These three magnets interact with the LSM that runs down the middle of the track and are crucial for propulsion. The alternating magnetic field induced in the LSM due to the high current flowing through the wires interacts with the magnetic field provided by these permanent magnets. As a result, the train car is propelled down the track.

10. CHALLENGES FACED

The significant challenges in implementing our particular design are as follows:

- Smoothing out the current waveform from the AC Drive to be more sinusoidal
- Achieving very low friction between the magnetic rails and disc magnets
- Winding the LSM by hand evenly and precisely enough to function properly.

Overcoming the challenges:
Efforts were made to reduce the challenges to the problem statement most efficiently with the available tools and machinery within the speculated time.

A. Smoothing the current waveform from the AC Drive to be sinusoidal:
Initially, a Lab Volt variable voltage three phase power source in Power electronics Laboratory was used to test the LSM. It was capable of providing 8 amps of current to the track windings, and a noticeable interaction was detected between the track and a magnet array.
However, since the output frequency of the Lab Volt source was fixed at 50Hz, linear motion of the magnet array was unachievable. Instead of sliding down the track, the array instead moved back and forth a small distance.

The speed at which the secondary, or magnet array, moves relative to the track windings is given by the following formula:

*Secondary Speed = 2*pole pitch*frequency of track current*

The pole pitch of a single magnet is equal to its diameter, which is 0.025m

Therefore, when the 50 Hz current was applied to the track, the magnet array attempted to accelerate from 0-2.5m/s instantaneously. This rapid acceleration would require a large force from the track windings in order to overcome the inertia of the stationary magnets.

In order to lessen the amount of force required from the track windings, a slow acceleration is needed. This can be achieved by gradually ramping up the frequency of the current supplied to the track windings.

To fulfil this requirement, a PWM was chosen with a frequency of 15Hz and a voltage of 25V. This meant the body will accelerate between 0-0.75m/s. Which meant the body will have lesser vibrations and a controlled linear motion.

B. Achieving low friction between magnetic rails and disc magnets: For achieving levitation, guideway was designed with magnetic rails arranged on the base and horizontal support on either side for horizontal stability. Disc magnets were places on the body with opposing poles as the magnetic rails so as to achieve levitation.

- Initial magnetic rail design:

Blocks of wood were placed giving equal gaps between the bar magnets so as not to weaken the magnetic strength of the magnets due to opposing poles being together.

Fig.12 Initial magnetic track design

After designing the track as shown it was observed that the poles of the bar magnets in the wooden gaps are opposite to that of the disc magnet moving over it and this caused vibrations in the motion f the body vertically.

To avoid these vibrations and to achieve vertical stability, though the strength of the magnets weaken by bringing opposite poles together, they stuck forcibly keeping in mind the high strength of the bar magnets.

The friction between the disc magnets on the body and the guideway was reduced by sticking a highly polished sheet on the inner sides of the guideway.

C. Overcoming challenges in track windings:

A three phase three pole winding was selected for the primary rotor windings. A 4 slots one pole machine was selected.

For winding the coils evenly, wooden strips were nailed into the base for the windings of one phase were wound around it as shown.

Fig. 13 One phase windings around wooden strips

A coreless type of motor is selected, so reducing in the air gap means increase the strength of the magnetic flux produced by the primary coil. To reduce the air gap, the wooden strips nailed to the base were removed and each phase was slowly removed from their slots. After removal, each winding was taped with cloth insulation.

Fig. 14 Removed wooden strips and coils are taped with insulation

After taping each winding of each phase, the coils were hammered closely. This hammering caused the coils to come closer and reduce the air gap.

To further prevent these coils to remove on the base, holes were drilled and each winding was tied together with the adjacent using a thread. This ensured that the coils were held steadfast on the base.

Fig. 15 Coils of three phases, taped, hammered and held together by thread

11. SUMMARY

After going through the design and modelling processes it is clear that any approach to this technology must be taken with much attention paid to the underlying theory, mathematical justification, and all the specifications of the materials used. The team has produced a design which uses an effective linear synchronous motor and has mechanics and geometry which allows this to be constructed into a full-length track. If magnetic strips were used as rails more robust results would have been achieved against vertical stability, they could continue to be incorporated in the design for stability and levitation.

In the future one could also improve the circuit, possibly using sensors and a microcontroller, to regulate energy use. The microcontroller could tell the electromagnets to turn off once a certain velocity is reached and turn back on again only when needed to maintain the velocity. Future projects could add these features to the track and train.

12. CONCLUSION

The project is a modest effort in understanding the principles in magnetic levitation, the magnetic materials and its properties, the chronological history of magnetic levitation, the propulsion systems used in magnetic levitation and its working.

Studying these, the team has come up with probable design for a body to levitate and propel over a track with magnetic levitation for a linear path.

The work has lead the team in understanding the magnitude of the problem and its wide scope applications.

A suggestion has been made among the team that for the progressive growth of the problem statement, the members should specialize in or who have heavy resources in:

- Electromagnetics
- Embedded Design
- Systems & Controls

The study is involved one due to the multiple disciplines and a clear outlook and understanding of them. Any team needs to have a good back-up of all components. The power electronics part is not included in this work. Figures in inch and centimetres are deliberately given. This is certainly a technology worth reconsidering in view of the present manufacturing seen even at toy level levitation. Economics of it may be seen in a different perspective if bulk transportation, pollution freeness and speed become overweighing factors.

ACKNOWLEDGMENT

The team would like to thank E. Bhargava Sai, P. Aravind, P. Pradeep for their contributions in understanding and working though the concepts and fundamentals of magnetic levitation. We would also like to thank the Power Electronics Department Laboratory staff, whose expertise helped in practically realizing our model. Finally, we would like to extend our sincerest and most humble thanks to our guide and mentor Professor A.S.R. Murty who has continued to inspire us to strive for more and to achieve the better. He has been the greatest source of information required for our project and has helped us to see the project all the way through.

REFERENCES

[1] A-2.James, Ben. "YouTube - Future Project for Electrodynamics Suspension for a Maglev Train." YouTube - Broadcast Yourself. 23 Apr. 2009 <http://www.youtube.com/watch?v=mumrEE82qAw>.

[2] A-3.Black, Nathan, Ben James, Greg Koo, Vivek Kumar, and Preston Rhea. "The Georgia Tech Maglev Train Project." School of Electrical and Computer Engineering at the Georgia Institute of Technology. 23 Apr. 2009 http://www.ece.gatech.edu/academic/courses/ece4007/09spring/ece4007l01/sk4/

[3] Electrical4u, http://www.electrical4u.com/armature-winding-of-alternator/

[4] Japanese Maglev, 581km/h, online video, (2006), Youtube, http://www.youtube.com/watch?v=VuSrLvCVoVk&feature=related (accessed 30 January 2009).

[5] Maglev Train Technologies, fig. 2,3, https://sites.google.com/site/km4774 maglevtraintechnologies

[6] Manjeet Kumar Tummalapalli, Srujan Roha Kommula, Bhargava Sai Edara, Sai Pradeep Pativada, Aravind Perabathula, A S R Murty, “Magnetic Levitation Vehicle-Supporting Magnetic and Electromagnetic Principles Theories for Designers”, Dec 2016 http://www.iaeme.com/ijmet/ IJMET_Paper.asp?sno=6633

[7] Wikipedia, Earnshaw’s Theorem, https://en.wikipedia.org/wiki/Earnshaw%27s_theorem .

[8] Wikipedia, Magnetic Levitation, https://en.wikipedia.org/wiki/Magnetic_levitation