet. The lugs were set such that the internal dipole field was vertical when the lugs were level with respect to gravity. The spacing across the magnet is 381 mm, and the distance along the beam is 3404 mm for dipoles and 927 mm for normal quads. By measuring the angle of the lugs with respect to gravity the roll of the magnet can be calculated.

In the initial installation of the Tevatron the lugs were set level to with in ±1mr tolerance. The lugs are also used to set the absolute elevation of the magnets around the ring. To maintain the roll with in tolerance it is necessary to periodically measure every magnet and adjust for changes in roll. A simple system was devised that allowed for these measurements to be made at the start of every long shutdown.

2.2. Initial devices

The current system used to measure roll was derived from an earlier system developed by Hans Jostlein and Craig Moore. That system used a 25 year old Talyvel Clinometer mounted onto a fixture that rests on the fiducials of the magnet. The measurements taken were manually entered into a spreadsheet for later analysis. The Talyvel has a resolution of better than 0.1 milli-radian the instrument was subject to failure due to the delicate nature of the device. In many cases the Tevatron dipoles are under old main ring magnets this makes installation of the device on the survey lugs difficult and can lead to damage of the Talyvel and bad data. It was determined to find a more robust measurement tool even at the sacrifice of resolution.

2.3. Digital Level

The updated system uses a similar fixture with a Mitutoyo Digital Protractor, model 950-316. Figure 1 shows the digital level on the fixture. The interface uses an RS232C cable with a switch (model 10P-25P) and the laptop's serial port. Executable routines used to acquire data and interface with the operator were written using the graphical software system Lab VIEW. An MS Excel spreadsheet of the magnet names and tunnel position to be surveyed is the reference database for the program.

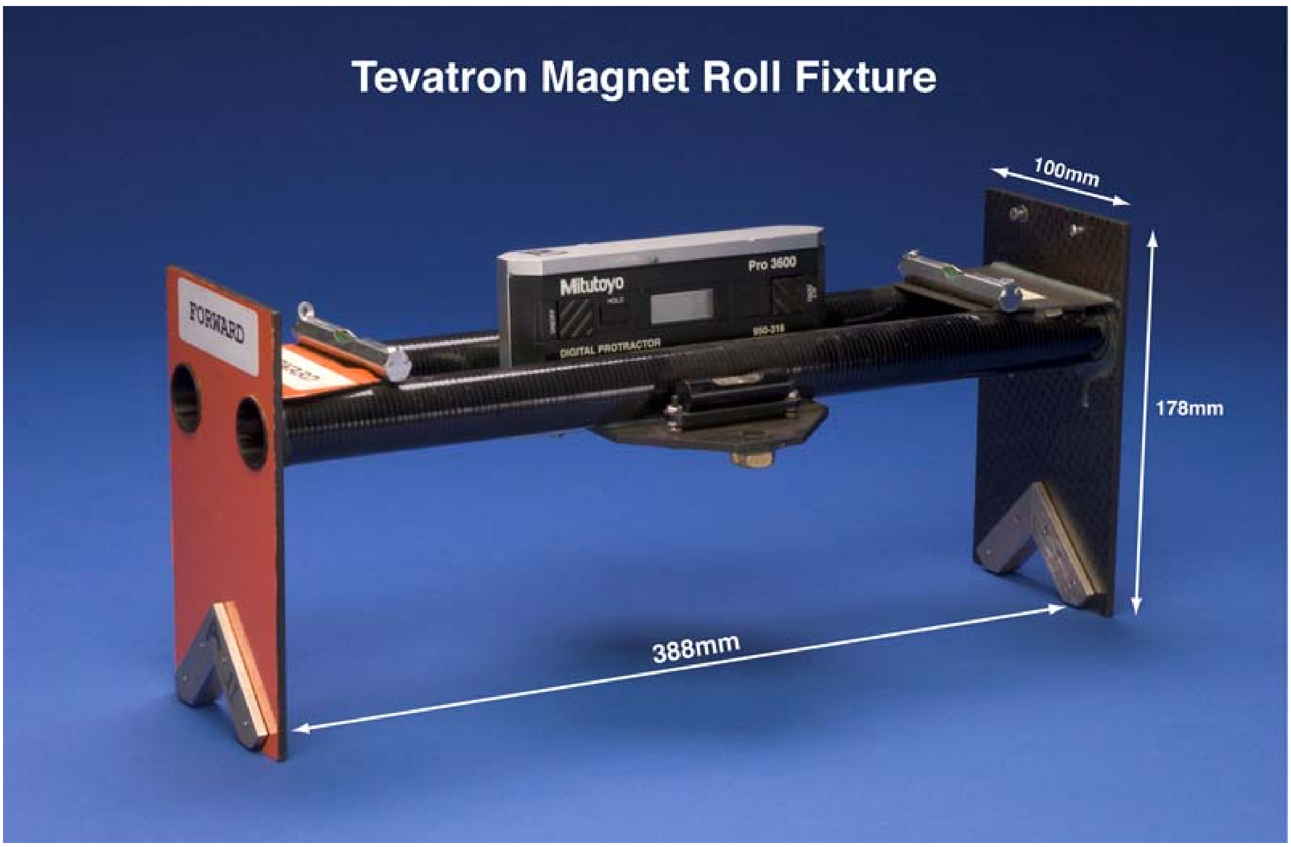

Figure 1 Tevatron Magnet Roll Fixture

When the program is started, the operator can begin collecting measurements from the beginning of the database, resume from his last known position or enter some other magnet location in the database. Figure 2 show the laptop and cart used to transport it around the Tevatron.

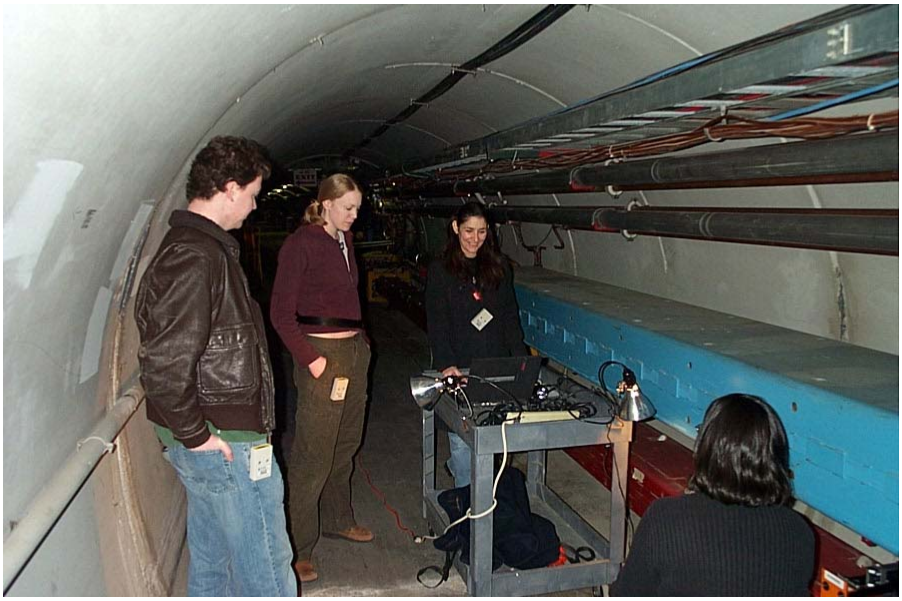

Figure 2 Cart and laptop the digital level is in the lower right hand corner of the picture

Two measurements are taken at each end of the magnet and averaged to eliminate any systematic offset. The first measurement is taken with the fixture in one orientation; the fixture is rotated 180^o about the vertical axis for the second measurement. The program checks the reliability of the data and if the difference between the measurements is larger than 4 mrad, the operator is prompted to either accept the measurement or repeat it. The operator can also add comments after each measurement noting any special circumstances. A second limit of 25 mrad generates a red pop up window for the operator. Figure 3 shows the level set on a Tevatron dipole.

Figure 3 Digital level set on survey lugs of a Tevatron dipole

The collected data is saved in an MS Excel text file which contains the magnet name and position, time of the measurement, measured data, averages of the data, and automatically generated comments of the measurement along with the optional operator comments. The beginning of the file includes the name(s) of the operator(s) and date. Using two such setups and two people for each setup all the dipoles and quadrupoles in the Tevatron could be measured in 3 days.

3. ROLL DATA

3.1. 2003 Shutdown Data

Figure 4 shows roll data for all dipoles and quadrupoles in the Tevatron as measured in October of 2003. Note the scale ranges from -4 to +10 milli radians, the worst rolls occurred in A sector the second worst rolls in E sector. Both of these regions are noted for poor soil conditions and water seepage into the tunnel. During the Fall 2003 shutdown the alignment group removed the worst of the rolls around the Tevatron ring.

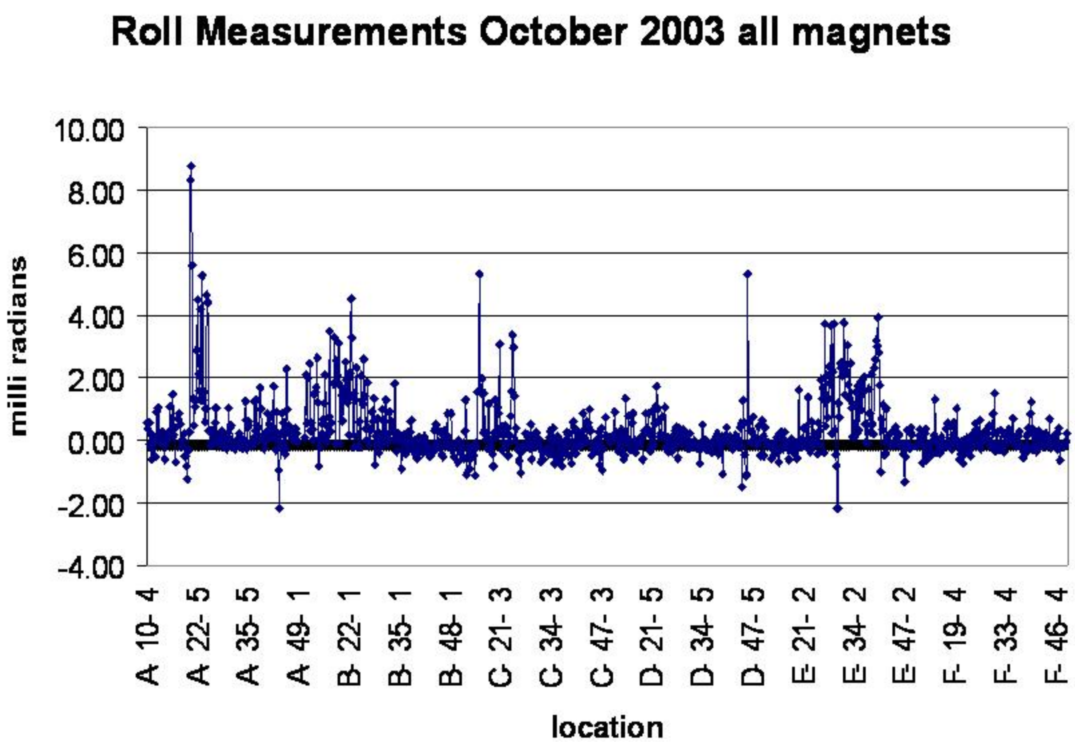

Figure 4 Roll data from October 2003 note large rolls in A sector

3.2. Later Shutdown Data

In the Fall 2004 shutdown the alignment group finished the task of unrolling all magnets with roll greater than ±1 milli-radian. Figure 5 shows the data as of November 2004. Note the scale change of a factor of 10. All rolls were set at less than 1 milli-radian with in alignment tolerance.

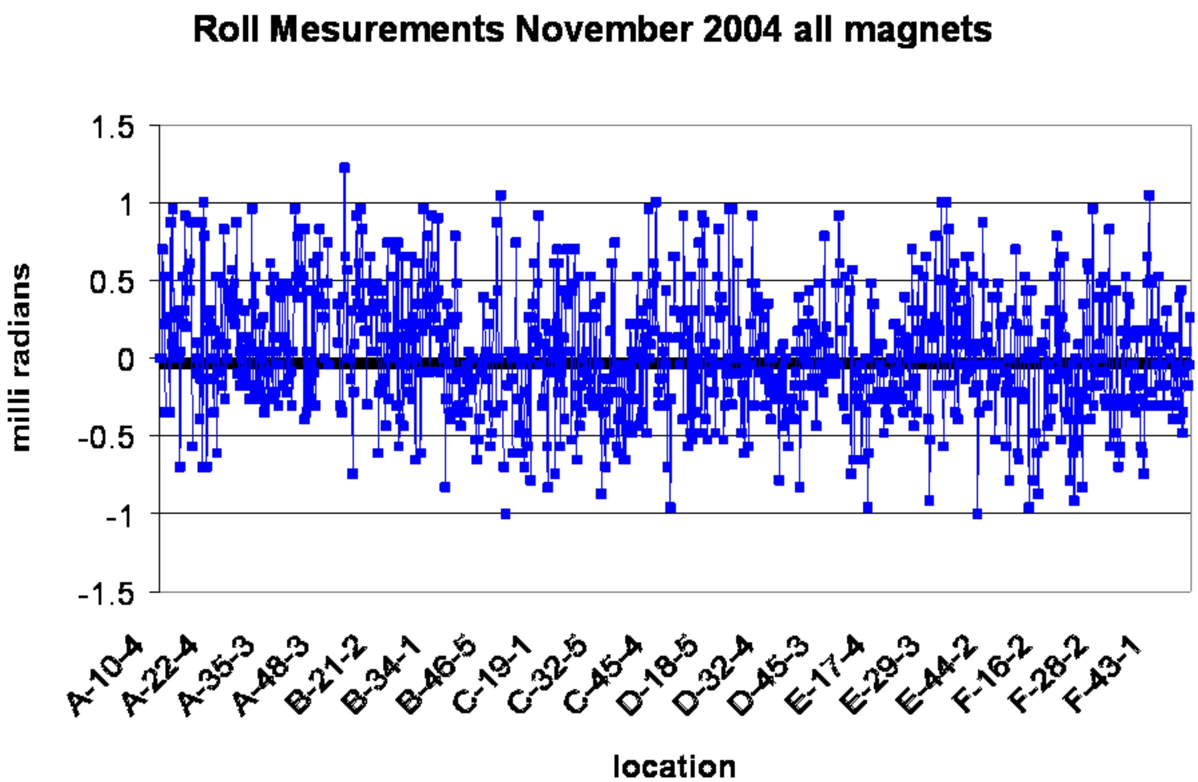

Figure 5 roll data as of November 2004

At the start of the spring 2006 shutdown rolls were again measured. Figure 6 shows the data. It was found that 41 magnets have rolled to greater than 1 milli-radian during the course of the 14 month long run. It is assumed that ground motion accounts for these shifts.

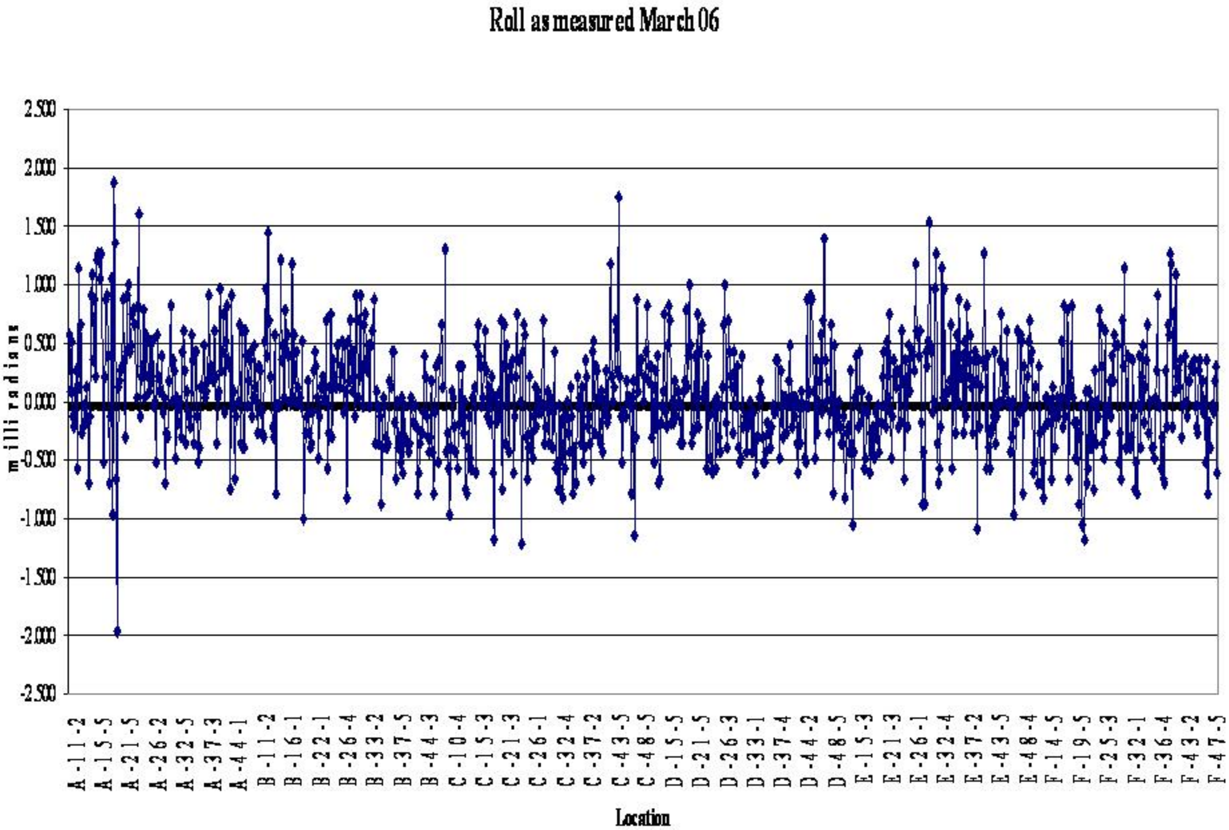

Figure 6 Roll measurements March of 2006 note magnets that have shifted above the 1 milli-radian tolerance

During the shutdown the alignment group un rolled the out of tolerance magnets as startup of the Tevatron in June of 2006 the distribution of roll was as shown in figure 7.

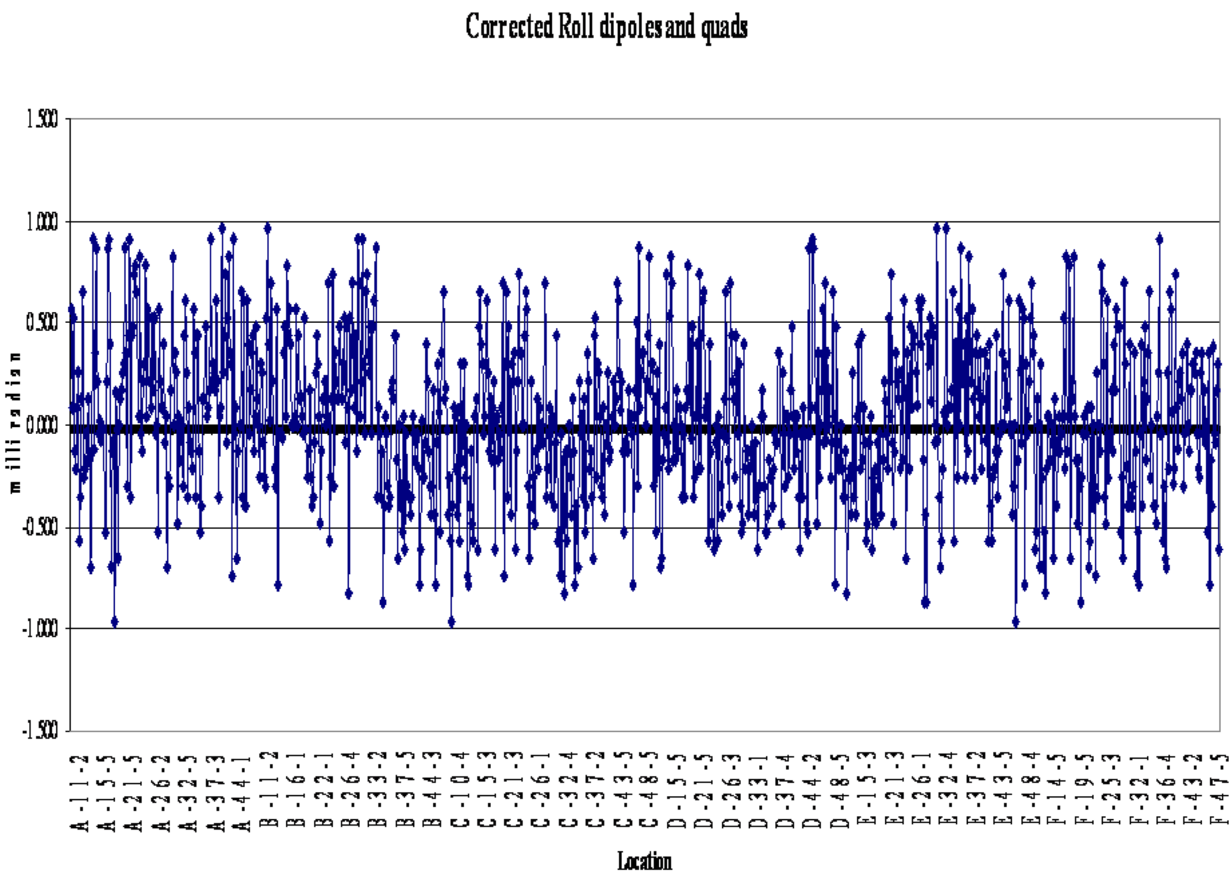

Figure 7 rolls of Tevatron dipoles and quadrupoles June 2006

4. CONCULSION

Magnets move due to ground motion and other cultural factors. Periodic measurements of rolls need to be made. We have presented a simple fast and efficient method to check large numbers of magnets so that out of tolerance rolls can be found and eliminated.

Acknowledgments

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References

[1] Tevatron Alignment Issues 2003 J T Volk PAC 2005 TPAP 030