Semi-Linear Induction Motor

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Outline of Presentation

- Background and Project Overview
- Investigate 2016 SLIM Capstone Project
- Rotor Design
- Economic Analysis
- Results
- Conclusion

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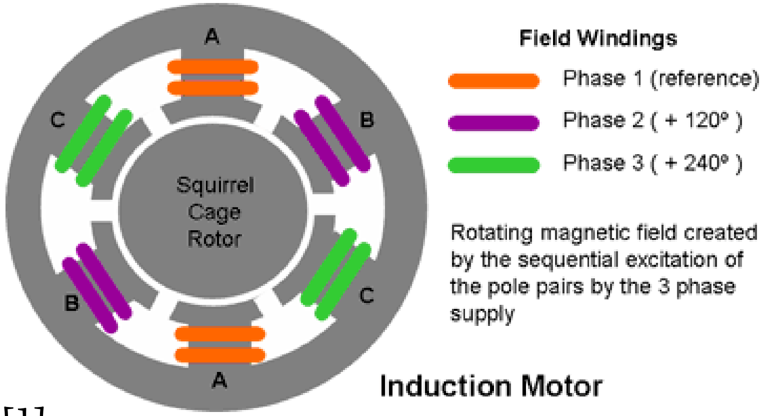
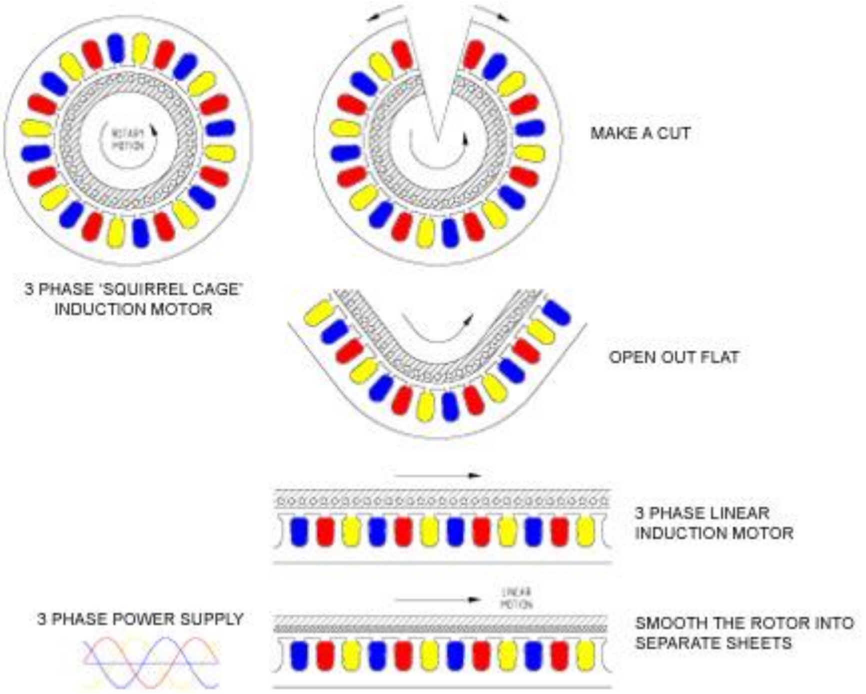
Alternating Current Induction Machines

- Produces magnetic fields in an infinite loop of rotary motion
- Current-carrying coils create rotating magnetic field
- Powered by three phase voltages
- Stator wraps the rotor completely



[1]

Linear Transformation



[2]

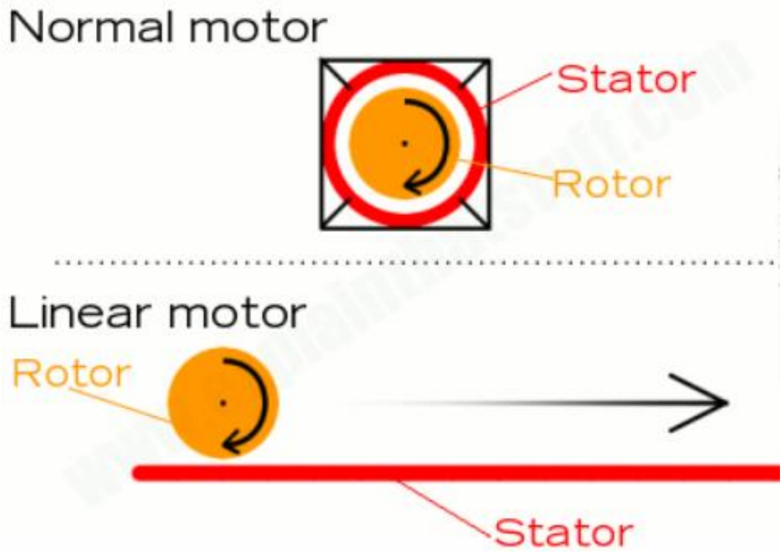
Applications

[3]

[4]

Why Semi-linear?

- For a normal motor, the rotor is in motion
- For a linear motor, the stator is in motion
- Having a linear track would take up too much space
    - Significant increase in cost
    - Wouldn't be able to reach higher speeds
    - Would require a portable 3-phase voltage supply



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Project Overview

- Investigate 2016 SLIM Capstone Project to identify design deficiencies
- Design a new rotor for the semi-linear induction motor

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Prior Work

- 2016 SLIM team designed a stator for the linear induction motor
- Built stator coils

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[7]

Prior Work

- 2016 SLIM team mounted stator and air core rotor
- Began testing of the SLIM

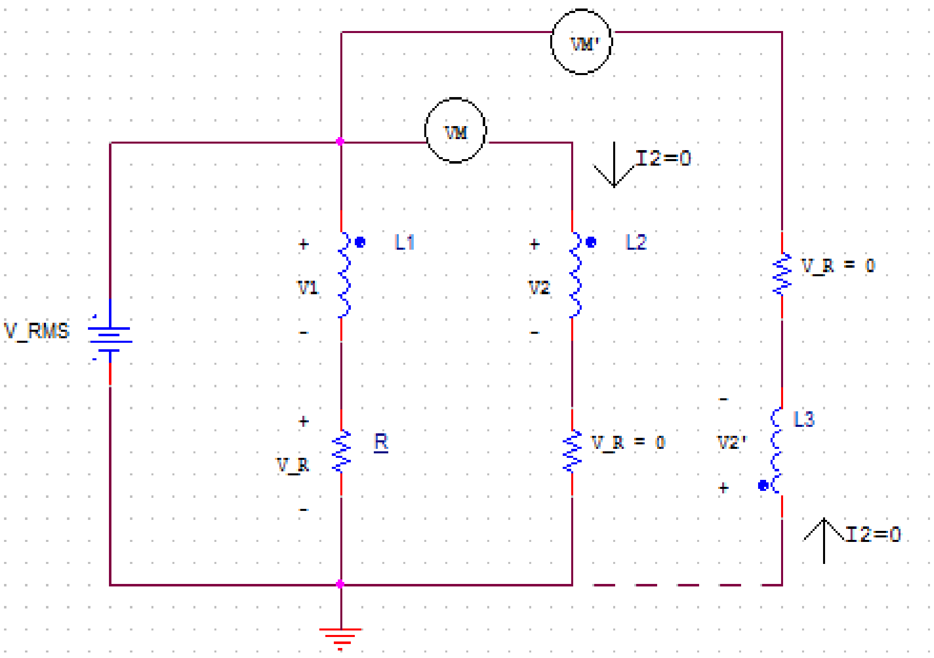
[8]

Investigation

- 2017 SLIM team performed a more complete analysis
  - Confirming Coil Orientation
  - Magnetic Field Mapping
  - Inductance Computations

Coil Orientation

- Arranged coils to match the configuration shown in Fig [9].
  - If results didn't match, we would further investigate their orientation
  - Confirming the dot notation was crucial
    - If the notation wasn't correct, magnetic field supplied to the stator would be reduced



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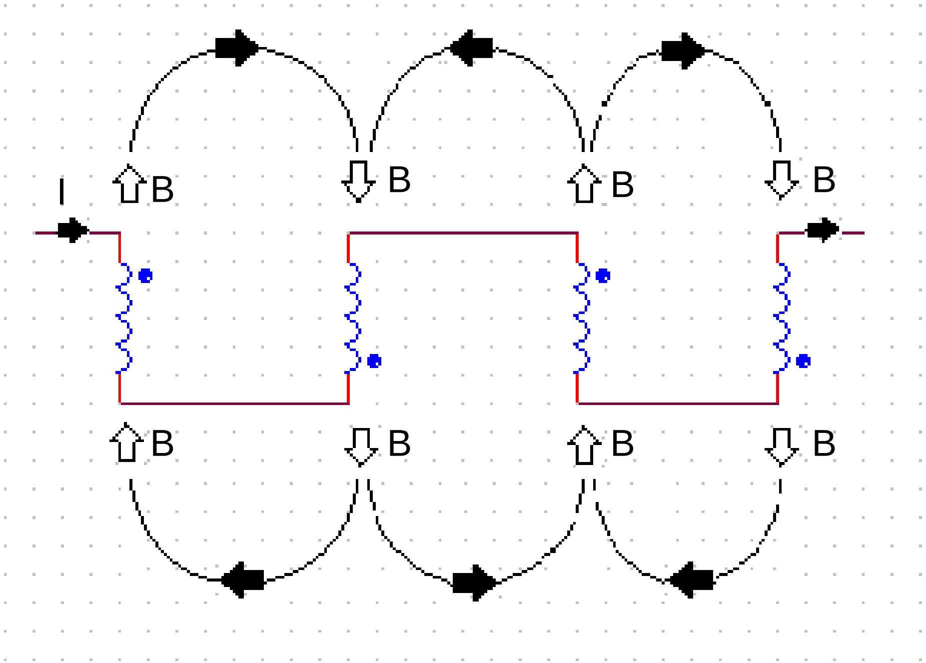
Coil Orientation with Magnetic Field for One Phase



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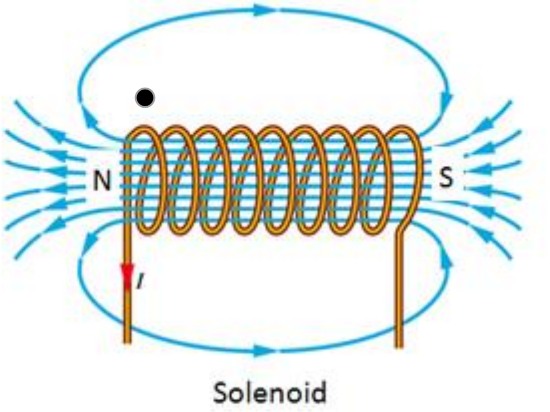
Magnetic Field Mapping



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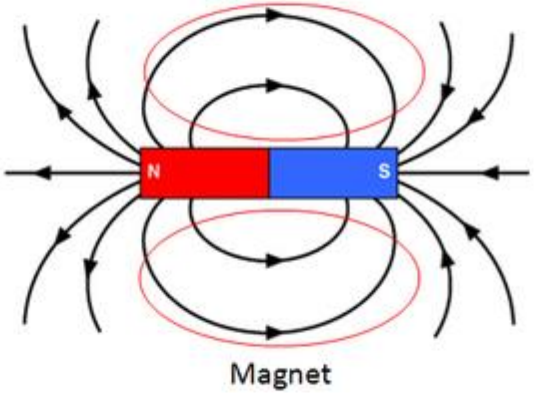

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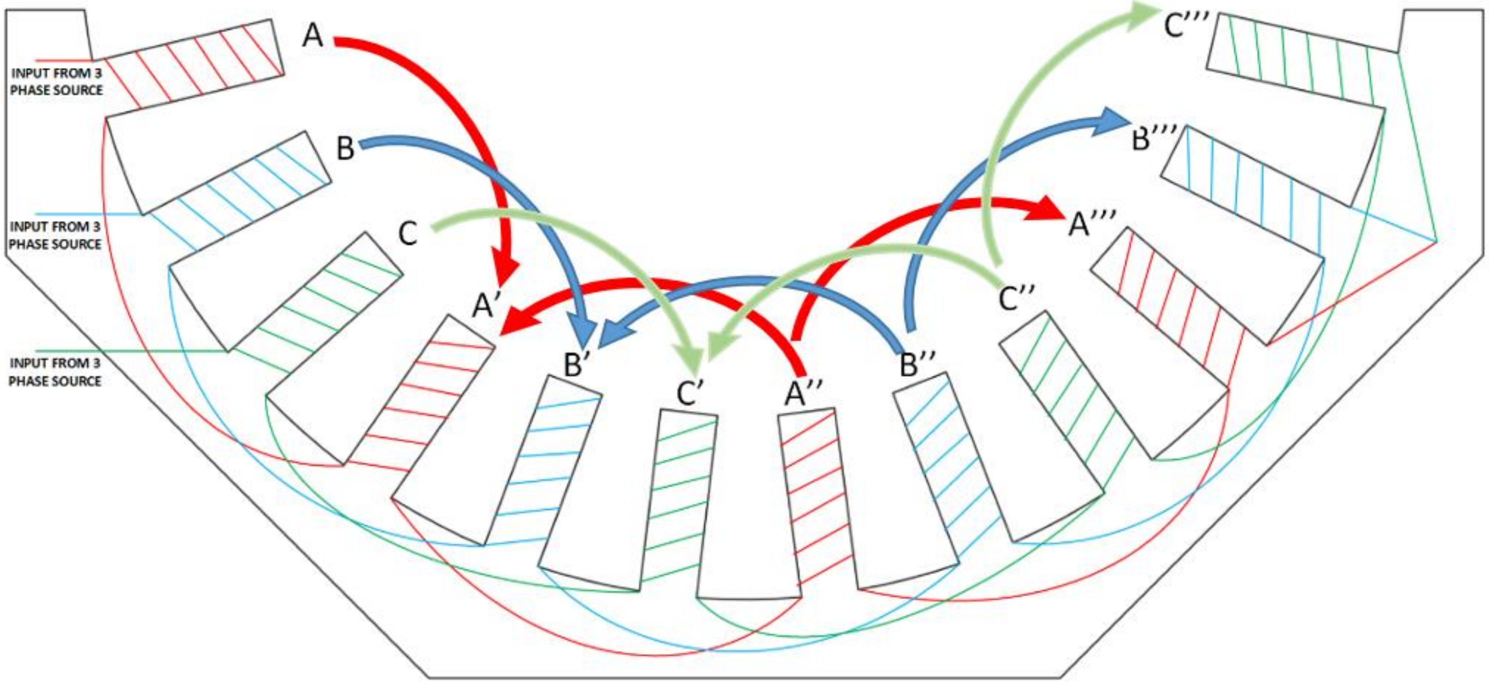
Map of magnetic field



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Rotor Redesign

- New design based on results of magnetic analysis
- Why redesign?
  - The pre-existing rotor was initially designed to work as part of a magnetic levitation capstone project
  - The rotor didn't produce acceptable results
  - Minimal rotation occurred

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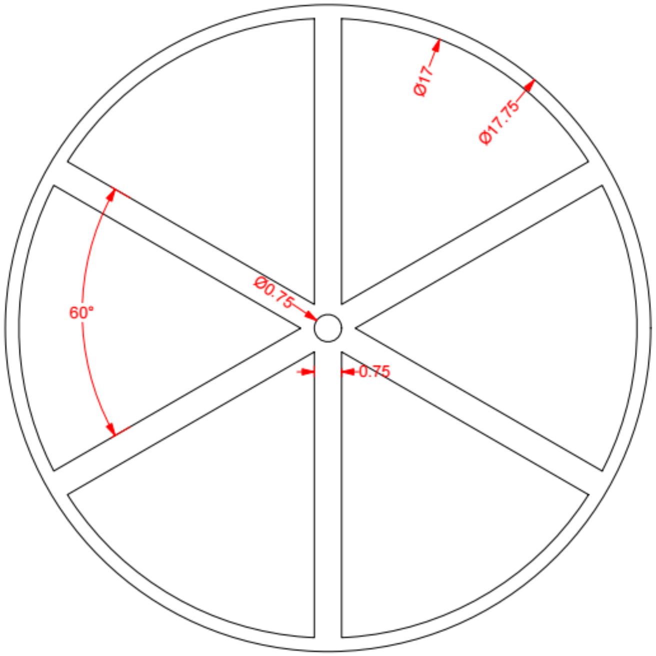
Preliminary Rotor Designs



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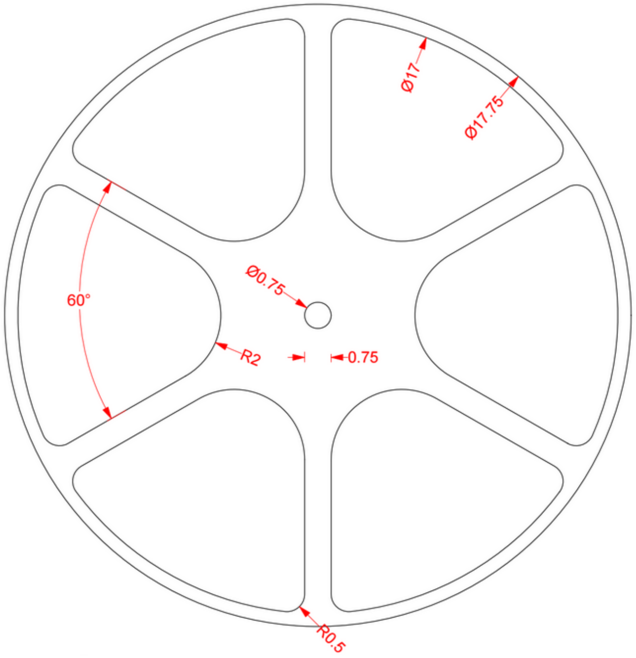

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Inductance Computations

$$L = \frac{\lambda}{I_L} = \frac{N\Phi}{I_L} \tag{1.1}$$

L = Inductance [H]

$\boldsymbol{\lambda}$ = Total linkage flux [Wb]

I_L = Inductor current [A]

N = Number of turns

Φ = Flux

Inductance Computations

$$L = \frac{N(\mu_r \mu_o A_p A_{ag} A_{rotor} A_B)}{2 l_p A_{rotor} A_{ag} A_B + 2 l_{ag} A_{rotor} A_p A_B \mu_r + l_{rotor} A_p A_{ag} A_B + l_B A_p A_{ag} A_{rotor}} \tag{1.9}$$

μ_r = *relative permeability*

μ_o = *permeability of free space*

A_{rotor} = *cross-sectional area of the rotor* $[m^2]$

$A_{p1} = A_{p2}$ = *cross-sectional area of the pole* $[m^2]$

$A_{ag1} = A_{ag2}$ = *cross-sectional area of the air gap* $[m^2]$

l_{rotor} = *length of the rotor* $[m]$

$l_{p1} = l_{p2}$ = *length of the pole* $[m]$

l_{ag} = *length of the air gap* $[m]$

l_B = *length of the base (stator)* $[m]$

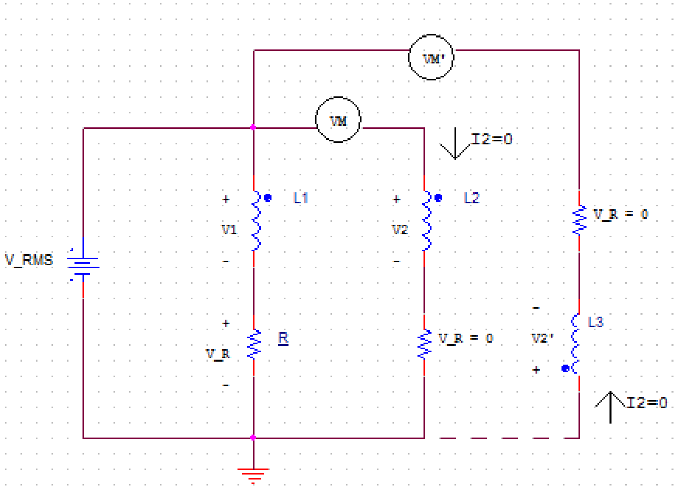
Inductance Computations

- Took measurements in Fig. [17] for V_S, $V_1+V_R=V_L$, V_2, VM, I, V_2', and VM′ to calculate the inductance of the coils

- Using Fig. [18], calculated inductance with equation Eq. 1.10,

$$\overline{V_L} = \overline{I}\,\overline{Z_L} \Rightarrow \overline{Z_L} = \frac{\overline{V_L}}{I} \Rightarrow |\overline{Z_L}| = \frac{V_L}{I} \Rightarrow 2\pi f L = \frac{V_L}{I} \Rightarrow L = \frac{V_L}{I(2\pi f)} \qquad (1.10)$$

V_L = Inductance voltage [V]
I = Coil current [A]
L = Inductance [H]
Z_L = Inductor impedance [Ω]
f = Operating frequency [Hz]



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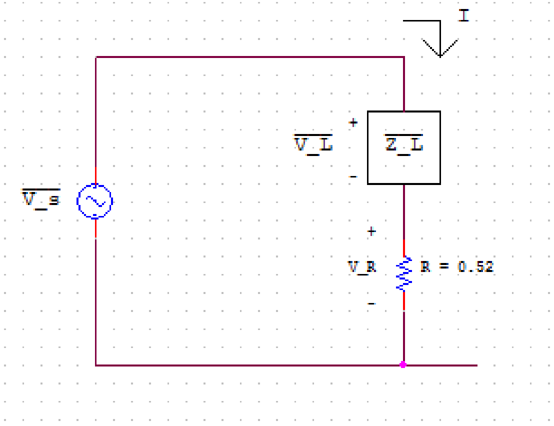


[18]

Inductance Computations

- These equations proved that output power is directly proportional to the value of phase inductance
- Old rotor was resulting in really small values of inductance

$$P_{out} = 6.66 * P * f_m * \Phi_{ag} * T_{ph} * K_W * I_{ph} * \eta * (P.F.) \tag{1.11}$$

$$P_{out} = 6.66 * P * f_m * \lambda_{ph} * K_W * I_{ph} * \eta * (P.F.) \tag{1.12}$$

$$\lambda_{ph} = T_{ph} * \Phi_{ag} \tag{1.13}$$

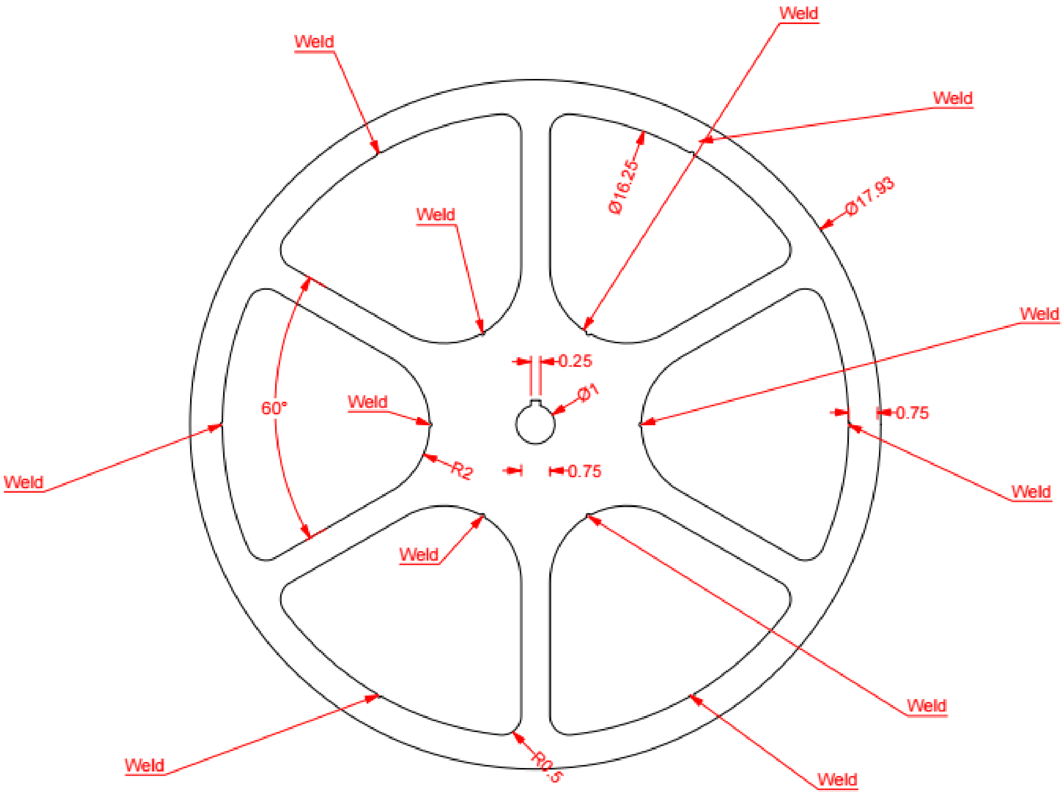
$$P_{out} = 6.66 * P * f_m * \frac{\lambda_{ph}}{I_{ph}} * K_W * I_{ph}^{2} * \eta * (P.F.) \tag{1.14}$$

$$P_{out} = 6.66 * P * f_m * L_{ph} * K_W * I_{ph}^{2} * \eta * (P.F.) \tag{1.15}$$

$$P_{out} = K * L_{ph} \tag{1.16}$$

$$\text{Where: } K = 6.66 * P * f_m * K_W * I_{ph}^{2} * \eta * (P.F.) \tag{1.17}$$

Final Rotor Design



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New Rotor manufactured by Laser Laminations

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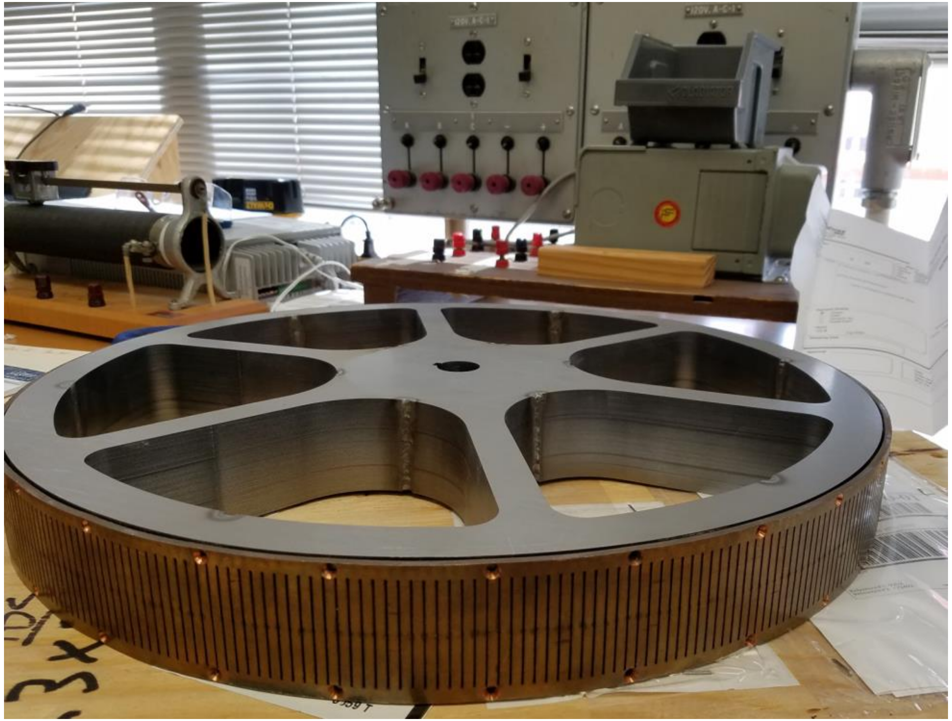
Mounting Copper Track



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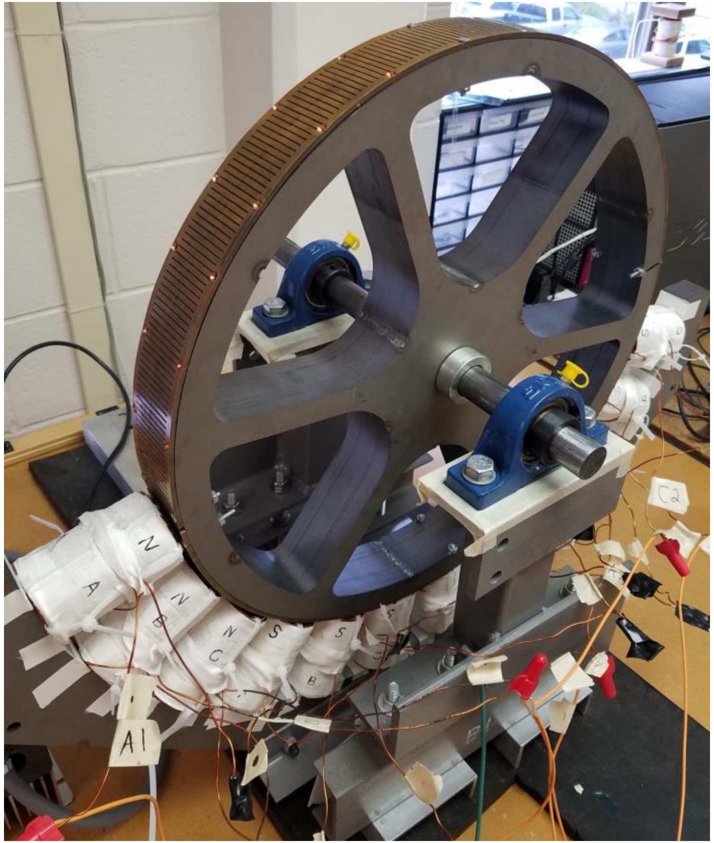
SLIM with new rotor



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Bill of Material

TABLE I: BILL OF MATERIAL				
Component	**Supplier**	**Price**	**Quantity**	**Total Price**
Laminated Rotor	**Laser Laminations**	**$575**	**1**	**$575**

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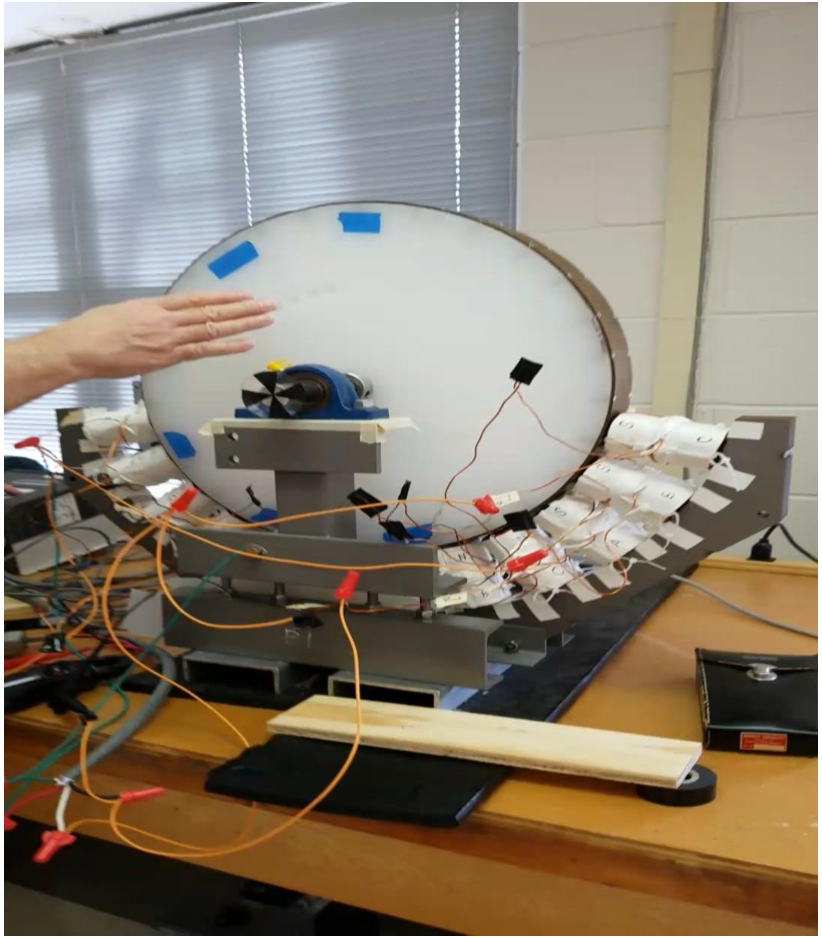
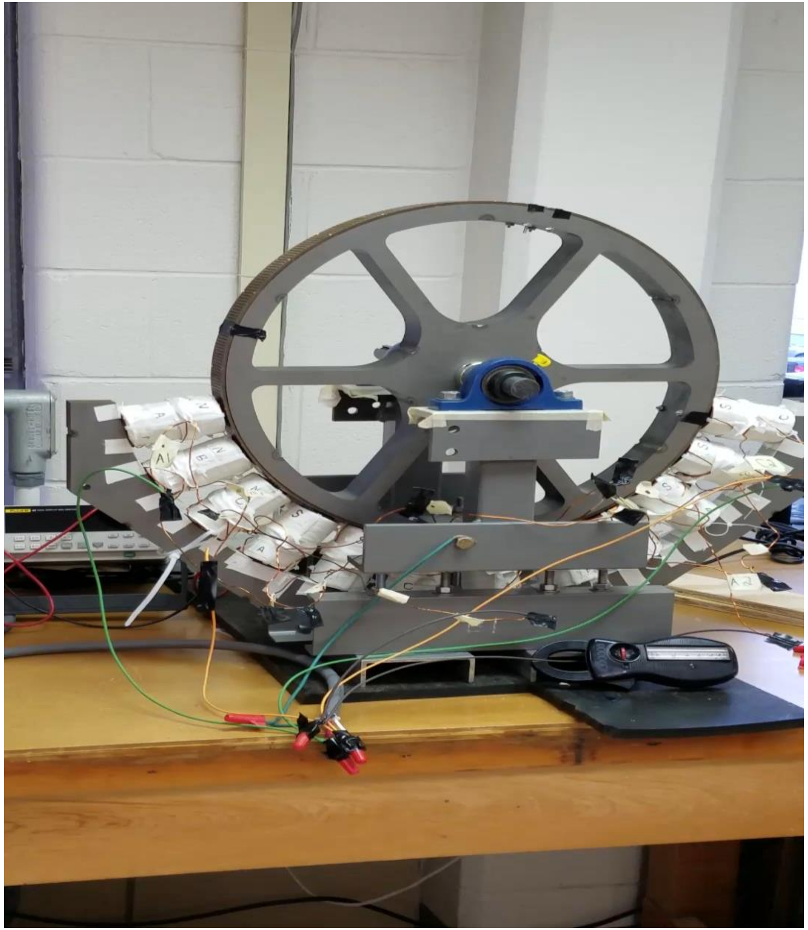
Results with old rotor



Results with new rotor



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Conclusions

- Designing a rotor with higher inductances values resulted in an increase in rotational speed
- Further testing could identify areas that could improve results
- Future teams could implement a control scheme and reinstall the magnetic levitation system

Questions?

References

[1] Linear Induction Motor. [Photograph]. Retrieved from 2016 SLIM team Final Presentation

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[11] and [12] Magnetic Field with Solenoid and Magnet. [Photograph]. Retrieved from Online Phys

[14] Simulated Track Shot 2. [Photograph]. Retrieved from 2016 SLIM team final Presentation