LINEAR INDUCTION MOTOR

Electrical and Computer Engineering

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Outline of Presentation

- Background Information
- Design Approach
- Economic Analysis
- Societal and Environmental Impacts
- Timeline
- Division of Labor
- Conclusion
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Background Information
Linear Induction Motor Background

• Alternating Current electric motor
• Powered by a multiple phase voltage scheme
• Force and motion are produced by a linearly moving magnetic field
• Used to turn large diameter wheels
Alternating Current Induction Machines

- Most common AC machine in industry
- Produces magnetic fields in an infinite loop of rotary motion
- Stator wrapped around rotor

![Induction Motor Diagram]

Field Windings
- Phase 1 (reference)
- Phase 2 (+120°)
- Phase 3 (+240°)

Rotating magnetic field created by the sequential excitation of the pole pairs by the 3 phase supply

[2]
Rotary to Linear

3 PHASE ‘SQUIRREL CAGE’ INDUCTION MOTOR

MAKE A CUT

OPEN OUT FLAT

3 PHASE LINEAR INDUCTION MOTOR

3 PHASE POWER SUPPLY

SMOOTH THE ROTOR INTO SEPARATE SHEETS

[3]
Design Constraints

• 3 Phase Voltage Scheme
• Simulated linear track cannot exceed 1,100 rotations per minute (RPM)
Patent/ Product/ Literature Review

• Datasheets
  • Atmega 128 Documentation
  • Lenze Tech MH250B Documentation

• Journal
  • Design of a Single Sided Linear Induction Motor (SLIM) Using a User Interactive Computer Program [32]

• Books
  • Linear Induction Motor [33]

• Patents
  • Linear Induction Motor Construction [34]
  • Secondary member for single-sided linear induction motor [35]
  • Linear Induction Motor [36]
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Design Approach
Problem

- Rotate the simulated linear track
- Rotate under safe speeds (<1100 RPM)
Solution to Problem

• Develop
• Design
• Implement a Linear Induction Motor to produce linear motion

[12]
Additional Research

• Pole Pitch
  • Design phase

• Pole Arrangements
  • Salient vs. non-salient
  • Design phase

• Interfacing sensors
  • Implementation phase
Key Components

- Stator Lamination Segments
- VFD
  - Lenze-tech MH250B
- Microcontroller
  - Atmega 128
Key Components Availability

- Stator
  - Design and have manufactured
- VFD
  - Provided by Caterpillar
- Microcontroller
  - Provided by Bradley
Alternative Solutions

• Lower velocity output
• Different material
• Change the number of poles
• Vary the dimensions of motor
• Lower frequency range
Alternative Components

- Solid manufactured stator
- Transformer E laminations
- Different Microcontroller
Skill Set Required

- Experience Interfacing components in C++
- MATLAB
- Understand of high level mathematics
- Power electronics
- Manufacturing skills
Multidisciplinary

• Main focus on Electrical Engineering
• Stator design may take some Mechanical Engineering background
  • May require additional help in 3-D modeling
Work Locations

• Bradley University
  • Power Lab
  • Senior Lab
Experimentation

• Location – Power Lab
• Supervisor – Professor Gutschlag
Solution Testing

- Current measurements
- Efficiency calculations
- RPM measurements
- Torque measurements
- Comparison to simulated/calculated results
Criteria for Solution Testing

- Rotation of the simulated linear track
- Output max speed within 50% of calculated max speed
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Economic Analysis
Project Feasibility

- Highly feasible
- Work is divided equally
- Staying focused on objective goals
Consumer Market

- Lab Setting Only
- No Market
- Will not be sold
### Overview of Total Component cost

<table>
<thead>
<tr>
<th>Components</th>
<th>School Provided or Purchase</th>
<th>Cost (If Applicable)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stator</td>
<td>Purchase</td>
<td>$800.00</td>
</tr>
<tr>
<td>Variable Frequency Drive</td>
<td>School</td>
<td>$848.00</td>
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<tr>
<td>Sensors</td>
<td>Purchase</td>
<td>$20.00</td>
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<tr>
<td>Tachometer EE-SG3</td>
<td>School</td>
<td>$2.00</td>
</tr>
<tr>
<td>Microcontroller/ LCD Screen</td>
<td>School</td>
<td>$80.00</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>Purchase</td>
<td>$100.00</td>
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<tr>
<td><strong>Total Cost:</strong></td>
<td></td>
<td><strong>$1850.00</strong></td>
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</tbody>
</table>
## Cost Expenditures

<table>
<thead>
<tr>
<th>Components</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stator</td>
<td>$800.00</td>
</tr>
<tr>
<td>Sensors</td>
<td>$20.00</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>$100.00</td>
</tr>
</tbody>
</table>
Cost Constraints

• Major:
  • Stator
  • VFD

• Minor
  • Coil Windings
  • Tachometer photo-interrupter
Maintenance Cost

• Power consumption usage
• Dedicated Atmega128 Board for usage on only that device
• New coil windings
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Societal and Environmental Impacts
Affected Individuals

• The project group
  • Tyler Berchtold, Mason Biernat and Tim Zastawny

• Project Advisor
  • Professor Gutschlag

• Course Instructor
  • Doctor Sanchez

• Fellow students in ECE 498
Natural Resource

- Metal
  - Steel Laminates
  - Copper
- Reusing equipment instead of purchasing new equipment
  - VFD
  - Variac
  - Tachometer
  - ATmega128
Ethical Development

• Does not violate Human Rights
• Not a weapon of mass destruction
• Ethically Made
• Ethical Use
Ensuring Safety

• Respecting Power Lab rules
  • Always wear safety glasses
  • Work in pairs
  • Turn off power when not using

• Checking power connections to the motors

• Observing Motor for possible issues

• Monitoring sensors

• Construction and implementation is done correctly
Safety Concerns

• Putting unsafe current levels through the stator.
• Heat Levels on Stator
• RPM of Simulated Linear Track
• Unauthorized individual attempting to use
  • Children, Adults, Disabled
Outcomes of Ignoring Safety

- Stator meltdown
- Stator exploding
- Electrocution
- Fire
- Microcontroller and sensor destruction
- Simulated Linear Track vibrations
- Personal Injury
Additional Safety Protocol

• Used under proper supervision and settings
• More monitoring equipment
• Integrated heat sensor with sound alert when temperatures are too high
• Shielding around stator to prevent accidently contact
• Adequate airflow to allow for proper cooling
Liability Concerns

- Damage to lab space
- Injury to others

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Timeline / Division of Labor
High Level - Division of Labor

- Design
  - Microcontroller
    - Tyler
  - Stator
    - Mason and Tim

- Purchasing
  - Entire Group
High Level - Division of Labor

• Construction
  • Sensors
    • Tyler
  • Motor
    • Mason and Tim

• Implementation
  • Tyler, Mason and Tim

• Testing
  • Tyler, Mason and Tim
Interfacing Work – Tyler B.

- Interfacing
  - Input from Sensors
    - Tachometer
    - VFD Frequency
    - Voltage
  - LCD Screen
    - Voltage
    - Slip
    - Speed
Stator Work – Mason B. and Tim Z.

• Stator
  • Dimensions
    • Pole Pitch
    • Length
    • Width
    • Height
  • Mounting hardware
  • Coil Windings
    • Gauge
    • # of wraps
Gantt Chart – Main Components

- Design
- Purchasing
- Construction
- Implementation
- Testing
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Conclusion
Conclusion

- Overall Goals:
  - Complete Design and Implementation if a linear machine
    - Prototype a linear stator
    - Develop working subsystems for control
    - Achieve linear motion
  - Gain experience
    - Power systems
    - Design and construction
    - Interfacing
    - Group dynamics
    - Useful engineering skills
Questions?
References #1-5


References #6-10


[10] T. Zastawny. Wheel Turning. [Figure].
References #11-15

[12] T. Zastawny. 3-D Prototype Model of Stator. [Figure].
[13] T. Zastawny. Polepitch. [Figure].
References #16-19


References #20-25


[22] T. Zastawny. Senior Lab. [Photograph].


[25] T. Zastawny. Main Component Gantt Chart. [Figure].
References #26-31

[26] T. Zastawny. *Detailed Gantt Chart*. [Figure].
[27] M. Beirnat. *Ideal Linear Synchronous Speed Vs. Frequency*. [Figure].
[28] T. Zastawny. *System Block Diagram*. [Figure].
[29] T. Zastawny. *System Block Diagram with highlighted portion*. [Figure].
[30] T. Zastawny. *Close up of VFD Block Diagram*. [Figure].
[31] T. Zastawny. *Flowchart of Internal Interrupt*. [Figure].
References #32-36


Detailed Gantt Chart

Salient/ Non-Salient Coil Windings
- Pole Pitch
- Air Gap
- Slip
- Speed
- Current

Variable Frequency Drive
- Tachometer
- Current Probe
- Slip Calculation

Parts Review
- Purchasing
- Coding Microcontroller
- Shaping Core
- Coil Winding
- Core Housing
- LIM to Track

Connect LIM to Microcontroller
- Attach Variable to System
- Slip Testing
- Speed Testing
- Power Efficiency
## Detailed Budget – Buying

<table>
<thead>
<tr>
<th>Component</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stator Laminates</td>
<td>$800.00</td>
</tr>
<tr>
<td>Copper Wire</td>
<td>$10.00</td>
</tr>
<tr>
<td>Metal Bracing</td>
<td>$50.00</td>
</tr>
<tr>
<td>Fasteners</td>
<td>$10.00</td>
</tr>
<tr>
<td>Speed Sensor</td>
<td>$5.00</td>
</tr>
<tr>
<td>Tachometer</td>
<td>$2.00</td>
</tr>
<tr>
<td>Miscellaneous Small Components</td>
<td>$100.00</td>
</tr>
<tr>
<td><strong>Total Cost:</strong></td>
<td><strong>$967.00</strong></td>
</tr>
</tbody>
</table>
Equipment Already Have

<table>
<thead>
<tr>
<th>Component</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulated Linear Track</td>
</tr>
<tr>
<td>Variable Frequency Drive (Lenze AC Tech MH250B)</td>
</tr>
<tr>
<td>Variac</td>
</tr>
<tr>
<td>High Voltage Current Meter</td>
</tr>
<tr>
<td>Microcontroller (Atmega128)</td>
</tr>
<tr>
<td>Tachometer (EE-SG3)</td>
</tr>
</tbody>
</table>
Formal Test procedures

• Measuring input and output current
• Measuring torque
• Measuring speed
• Calculating efficiencies
Preliminary Test Results

Ideal Linear Synchronous Speed vs. Frequency

- 2-Pole Machine
- 4-Pole Machine

Output Synchronous Speed [m/s]

Frequency [Hz]
Diagram of Entire System

Atmega 128 Micro Controller

Keypad

LCD

D/A

Start/Stop 0-10V Signal

A/D

Analog 0-10V

Variable Frequency Drive

3-Phase Power Source

Linear Induction Motor Stator

Simulated Linear Track

Speed Sensor
Diagram of Entire System
Close up of VFD System

Atmega 128 Microcontroller

D/A

A/D

Variable Frequency Drive

Start/Stop 0-10V Signal

Analog 0-10V

[30]
Flowchart of Internal Interrupt

1. Initialize Count = 0
2. Count < 249
   - Pin E3 = 0
     - Count++
   - Pin E3 = 1
     - Count = 0
3. Else