Dynamic Effects in Tevatron Dipoles

P. Bauer for

& the MTF operations & maintenance team

Also thanks to L. Bottura, M. Haverkamp, V. Shiltsev, A. Tollestrup for advice and interest..
MTF – Tevatron Test Stands

Rotating Coils
Tevatron stand 4
Sextupole Hall probe array

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**Motivation**

Tune & Coupling drift in Tevatron – reminiscent of chromaticity drift in magnets!

TD launched a magnet study to search for drifting $a_1$ and $b_1$ in Tevatron dipoles or quadrupoles!

Magnitude of effect: 0.1 / 2 (units) drift over 1 hour in all dipoles / quadrupoles!

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M. Martens and J. Annala

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Basics on Tevatron Dipole Magnets

<table>
<thead>
<tr>
<th>&quot;geometric fields&quot;</th>
<th>&quot;hysteretic loops&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>dipole</strong></td>
<td>~1mT/A</td>
</tr>
<tr>
<td><strong>sextupole</strong></td>
<td>14.4u / -600u</td>
</tr>
<tr>
<td><strong>decapole</strong></td>
<td>1.8u / -80u</td>
</tr>
<tr>
<td><strong>18-pole</strong></td>
<td>-12.5u / -12.5u</td>
</tr>
<tr>
<td><strong>dipole</strong></td>
<td>width ~20 u inj</td>
</tr>
<tr>
<td><strong>sextupole</strong></td>
<td>width ~10 u inj</td>
</tr>
</tbody>
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**Dipole Measurement Program**

Measurement ramping cycle = current Tevatron operation cycle and variations (of the pre-cycle parameters).

Parameters varied: front-porch, flat-top, back-porch, injection porch, FT energy, # of pre-cycles, probe position, magnet temp.

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Qualitative Model of Dynamic Effects

Uneven current distributions across strands in the cable produce time varying “pattern”. At constant excitation in magnet it brings out non-linear magnetization effects – drift and snapback.

Courtesy of M. Haverkamp, L. Bottura
**Dynamic b2 in Tevatron Dipoles: Drift and Snapback in 1-20-1 Case**

**dynamic b2:** 1-2 u drift in 30 mins at inject., log dependence; magnet-to-magnet spread; dependence on powering “history” – see standard case below:

![Graph showing dynamic b2 data with time on the x-axis and b2 units on the y-axis. The graph includes various data points and fitting lines with labels indicating different cases such as 20 min FT, 1 min BP, 30 min IP.](image)

- **Time (secs)**: 1 10 100 1000
- **b2 (units @ 25.4 mm)**: -1 -0.6 -0.2 0 0.2 0.6 1 1.2 1.6 1.8 2
- **TC1220**
- **TC0483**
- **TB0834**
- **TC0269**
- **TC1052**
- **Tev b2 fit**
- **TB1198**
- **TB0710**
- **TB0525**

- **~ 4 K**

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Beam Based Measurements – b2 Snapback

- Measured SB longer than predicted by fit
  - drift amplitude larger than predicted by fit
  - First study: ~0.5 unit error?

Average Tevatron dipole b2 SB after 20 & 120 min injection porch, derived from measured beam chromaticity (dashed: b2 compensation)
Effect of Main Operational Parameters on Dynamic $b_2$ – Flattop and BackPorch Duration

Effect of flat-top duration;

Effect of back-porch duration;
Proposals for Improved Dynamic b2 Feed Forward Correction in the Tevatron

1) Fix (and extend) back-porch time
2) Reduce # of beam-less pre-cycles following a Tevatron quench from 6 to 1 (min 40 min flat-top);
3) Change b2 SB fit $\rightarrow$ Gaussian
4) saturation of flat-top duration effect on drift amplitude and absence of effect of front-porch duration $\rightarrow$ Eliminate pre-cycle
5) Improve drift fit – a parameter in the old fit is history dependent although it shouldn’t be, a double exponential appears to be slightly better than the log fit.
b2 Beam Study in Preparation

Test new Tevatron b2 correction for:

- 5 min back-porch
- no pre-cycle (directly from store to injection)

\[
b_2 = p_1 + p_2 \times \ln((p_3 + t)/p_3)
\]

\[
p_2 = 0.3837 \text{ units} \quad p_3 = 328.3 \text{ s}
\]

\[
b_2 = b_2^0 \times \exp(-t_s^2/2 \cdot t_0^2)
\]

\[
t_0 = \sqrt{0.5 \times (b_2^0 - p_4)/p_5}
\]

\[
p_4 = 0.0606 \quad p_5 = 0.0342
\]

Plot of 1055 drift for 5 min back-porch duration
Other Related Study Topics:

- Normal and skew quad drifts
- Main field drifts

- Drifts in higher mps (b4,..)
- End-body differences
- Temperature effects

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