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Construction and Performance Evaluation of a Model Magnetic Levitation Train

[1]Agbolade, J. O. [1]Petinrin, J. O. [1]Agbolade, E. Y. [2]Ojeme, J. O. [3]Amao, E, [1]Sanusi M. A.

[1]Department of Electrical / Electronic Engineering, Federal Polytechnic Ede
[2]Department of Physics and Solar Energy, Bowen University, Iwo
[3]Department of Physics, Federal Polytechnic Bida.
yemilade2013@gmail.com; jopetinrin2@gmail.com

Abstract - Magnetic levitation is a method of transportation that uses magnetic repulsion and attraction to propel vehicles with magnets rather than with wheels, axles and bearings. The problem of rolling resistance, wear and tear associated with wheel train is overcome with this technology and it can be used to improve the quality of transportation system in Nigeria. A simple prototype of magnetic levitation train was constructed using plywood, tongue depressors, neodymium block earth magnets, adhesive glue and acrylic glass. Magnets were attached on both sides of the track; this was done so as to allow the magnets align with the model train. The train was suspending with about 70 to 80 grams of mass. The model magnetic levitation train was tested, then readings were taken and results were obtained which include mass of 10 to 80 grams, force, time, acceleration and velocity. The results, deduced that the force applied to the train depends on the magnetic field of the magnets under the train. This can be used in advanced applications such as, field and industrial train.

Keywords: Magnetic levitation, Maglev, neodymium, magnetic repulsion and attraction

1.0 Introduction

Magnetism refers to the force generated in matter due to electrons movement within its atoms. The history of magnetism emerged in sixth century, but scientists became interested in the twentieth century. They dedicated their efforts to understand the mineral and develop it further to advance the human life in different applications (Thompson, 2000). Magnetism was initially analysed in a form of the mineral magnetite called lodestone that consists of iron oxide, which is a chemical compound of iron and oxygen. The ancient Greeks were the first people to use the mineral. In fact, they called it magnet due to its ability to attract other magnets and iron (Lee, Kim, and Lee, 2006).

Train transportation have been a staple of progress since its creation during the early 1800's, people have used this advancement in order to alter the economies, increase the speed of industrialization as well as human expansion. It started from inefficient steam engines to powerful diesel engines found all over parts of the world. Now the magnetic levitation technology was implemented into the train transport system and improvements were added to the trains which make it safer and most importantly faster than conventional trains (Yaghoubi, 2013).

The first time magnets were discussed in terms of transportation was in the early 1900s. High speed patents were awarded to different inventors throughout the world. Early United States patents for a linear motor propelled train were awarded to the inventor, Alfred Zehden (German). Emile Bachelet of France and Frank Goddard talked about magnetically levitated vehicles that could be used for high speed travel, but no plan was ever realized. Twenty years later, the technology for the Magnetic Levitation train was developed by Hermann Kemper of Germany, using the attractive ends of magnets in a process known as Electromagnetic Suspension.

However, he had no practical system for applying the technology to a high speed train and the first working train would not be developed for another 60 years. (Bosnor, 2000). The initial trails of the train looked good as it reached top speeds of up to 100mph. The British built a fully working commercial maglev train in Birmingham, England. It was used to shuttle passengers between Birmingham airport and a main train station a few hundred yards away which operated for about ten years and was closed in the mid-1990s due to shortage of spare parts. The maglev technology today is no longer a dream but, an achievement (Simon, Jack, Biddle and Gordon 1997).

Magnetic levitation is a way of using electromagnetic fields to levitate objects without any noise. It employs diamagnetism, which is an intrinsic property of many materials referring to their ability to temporarily expel a portion of an external magnetic field. As a result, diamagnetic materials are repelled by strong magnetic fields. This repulsive force, however, is very weak compared with the attractive force due to magnetic fields. Furthermore, magnetic levitation is a means of floating one magnet over another. This maglev system is divided into two types' attractive systems and repulsive systems, which are referred to as electromagnetic suspension and electrodynamics suspension. Thus, many countries spend billions of dollars to use this magnetic levitation system (Cajetan and Mattew, 2006).

Magnetic levitation train is a system of train transportation that uses two sets of magnets, one set to repel and move the train up off the guide way (the train then levitates), then the other set is to propel the train ahead at great speeds taking advantage of the lack of friction (Monika, Nivritti and Aman, 2013). A magnetic levitation system has three basic elements: (i) An electrical power source, (ii) Metal coils lining a track, (iii) Guidance magnets attached to the underside of the train. With magnetic levitation technology, there are no moving parts. The train travels along a guide way of magnets which control the trains stability and speed. Magnetic levitation trains are therefore quieter and smoother than conventional trains, and have the potential for much higher speeds and lower energy consumption (Aastha and Chauhan, 2016).

The Maglev train is proved very much useful by its environmental consideration benefits and is important from the study point of view (Vignesh, Vigneshwaran, and Vijay, 2007). A maglev train can go up to speeds of (590 km/h), it is faster than the conventional on rail train because there is no friction between the train and the guide way. This paper focused on the construction and performance evaluation of the prototype model of this magnetic levitation train. The materials used for the levitation tracks were; long piece of plywood which was used as the base of the model, set of Noedymium block magnets with thickness of (10×5×2) mm, acrylic glass, a pack of tongue depressors, adhesive glue and double- sided sticky tape.

The performance of this constructed magnetic levitation train was tested with suspending mass of (10 to 80) grams. Readings were taken for the force, time, acceleration and velocity. The results deduced that, the force applied to the train depends on the magnetic field of the magnet under the train. Implementation of this magnetic levitation technology into the train transportation system would make much improvement in terms of safety and faster in speed than the existing conventional trains (Yaghoubi and Hoseini, 2010).

2. 0 Materials and Methodology

The materials used in the construction and design of the model magnetic levitation train consists of long piece of plywood for the base of the model, other components are; set of Noedymium block magnets with thickness of (10x5x2) mm, acrylic glass, a pack of tongue depressors, adhesive glue, and double-sided sticky tape. The method used to build this simple model of a magnetic levitating train was on the principle of attraction and repulsion of magnetic materials. The simplified train works on, two equal magnetic like poles repel each other while the unlike poles attract, leaving the train in levitation.

Long piece of plywood was used as the base board for the prototype construction; double coated tape was put at the two edges of the board. Magnets were attached on the tape, all aligned in the same way on two straight tracks. For the tracks to be stable, transparent acrylic glass boards were glued near the magnets on each side of the tracks. The train consists of glued together tongue depressors as shown in figure 5.0. Neodymium block magnets turned at 90^0 to the left and right were glued on the tongue depressors.

The magnetic blocks attached to the base board plywood and those on the tongue depressors were equally spaced at one centimeter apart and at opposite polarities which leads to levitation as shown in figure 7.0. The model train levitating above the track is also shown in figure 8.0. Magnets were set in line so that both the maglev and the tracks will be of a repulsive force for the movement of the maglev. The tracks were set to be stable and levitation was possible.

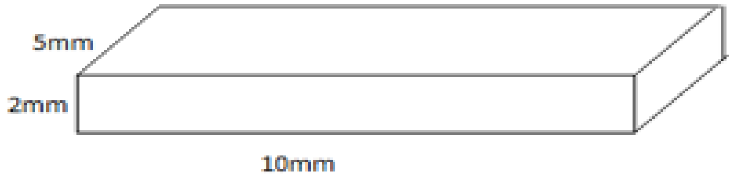

Figure 1.0: Neodymium block earth magnet

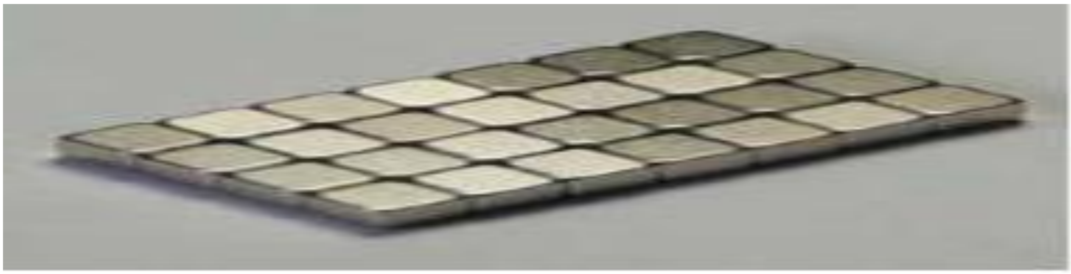

Figure 2.0: Neodymium block earth magnet, source (mane, 2016)

Figure 3.0: Pack of tongue depressors

Figure 4.0: Adhesive glue

Figure 5.0: Tongue depressors with magnets attached to both sides

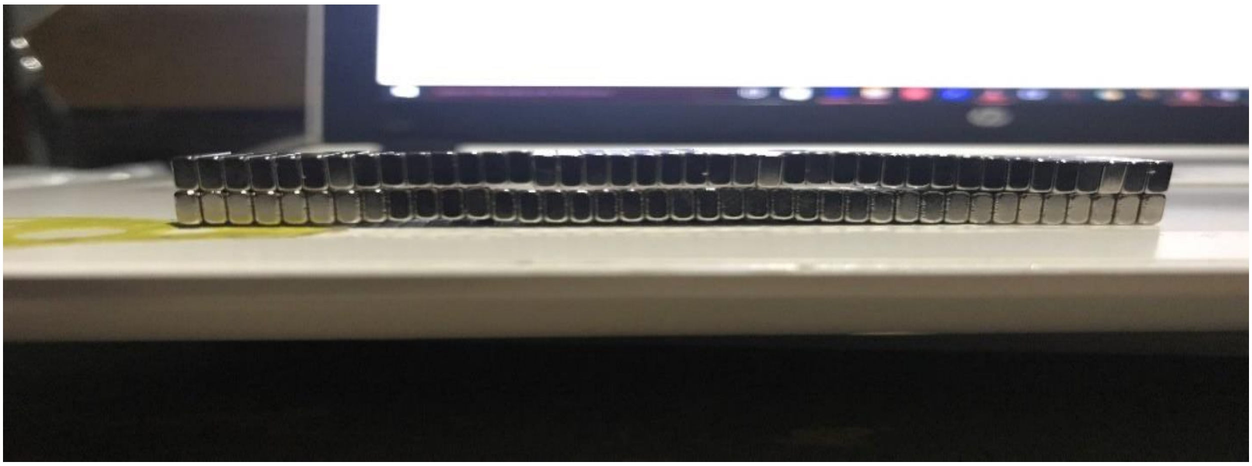

Figure 6.0: Neodymium block earth magnets

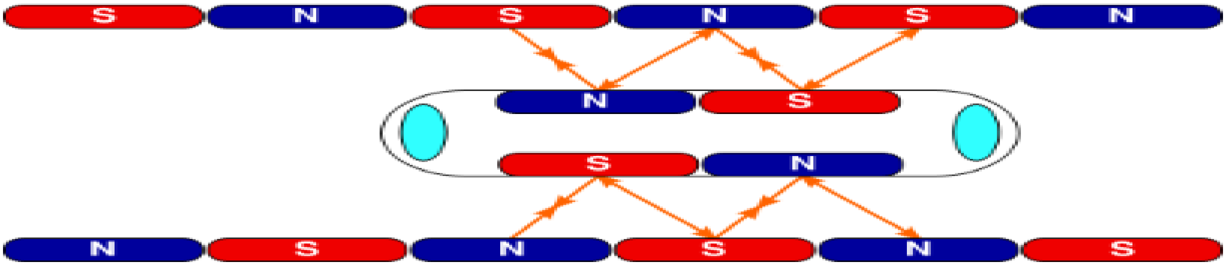

Figure 7.0: Diagram of the magnetic tracks and train system

Figure 8.0: The model train levitating above the track

3. 0 Equations Analysis

Force between the bogie (train) and the track is given as:

$$F = \frac{AB^2}{2\mu_0} = mg \quad (1)$$

where: A = Total area (area of one magnet bar x number of bars under the bogie and on the track), B = Flux density, m = mass of the magnet (0.7 g), g = 9.8 m/s^2, μ_0 = $4\pi \; x \; 10^{-7}$, $\pi = 3.142$.We have, Area of one magnet = length x breadth = 1cm x 0.4cm = 0.4cm. Total area (A) = 0.4 x 16 x 214 = 1369.

$$\frac{AB^2}{2\mu_0} = mg \quad (2)$$

The flux density (B) is not given in the equation above. Therefore, B is the subject of formula:

$$B = \sqrt{\frac{2\mu_0 mg}{A}} \quad (3)$$

where B = magnetic flux (T)

$$B = \sqrt{\frac{2 \; X \; 4 \; X \; 3.142 \; X \; 10^{-7} \; x \; 0.7 \; x \; 9.8}{1369}}$$

B = 1.12 x 10^{-4} T

Going back to the original equation:

$$F = \frac{AB^2}{2\mu_0} = mg$$

$$F = \sqrt{\frac{1369 \times (1.12 \times 10^{-4})^2}{2 \times 4 \times 3.142 \times 10^{-7}}}$$

F = 2.6137 N

Total length of track = 122 cm = 1.22m

The Newton's equations of motion employed were given below:

$$V = U + at \quad (4)$$

$$v^2 = u^2 + 2as \quad (5)$$

$$s = ut + \frac{1}{2} at^2 \quad (6)$$

4. 0 Results and Discussion

Table 1: List of parameters used for the calculation of mass and velocity of the Magnetic levitation train

M(g)	t_1(s)	t_2(s)	$T_{av} = \frac{t1+t2}{2}(s)$	S(m)	a(m/s^2)	F(N)	V(m/s)
10.00	0.95	0.70	0.82	0.56	0.68	6.82	0.55
20.00	0.60	o.50	0.55	0.48	0.87	17.44	0.47
30.00	0.45	0.30	0.37	0.42	1.13	33.99	0.42
40.00	0.45	0.45	0.45	0.39	0.86	34.64	0.38
50.00	0.60	0.30	0.45	0.340	0.88	44.40	0.39
60.00	0.60	0.60	0.60	0.56	0.93	55.98	0.55
70.00	0.45	0.70	0.57	0.73	1.27	89.46	0.73
80.00	o.55	0.60	0.57	0.35	0.61	49.12	0.34

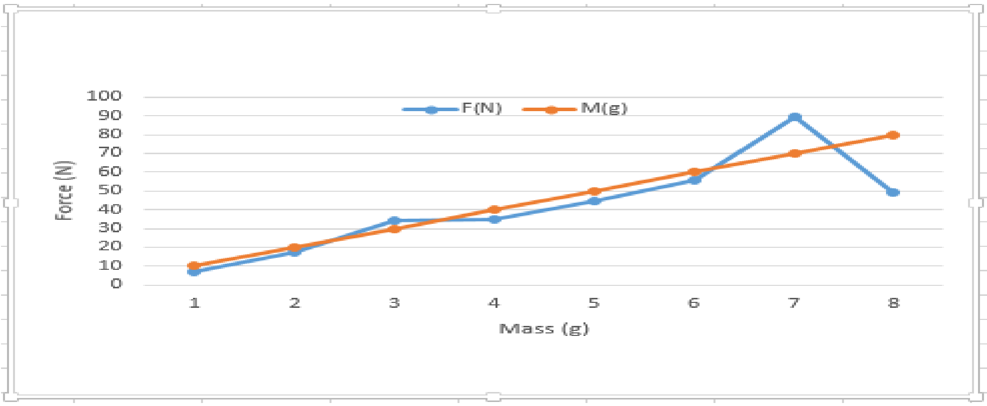

Figure 9.0: Force – mass graph

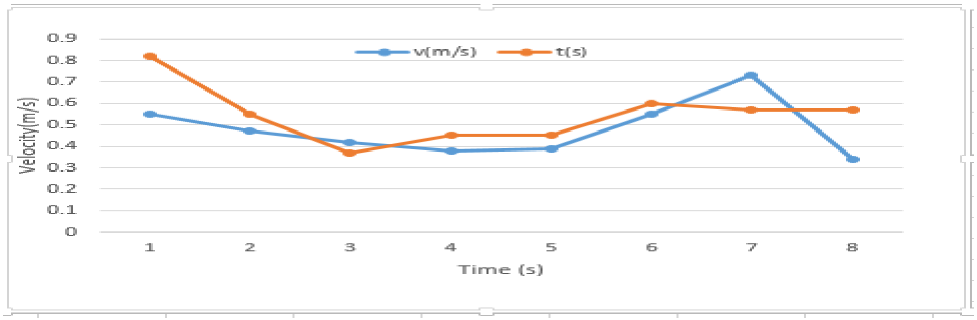

Figure 10.0: velocity time graph

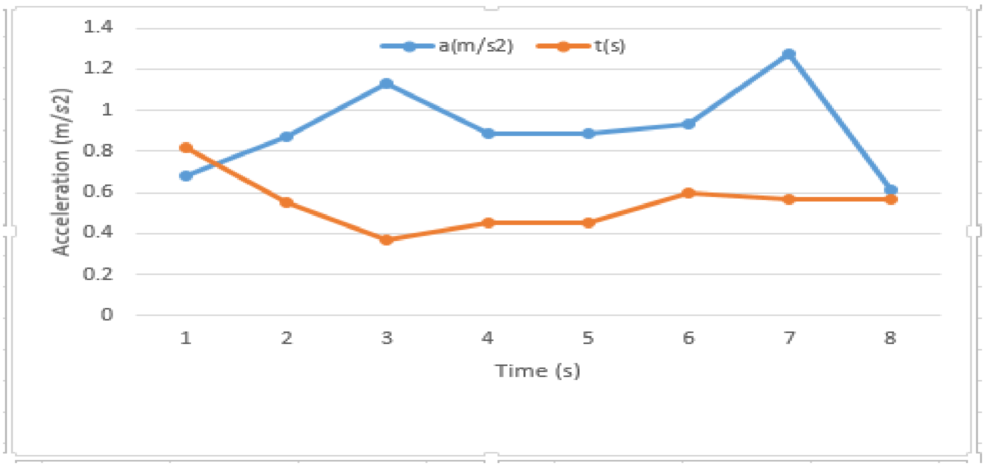

Figure 11.0: Acceleration time graph

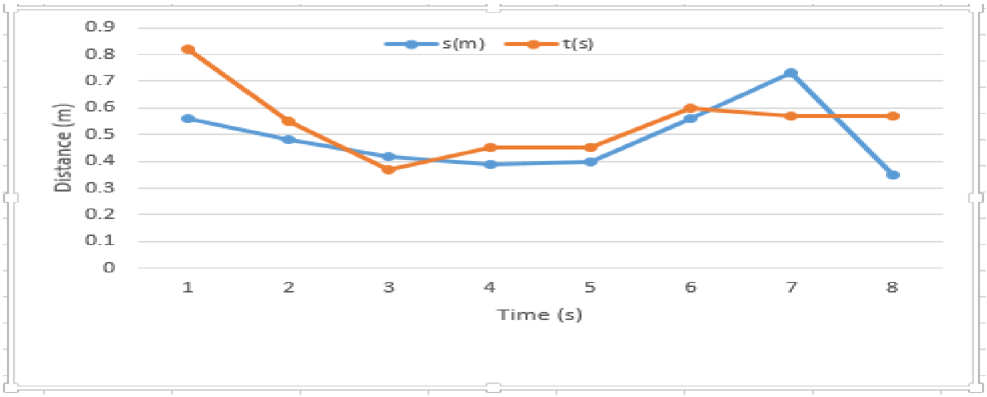

Figure 12.0: Distance time graph

Figure 9.0 shows the graph of force versus mass which indicate that, as the size of mass placed on the model train increases, the force applied also increases. The trend where the force increases with the increase in mass can be considered normal. But to the point where the mass reaches 70 grams, the force applied increases drastically, but as the mass continues to increase there was a drop and the force reduces. The sudden increase in force at 70 grams of mass was due to human error; hence the relationship deduced that, with increase in mass the movement of the train would not be affected. This makes it a better option of transportation.

From Newton's law of motion, a body would remain at rest or in uniform motion on a straight line unless acted upon by external force. From figure10.0, it was observed that the velocity forms a scattered relationship with time which was deduced from Newton's first law that this relationship is due to the instantaneous change in the magnetic force influencing the levitation. This also ensures that, problem rolling resistance is avoided in the system.

Figure 11.0 gives the acceleration and time graph which shows that, acceleration and time start almost at the same point but end at the same point. The area under the acceleration graph represents the change in velocity during the time interval. It was observed that the acceleration has a scattered relationship with the time but this is due to the instantaneous change in the magnetic field. The response of start and stop between acceleration and time on the graph is good for the transportation system.

The distance versus time graph is given in figure 12.0, here the distance drops and becomes steady at some points, then rises and falls again. The force exerted at the beginning was high so, it took a longer time for the trend to drop. The train cannot cover far distance when there is excess load on it. The distance reduces as the mass increases to about 50grams on the train but , the distance increases again due to the human error factor which is the force applied manually .In relation to time, the distance and time both drops. Basically, it is the masses that influence the distance covered by the train at a given time. This relationship of distance and time graph indicates the absence of friction and other hindrance in the levitation movement.

5.0 Conclusion

The prototype model of the magnetic levitation train has been constructed and its performance indicates that, magnetic levitation train has overcome the problems of rolling resistance (friction), wear and tear associated the conventional wheel and axle train. Also, it is faster in speed and highly economical to run. The non-contact technology of the maglev train helps in reducing operating cost because the system is almost free from wear and tear .Hence; operating expenses are potentially lower than those of traditional rail road systems.

The results revealed that magnetic levitation train is a better option for transportation and if practice in Nigeria, transportation systems would be made more convenience and easier. Also, our economy would be better for it, as practiced in China and other countries of the world. However, in the course of construction like this, the dimension of the tracks and vehicle should be accurate in order to get better results.. More so, from the model magnetic levitation train, the results obtained can be further improved by implementing electromagnets and a DC motor to enable an automated propulsion system and more efficiency.

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