Road Bicycle Frame Testing
A Summary

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Presentation Outline

- Background
- Description of Fixtures
- Some Test Result
- Discussion and Conclusions
Background

➢ Previous Research
  • Frame Stiffness Testing
    • Klein – Old Catalog
    • Miller – Bike Tech
    • Rinard - Web
    • Cannondale - Web
    • Specialized - Catalog
    • Open University - Web
    • Velonews
Background

- Transmitted Vibration Testing
  - Hastings, Blair, Culligan and Pober
    - Treadmill
  - Levy and Smith
    - Mountain Bike
  - Champoux, Richard and Drouet
    - Structural Dynamics, Treadmill

- Fatigue Testing
  - Very little in the literature
Background

- Effects of Vibration on the Cyclist
  - Testing by Pivit
  - HAVS Standards
  - 2.8 meters per second squared
  - 5-20 hertz
  - Accumulated time riding road bicycles can possibly cause damage
Bicycling’s new frame rigidity testing machine.
Description of Fixtures

Test Fixtures
- Cantilever Beam Testing
- Frame Deflection Testing
- Fork Deflection Testing
- Fatigue Testing
- Fork Vibration Testing
- Bicycle Dynamic Testing
Cantilever Beam Testing

- Calibration
- Thin-walled Tubing Issues
Cantilever Beam Testing
### Table 2.4: Deflection of 1.125 dia. by .035 Wall Tubing

<table>
<thead>
<tr>
<th>Pressure psi</th>
<th>Force calculated pounds</th>
<th>Deflection actual inches</th>
<th>Deflection calculated inches</th>
<th>Bridge voltage volts</th>
<th>Stress calculated psi</th>
<th>Strain calculated in/in</th>
<th>Strain measured in/in</th>
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<tbody>
<tr>
<td>2.98</td>
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<td>.0262</td>
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<td>.0001585</td>
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<td>.0439</td>
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<td>7958.93</td>
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<td>.000255</td>
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<tr>
<td>7.97</td>
<td>25.04</td>
<td>.090</td>
<td>.0700</td>
<td>.1620</td>
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<td>.000405</td>
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</table>

### Table 2.5: Deflection of 1.250 dia. by .035 Wall Tubing

<table>
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<th>Pressure psi</th>
<th>Force calculated pounds</th>
<th>Deflection actual inches</th>
<th>Deflection calculated inches</th>
<th>Bridge voltage volts</th>
<th>Stress calculated psi</th>
<th>Strain calculated in/in</th>
<th>Strain measured in/in</th>
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Cantilever Beam Testing
Frame and Fork Deflection Testing

➢ Static Testing
  • Frame-Lateral
  • Frame-Vertical
  • Fork
Frame Deflection Testing
Frame Test Fixture Details
Frame Test Fixture Details
Controls and Instrumentation
Frames and Forks Used For Testing
Fork Deflection Testing
Fatigue Testing

- Allows Cycling of Chain Stays in Bending
- Large Number of Failures Found in Chain Stay/Bridge/Bottom Bracket Area
- Could also be Used to Test Seat Tube/BB and Down Tube/BB Joints
Fatigue Testing

- Cycle Chain Stays to Failure Example
  - 103 pound load
  - .386 inch initial deflection
  - .410 inch deflection at 1200 cycles, crack
  - .505 inch deflection at 1400 cycles, crack progressed
  - .545 inch deflection at 1660 cycles, crack progressed and crack in other stay
Fatigue Testing
Fork Vibration Testing

- Measure Vibration Transmitted to Top of Steerer
Fork Vibration Testing
Bicycle Dynamic Testing

Testing Methods

- Test Loop
- Bumps
- Fork Vibration (Vibration at Stem)
- Tire Pressure
Accelerometers
Bump Test Strip
Bump Testing
Test Loop Raw Data
Test Loop Data Histogram
Tire Pressure Comparison
<table>
<thead>
<tr>
<th>Frames Min.</th>
<th>Max. Vert. Defl. inches</th>
<th>Lateral Deflection</th>
<th>Acc. Range Rear Bike Test Loops</th>
<th>Acc. Range Rear Bump Surface g</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Havnoonian Alum. .003 (2)</td>
<td>6  .698</td>
<td>12.0 to -8.2 20.2</td>
<td>6.3 to -1.0 7.3</td>
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<tr>
<td>Fuji .004 (3)</td>
<td>5  .666</td>
<td>12.4 to -6.6 19.0</td>
<td>8.4 to -2.0 10.4</td>
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<tr>
<td>Havnoonian Stl. .004 (1)</td>
<td>4  .592</td>
<td>12.5 to -6.4 18.9</td>
<td>8.4 to -2.7 11.1</td>
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<tr>
<td>Masi .0048 (5)</td>
<td>1  .331</td>
<td>11.8 to -6.8 18.6</td>
<td>7.1 to -1.9 9.0</td>
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<td></td>
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<td>Schwinn .005 (6)</td>
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<td>12.1 to -8.2 20.3</td>
<td>9.8 to -7.1 16.9</td>
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<td>Cannondale .005 (4)</td>
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Table 4.6: Summary of Rear Test Data

Max and Min Bump Surface
<table>
<thead>
<tr>
<th>Forks</th>
<th>Maximum Deflection inches</th>
<th>Acc. Range Fork Vibration g</th>
<th>Acc. Range Frt Bike Loop g</th>
<th>Acc. Range Frt Test g</th>
<th>Acc. Range Frt Bump Surface g</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Masi (2)</td>
<td>.222</td>
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<td>9.8 to -5.4 15.2</td>
<td>5.2 to -1.3 6.5</td>
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<td>Reynolds (3)</td>
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<td>10.3 to -5.9 16.2</td>
<td>4.8 to -1.6 6.4</td>
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<tr>
<td>Time (5)</td>
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<td>5.3 to -7.7 13.0</td>
<td>11.2 to -5.1 16.3</td>
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<td>Fuji (1)</td>
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<td></td>
</tr>
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<td>Ritchey (4)</td>
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<td>5.8 to -5.8 11.6</td>
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<td>4.5 to -1.4 5.9</td>
<td>HH AL Frame</td>
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<tr>
<td>Ritchey (4)</td>
<td>.302</td>
<td>5.8 to -5.8 11.6</td>
<td>9.5 to -4.8 14.3</td>
<td>5.6 to -3.3 8.9</td>
<td>HH STL Frame</td>
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Table 4.7: Summary of Front Test Data

Fork Max Value Bump
### Table 4.8: Summary of Additional Test Data

<table>
<thead>
<tr>
<th>Frame</th>
<th>Loop Frt. g</th>
<th>Loop Rear g</th>
<th>Bumps Frt. g</th>
<th>Bumps Rear g</th>
<th>Loop Frt. g</th>
<th>Loop Rear g</th>
<th>Bumps Frt. g</th>
<th>Bumps Rear g</th>
</tr>
</thead>
<tbody>
<tr>
<td>HH Std (1)</td>
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<td>HH Al (2)</td>
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<td>Fuji (3)</td>
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<td>C’dale (4)</td>
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<td>1.34</td>
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<td>1.001595</td>
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<td>1.59</td>
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Note 1: This value is taken from the individual histograms of the data.

Note 2: This is the average of the raw data.

Table 4.8: Summary of Additional Test Data

Note Schwinn Values
<table>
<thead>
<tr>
<th>Frame</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
<th>Avg</th>
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<td>1</td>
<td>1.38</td>
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</table>

Frame=Numbers in Table 4.2
A=Vertical Deflection Ranking: Least Deflection to Most
B=Lateral Deflection Ranking: Least Deflection to Most
C=Maximum Rear Loop g Value, Highest to Lowest
D=Maximum Range Rear Loop g Value, Highest to Lowest
E=Maximum Rear Bumps g Value, Highest to Lowest
F=Maximum Range Rear Bumps g Value, Highest to Lowest
G=Maximum Histogram Rear Loop g Value, Highest to Lowest
H=Maximum Histogram Rear Bumps Value, Highest to Lowest
I=Average Rear Loop g Value, Highest to Lowest
J=Average Rear Bumps g Value, Highest to Lowest
Avg=Average of Rankings, Not Including A: Vertical Deflection or B: Lateral Deflection

Figure 4.9: Summary and Average of Rear Stiffness Ranking Values

Schwinn Stiffest  Masi Least Stiff
<table>
<thead>
<tr>
<th>Frame Fork</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
<th>K</th>
<th>Avg</th>
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<tbody>
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<td>1</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Frame=Numbers in Table 4.2  
Fork= Numbers in Table 4.3  
A=Fork Deflection Ranking, Least Deflection to Most  
B=Fork Vibration Ranking, g Value, Highest to Lowest  
C=Fork Vibration Ranking Total Range, g Value, Highest to Lowest  
D=Maximum Front Loop g Value, Highest to Lowest  
E=Maximum Range Front Loop g Value, Highest to Lowest  
F=Maximum Front Bumps g Value, Highest to Lowest  
G=Maximum Range Front Bumps g Value, Highest to Lowest  
H=Maximum Histogram Front Loop g Value, Highest to Lowest  
I=Maximum Histogram Front Bumps Value, Highest to Lowest  
J=Average Front Loop g Value, Highest to Lowest  
K=Average Front Bumps g Value, Highest to Lowest  
Avg=Average of Rankings, Not Including A: Fork Deflection  

Figure 4.10: Summary and Average of Front Stiffness Ranking Values  

Again, Schwinn vs. Masi
Discussion and Conclusions

- Test Fixtures Designed and Built
  - Deflection, Fatigue and Vibration
- Simple Modeling
  - Not Discussed Today
- Failure Analysis and Testing
  - Not Enough Time to Discuss too Much
- Vibration Measurement and Ride Quality
  - Some Correlation to Stiffness but not that Simple