IPRO 324-Power Measurement in Road Bicycles

“No Strain, No Gain...”

Final Presentation
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Why Power Measurement?

• Measures actual input into the bicycle
  – Instant feedback
  – Cyclists can train at different levels

• Survey results taken from 100 members of the cycling community
  – Accuracy
  – Weight
  – Lower price than current product
What is Power?

- Power is the work per unit time
- Computed from the torque applied to the crank and the rate of pedaling
- Torque is rotational force applied to the axis of rotation through a lever arm

<table>
<thead>
<tr>
<th>Force (lbs)</th>
<th>Angle (°)</th>
<th>RPM</th>
<th>Torque (ft-lb)</th>
<th>Power (Watt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>90</td>
<td>125</td>
<td>60</td>
<td>41.72</td>
<td>355.48</td>
</tr>
<tr>
<td>65</td>
<td>35</td>
<td>60</td>
<td>21.10</td>
<td>179.77</td>
</tr>
<tr>
<td>120</td>
<td>70</td>
<td>45</td>
<td>63.82</td>
<td>407.80</td>
</tr>
</tbody>
</table>
Background

- Existing products are too expensive
  - Cost of current products
    - Power Tap ($999.00)
    - SRM ($2,607.80)
    - Quarq CinQo ($1,495.00)
Crankset Power Measurement Setup

- Strain Gages
- Power Measurement Circuit
- Wireless Transmission Protocol
  - ANT+
- Bicycle Computer
  - Garmin Edge 705

[Images of Chain Rings, Spider, Crank Arm, and Garmin Edge 705]
Our Approach

• Use the strain in the crankset (spider) to find torque
• Torque increases linearly with the strain
• Strains can be multiplied by coefficients to find torque at different crank angles
• Strain gages are used to find strain by finding change in resistance through voltage drop across Wheatstone bridge
Mechanical Team Objectives

- Define strain gage position on crankset
- Apply strain gages on the crankset
- Design an experiment to measure the output of the strain gages under different load conditions
  - Crank angle
  - Point of force application
    - Left pedal
    - Right pedal
  - Outer chain ring vs. inner chain ring
- Analyze data and implement an algorithm to calculate torque
Mechanical Setup

• 4 bridges used
  – one for each spider arm plus bridge for the two spider arms by crank
• Use Vishay 6200 scanner to measure strain
• Use Instron 5500 to apply load
Mechanical Obstacles

- Chosen strain gage position made gluing and soldering difficult and time consuming
- Communication between the scanner used to take strain measurements and the computer
- Compatibility issues between new crank set and existing test apparatus
- Predicting the effect of inner and outer chain rings on torque measurement
Mechanical Results
Mechanical Results

Strain v. Angle
(Inner Chain Ring; Right Crank Arm)
Mechanical Results

Strain v. Angle
(Outer Chain Ring; Left Crank Arm)
Mechanical Results

- Two chain rings -> Two bridges used, Two coefficients
- Bridges 2 and 4 used for torque calculation
- Voltage read at angles below, multiplied by coefficients and added to get torque

\[ T = C_2 \cdot V_2 + C_4 \cdot V_4 \]

<table>
<thead>
<tr>
<th>Angle (°)</th>
<th>22.5</th>
<th>67.5</th>
<th>112.5</th>
<th>157.5</th>
<th>202.5</th>
<th>247.5</th>
<th>292.5</th>
<th>337.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>( C_2 )</td>
<td>-5559</td>
<td>-6533</td>
<td>2027</td>
<td>1215</td>
<td>1295</td>
<td>567.6</td>
<td>656.8</td>
<td>-39803</td>
</tr>
<tr>
<td>( C_4 )</td>
<td>711.5</td>
<td>-1302</td>
<td>-11251</td>
<td>-5350</td>
<td>-9459</td>
<td>-2920</td>
<td>-1806</td>
<td>11456</td>
</tr>
</tbody>
</table>
Electrical Objectives

• Develop a circuit to:
  – Trigger measurement at specific angles using Reed switches
  – Amplify the voltage to a value that can be used in the calculations of the force
  – Minimize noise
  – Convert the analog signal to digital for use in calculation
  – Develop code to transmit power output to the Garmin bike computer using the wireless ANT+ protocol
Electrical Obstacles

- Full bridge setup
  - Balancing the bridge
  - Saturation of amplifier
- Erratic operation of microcontroller
- SPI (data output) unit for synchronous transmission to ANT+
Electrical Results

- Power circuit supply
  - 3V battery and 1V voltage regulator giving constant voltage
  - Two switches used for each bridge
Electrical Results

- Wireless Transfer of data
  - Rectification of temporal resolution glitch
  - Accurate data transfer to Garmin

- RPM Circuit
  - Reed switches used 45° apart
  - Passed over magnets
  - Gives RPM and Angle
Conclusion

• Successful working prototype
  – Calculate torque using coefficients
  – Measure at intervals of 45 degrees
  – Wirelessly send info to Garmin

• Future work
  – Package product
  – Finite Element Analysis (FEA)
  – Optimize battery life