Hybrid Electric Bicycle

IPRO 315
Objectives and Goals

- Research both Hybrid and Electric Bicycles
- Publish all research and findings
- Build at least one Prototype
- Establish a test bench for comparison
- Explore Sponsorship and donation avenues
Group Organization

- Divide into subgroups for the following research categories
  - Regenerative braking
  - Mechanical Design
  - Motor Research
  - Battery Development
  - Control Devices
Regenerative Braking
What is Regenerative Braking?

- Takes the momentum of an electric vehicle and recharges the battery while braking.

Motor switches between Motor /Generator.
Components to turn an E-Bike into a Hybrid Bike

- Motor - motor/generator
- Control box - braking, generator, recharge
- Brakes – 2 stage brakes
Drawbacks

- Expensive
- Extra Possible extra energy storage
- Is it worth it?
Braking Energy

• Convert Kinetic energy into Electrical energy
• Less Energy stored the longer the rider brakes
• Faster braking could lead to friction braking
Problems

• What if the rider does not brake?

• How to store energy so quickly?
  • Ultra-capacitor?
  • Flywheel?
Mechanical Design
Serial Configuration

- Easy Management of power flow
- Complex mechanical set up for an ordinary bike
- Dead Batteries create problems
Parallel Configuration

- Compact design
- Simple concepts using an ordinary bicycle
Shaft Drive

- 95% efficient on flat and downhill surfaces
- Simple, safe, and clean
- Durable with low maintenance
- No gears make it difficult for a cyclist
Chain Drive

- 95% efficient on all surfaces
- Gears allow the cyclist to choose the pedal to wheel ratio
- Flexible and absorbs shock
- Cheaper than shaft drive
Planetary Gear Systems

- Gear device with two degrees of freedom
- Difficult to mount on a standard bicycle
Brushless DC Motors
Brushless Construction

- Often they come in a three phase, four pole configuration
- Wound Stator (stationary outer member), it helps dissipate winding heat efficiently
- Permanent magnet rotor (rare earth PM)
- Stator windings are connected in a conventional three phase wye configuration
Overview

- DC Motor is a three phase synchronous machine
- In the DC motor the rotor chases the Magnetic field of the stator windings.
- The revolving field is created by sequentially energizing two of the three phases.
Windings attached to stator, magnets attached to the rotor
A controller is needed to sense the rotor’s position respect to the windings magnetic field
Because of the coils are in contact with the stator, heat dissipation is more efficient
Brushless motor Advantages

• Less maintenance, long life (brush inspection is not needed)

• Low rotor inertia, improves acceleration/decel.

• Low EMI, and quiet Operation

• More power output per size than shunt wound motors or gear motors
Schematic Representation

Diagram showing a schematic representation of an electrical system. The diagram includes sections labeled 'Control', 'Motor', 'Phase A', 'Phase B', 'Phase C', 'Motor Windings', 'Ground', and 'Frame'. The control section has inputs labeled 'Power', 'Commutation Logic', and outputs connected to the motor. The motor section includes connections to the phases and sensors. The diagram also shows rotor position sensors and connections to the ground and frame.
Why did IPRO use it?

- Efficient, long life, low weight
- Small size, easy to interface with a custom designed controller.
- Reliable and moderate in price
- Low maintenance
Battery Group
Specifications

- Size
- Weight
- Energy
- Cycle Life
- Memory
- Applicability
Lead Acid Battery

- **Pros**
  - Price

- **Cons**
  - Weight
  - Size
  - Specific Energy
Nickel-Cadmium Battery

Pros
- Specific Energy high the Lead Acid
- Cycle Life

Cons
- Memory Effect
- Power
- Applicability with Hybrid Electric Bicycles
Nickel-Metal Hydride Battery

- Pros
  - Cycle Life
  - Motor Company usage
  - Price

- Cons
  - Size
  - Weight
  - Specific Energy and Power
Lithium Ion Battery

- **Pros**
  - Specific Energy and Power
  - Size
  - Quickness of Charge
  - Cycle Life

- **Cons**
  - Cost
  - Applicability
Controllers
Why do we need a Controller??

To accomplish winding Commutation

• Commutation is the control of current to produce torque. Torque is produced when the magnetic field from the winding interacts with the field from the magnet. When the motor is moving, the position of the windings changes. This means that the optimal path to channel the current changes, depending on the motor position.

• Brushless motors require *electronic* commutation. The controller determines how to channel current into the windings.
Common Control Strategies for Brushless Motors

- Control requires knowledge of rotor position and speed.
  - Sensorless
    - Estimation
      - Kalman Filtering
  - Sensored
    - Direct Measurement
      - Position Sensors
Sensorless Control

Why go “sensorless”? 

• Simple Design 
• Less costly implementation 
• Greater reliability of the system. 
• Certain applications (compressors) do not allow the use of external position sensors due to ambient conditions.
Sensorless Control

Why Not?

- Poor performance at low RPMs
- Limited accuracy
- Complex D.S.P. needed to perform estimation calculations
Kalman Filtering

- Relies on estimating the position and velocity of the rotor
- Mathematical description
- Instantaneous measurements of the motor
- Fine-tune the estimates
- Measurements of feedback EMF and currents
- Not position or velocity of rotor
Motor Modification

- No physical changes
- EMF and current probes
  - Implemented within controller
- Commutation Logic
  - Estimation
    - Feedback EMF
    - Phase Current
Sensorless Block Diagram
Sensorless BLDC Motor Drive

ROTOR POSITION ESTIMATION

- Back emf Integration

![Diagram of Motor Controller and Stator with Current Measurement]

- Use three integrators

$$\int v_A \, dt, \int v_B \, dt \text{ and } \int v_C \, dt$$
Sensored Control

Why go “sensored”?

- Accurate control at all speeds
- Easiest way to commute winding current
- Easy starting of motor
- Fewer mathematical calculations so only simple integrated circuits needed.
Sensored Control

Why Not?

- More components
- Larger packaging
- Questionable reliability
- Costs more to implement
Motor Modification

- Position Sensors
  - Hall Effect
    - Displacement of 60 degrees
    - Digital high/low for 120 degrees
- Commutation Logic
  - Sensor data
    - Lookup table
Sensored Block Diagram
BLDC Motor Drive

ROTOR POSITION MEASUREMENT

• Block Diagram

[Diagram of BLDC Motor Drive with block diagram and motor controller]

• Commutation Lookup table

[Table showing motor rotation and commutation lookup]

- Clockwise
- Counter Clockwise
So what designs shall be used?

- Parallel Configuration
- Chain Drive
- Permanent Magnet Brushless Motor
- Lithium Ion Battery
- Sensor Less Controller
- Regenerative Braking is still an issue to be pursued
Now that the design is decided upon, where shall we start?

- $$$
- Proposals monetary grants, product donations, and sponsorship
- Purchase of a small e-bike kit
E-bike Kit

- NYCeWheels kit
  - Included battery, motor, and controller
- Built on loaned bicycle
- Massed, measured and ridden
THANKS ! To...

- Santa Cruz Bicycles
  - Light weight mountain bike frame
- Argonne National Laboratory
  - Hosted a field trip to the HEV division
- TREK bicycles
  - Promise for a few simulation products and a field trip to the engineering facility in Madison, WI
- Dr. Al-Hallaj – IIT Chemical Engineering
  - Li-ion battery design and product
- Dr. Emadi – IIT Electrical Engineering
  - Expertise with controllers
Further Research and Plans

- Research on Alternative Technologies (motors, batteries, etc…)
- Simulation and Testing of different hybrid models.
- Build a Working Prototype of an electric hybrid bicycle.
- New Sponsorship (Grants, Donations and Advisement).
Research of Alternative Technologies

- Different forms of Regeneration (via Breaking, Solar, fuel cells etc.)
- Battery Technology (Lithium vs. Nickel Hydride Battery technologies)
- Controller Configuration and type
Simulation, Testing and Building of Prototype

- Simulations of different hybrid bicycle models.
- Building Prototype
  - parallel configuration
  - brush-less motor
  - Sensor-less Controls
  - Lithium ion Battery
- Testing Prototype (Trek)
New Sponsorship and Grants/Donations

• Acquiring new Sponsors for:
  • Parts (includes motor drives, batteries etc)
  • Grant Money (cover some expenses in yearly budget)
  • Use of testing Facilities
  • Provide Advisement (new direction)
Members

- Francis Carrera
- Darius Dubanski
- George Derrick
- Jeongwoo Lee
- Kitae Kim
- Kylie Klint
- Lee Nelson
- Mike George
- Ryan Lim
- Sam Choi
- Shaun Diggs
- Sungwoo Min
- Waqas Jamal
- Phillip Felber
Questions