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Magnetic Levitation

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Abstract: **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. Maglev is the 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 maglev system.**

Keywords: **Magnetic Levitation**

1. Introduction

Magnetic Levitation is a way to suspend objects in air without any support, as if in defiance of gravity. An unsung phenomenon of the past which is now being put to use in a variety of interesting and useful applications. As a child we must have seen a ping pong ball being levitated on an air stream at the output pipe of a vacuum cleaner. Magnetic levitation, also known as maglev is used in a similar way to levitate objects in air without any support, using magnetic field. Levitation is the process by which an object is suspended against gravity, in a stable position, without physical contact. For levitation on Earth, first, a force is required directed vertically upwards and equal to the gravitational force, second, for any small displacement of the levitating object, a returning force should appear to stabilize it. The stable levitation can be naturally achieved by, for example, magnetic or aerodynamic forces. Though any electromagnetic force could be used to counteract gravity, magnetic levitation is the most common. Though any electromagnetic force could be used to counteract gravity, magnetic levitation is the most common. Diamagnetic materials are commonly used for demonstration purposes. In this case the returning force appears from the interaction with the screening currents. For example, a superconducting sample, which can be considered either as a perfect diamagnet or an ideally hard superconductor, easily levitates an ambient external magnetic field. In very strong magnetic field, by means of diamagnetic levitation even small live animals have been levitated.

The word levitation is derived from a Latin word “LEVIS”, which means light. Magnetic levitation is the use of magnetic fields to levitate a metallic object. By manipulating magnetic fields and controlling their forces an object can be levitated. When the like poles of two permanent magnets come near each other, they produce a mutually repulsing force that grows stronger as the distance between the poles diminishes. When the unlike poles of two permanent magnets are brought close to each other, they produce a mutually attractive force that grows stronger as the distance between them diminish. A levitation system designed around the attractive force between unlike poles would require a perfect balance between the attractive magnetic force and the suspended weight. In the absence of a perfect lift and weight force profile, the conveyance would either be pulled up toward the magnets or would fall. This simple illustration of magnetic levitation shows that the force of gravity can be counterbalanced by magnetic force.

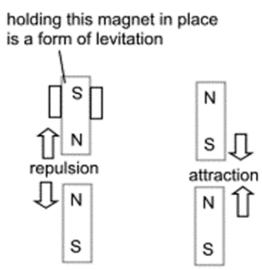

Fig. 1. A simple Magnetic Levitation

There are two ways of levitations are Active and Passive. In an active levitation system, electromagnets are coupled to amplifiers that receive signals from controllers. These controllers process signals from sensors that change the magnetic force to meet the needs of the magnetic system. Passive magnetic levitation systems are impractical without a stabilizing ingredient. Diamagnetic levitation can be used to add stability to passive levitation systems. The combination of passive and diamagnetic levitation is a functional approach to many magnetic levitation applications. Magnetic levitation is used in transportation particularly in monorails, and in levitating displays. Magnetic bearings have been used in pumps, compressors, steam turbines, gas turbines, motors, and centrifuges, but these complex applications require electromagnets, sensors, and control Electromagnets are also essential to magnetic levitation systems. Such systems often use a special kind of electromagnet whose coil is made of a superconducting metal. Because the coils of a superconducting electromagnet offers no resistance to the flow of electricity, no energy is wasted by the development of heat, and the magnetic field produced by the magnet can be very strong. All magnets, whether natural or electromagnets, have two poles. We all known that like poles repel and unlike poles attract. Magnetic levitation is the product of the repulsion generated as a result of two magnetic fields. An object is said to be levitated when the force created by electromagnetic repulsion equalizes the weight of the object. Technically, it's the electromagnetic force counteracting the gravitational force. Major applications of magnetic levitation are the Transportation: Maglev trains, Moving of metallic objects in steel industry: Magnetic floaters and Military applications: Rail-gun.

2. Types of levitation

Mechanical constraint (Pseudo-levitation) with a small amount of mechanical constraint for stability, pseudo-levitation is relatively straightforwardly achieved. If two magnets are mechanically constrained along a single vertical axis, for example, and arranged to repel each other strongly, this will act to levitate one of the magnets above the other. Another geometry is where the magnets are attracted, but constrained from touching by a tensile member, such as a string or cable. Another example is the Zippe-type centrifuge where a cylinder is suspended under an attractive magnet, and stabilized by a needle bearing from below.

Direct diamagnetic levitation a substance that is diamagnetic repels a magnetic field. All materials have diamagnetic properties, but the effect is very weak, and is usually overcome by the object's paramagnetic or ferromagnetic properties, which act in the opposite manner. Any material in which the diamagnetic component is strongest will be repelled by a magnet, though this force is not usually very large. Earnshaw's theorem does not apply to diamagnets. These behave in the opposite manner to normal magnets owing to their relative permeability of $\mu r < 1$ (i.e. negative magnetic susceptibility). Diamagnetic levitation can be used to levitate very light pieces of pyrolytic graphite or bismuth above a moderately strong permanent magnet. As water is predominantly diamagnetic, this technique has been used to levitate water droplets and even live animals, such as a grasshopper, frog and a mouse. However, the magnetic fields required for this are very high, typically in the range of 16 teslas, and therefore create significant problems if ferromagnetic materials are nearby.

3. The Principals of Magnetic Levitation

Imagine that two bar magnets are suspended one above the other with like poles (two north poles or two south poles) directly above and below each other. Any effort to bring these two magnets into contact with each other will have to overcome the force of repulsion that exists between two like magnetic poles. The strength of that force of repulsion depends, among other things, on the strength of the magnetic field between the two bar magnets. The stronger the magnet field, the stronger the force of repulsion. If one were to repeat this experiment using a very small, very light bar magnet as the upper member of the pair, one could imagine that the force of repulsion would be sufficient to hold the smaller magnet suspended—levitated—in air. This example illustrates the principle that the force of repulsion between the two magnets is able to keep the upper object suspended in air. In fact, the force of repulsion between two bar magnets would be too small to produce the effect described here. In actual experiments with magnetic levitation, the phenomenon is produced by magnetic fields obtained from electromagnets. For example, imagine that a metal ring is fitted loosely around a cylindrical metal core attached to an external source of electrical current. When current flows through the core, it sets up a magnetic field within the core. That magnetic field, in turn, sets up a current in the metal ring which produces its own magnetic field. According to Lenz's law, the two magnetic fields thus produced—one in the metal core and one in the metal ring—have opposing polarities. The effect one observes in such an experiment is that the metal ring rises upward along the metal core as the two parts of the system are repelled by each other. If the current is increased to a sufficient level, the ring can actually be caused to fly upward off the core. Alternatively, the current can be adjusted so that the ring can be held in suspension at any given height with relation to the core. If we hold two permanent magnets close together, we see that one of them will jump strongly toward (or away) from the other. In 1842, Samuel Earnshaw expressed the perversity of inanimate magnetic objects in his theorem. It explains this frustrating behavior will always prevent you from suspending one permanent magnet above or below another, no matter how one arranges the two magnets. However, an active control circuit can get around this problem by rapidly adjusting the magnet's strength. The general principle is straight forward: An electromagnet pulls a ball upward while a light beam measures the exact position of the ball's top edge. The magnet's lifting force is adjusted according to position. As less light is detected, the circuit reduces the electromagnet's current. With less current, the lifting effect is weaker and the ball can move downward until the light beam is less blocked. Voila! The ball stays centred on the detector! It is a small distance across the photo-detector, perhaps a millimeter or two, but this is sufficient to measure small changes in position. Of course, if the ball is removed the coil runs at full power. And conversely, if the light beam is blocked the coil is turned completely off. This device uses two photo-detectors: the "signal" detector looks for an interruption in the light beam, and the "reference" detector measures the background light. The circuit subtracts one signal from the other to determine the ball's position. The use of two detectors is my small contribution to advance the art of levitation. This design automatically compensates for changes in ambient light, and eliminates a manually adjusted potentiometer.

4. Magnetic levitation system

7 Magnetic levitation means “to rise and float in air”. The Maglev system is made possible by the use of electromagnets

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and magnetic fields. The basic principle behind Maglev is that if you put two magnets together in a certain way there will be a strong magnetic attraction and the two magnets will clamp together. This is called "attraction". If one of those magnets is flipped over then there will be a strong magnetic repulsion and the magnets will push each other apart. This is called "repulsion". Now imagine a long line of magnets alternatively placed along a track. A line of alternatively placed magnets on the bottom of the train. If these magnets are properly controlled the trains will lift of the ground by the magnetic repulsion or magnetic attraction. On the basis of this principle, Magnetic Levitation is broken into three main types of suspension or levitation; they are (a) Electromagnetic Suspension, (b) Electrodynamic Suspension, (c) Inductrack

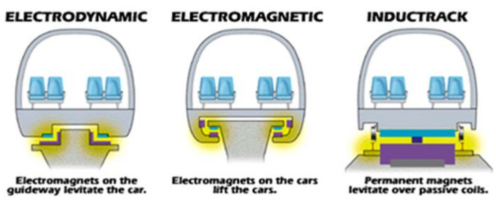

Fig. 2. Images of three types of levitation technique

Maglev trains float on a cushion of air: they do not sit on a track. The reason it can do this is because there are extremely powerful magnets on the track, and there are extremely powerful magnets on the bottom of the train. It was created like this because the lack of friction the train has now can cause it to reach speeds of up to 310 miles per hour. Also the maglev train has a very aero-dynamic design so therefore it can move faster. The maglev trains do not have wheels because they float. This keeps the train from having bumps, or rocking. The magnets on the track and the train are facing so that the same pole is towards the other. This will cause the magnets to strongly repel so that will cause the train to float. There is a extremely powerful electromagnet at the end of the track that can cause the magnets on the train to go forward or backward. This would not work if the train was not floating. Maglev trains do not have engines. The magnets on the track create a large magnetic field that causes the train to move. This causes the maglev system to be very eco-friendly, saving tons of fossil fuels. The U.S. is trying to make one of these trains so we can save fuel. The reason we are having trouble doing that is they cost so much money we can’t afford them in these economic times.

A. Obtained Magnetic levitation

It is proved that magnetic levitation cannot be obtained just by using static ferromagnetism, as the object would tend to gain instability. In order to create proper magnetic levitation condition, diamagnetic materials or superconductors have to be used. But in all these cases a little help from pseudo-levitation needs to be taken. Pseudo-levitation is a system that provides stability to the levitated object using a magnetic mechanism. For light objects, magnets made of diamagnetic materials are sufficient. The atoms of a diamagnetic substance such as silver and bismuth, doesn't have a specific dipole moment. When these objects are brought under the influence of a magnetic field, a dipole moment is induced in the direction opposite to that of the field applied. Because of this a repulsive force is generated that creates the desired levitation. Another way of obtaining magnetic levitation is by using electromagnetism. Electrodynamic fields are created when electricity is passed through a conductor. The moving charges that are created as a result of the magnetism, provides a vertical push that is equal to the gravitational pull, which in turn help to produce a stable levitation condition. Heavier objects are generally levitated by this method. Apart from these main methods, eddy currents or electrodynamic suspension, oscillating magnetic fields and permanent magnet suspension are also used.

B. Present and Future Use

Maglev train is a famous application of the maglev technology. Almost all the prominent countries have these trains as a major mode of transport in their system. Apart from this, maglev toys are also quite famous and are available in all the markets. Some of the famous maglev toys are maglev toy train, maglev toy cars, maglev clocks etc. Future might see maglev technology put to use in a variety of applications. Maglev cars are supposed to be under development. These cars won’t require a track but would fly in air. NASA is working on a maglev catapult that is predicted to reduce the costs and launching problems of a spacecraft. Also, Maglev elevators are already made and soon be put to use in Japan and China.

C. Magnetic Levitation Trains

In today's fast-paced and technological society, efficiency is critical. One essential factor in our lives is transportation-traveling between our home and workplace-and moving goods to marketplaces- to name a few examples. Consequently, other than airplanes, the conventional methods of transport such as cars, buses, and ships, are incomparable to more advanced transportation methods, such as maglev trains. Maglev, which stands for magnetic levitation, is a system of transportation that levitates, guides, and propels trains, with magnetism. Electromagnets along the guide-way beams and magnets underneath the train allow for repulsions and attractions, which move the train along the track. Steel wheels and tracks are removed to create a frictionless ride, allowing for speeds above 500 km/h. Specifically, only magnetic fields are relevant to the maglev train. Metal coils lining a guide-way become electromagnets when an electrical current runs through them, to begin the movement of the maglev train. The magnetic field created by this electromagnet is used to levitate the train 1-10 cm above the track by repelling the large magnets attached to the underside of the train. The beams on either side of the track also contain metal coils used for propulsion. Once the train begins to levitate, an electric current is supplied to these propulsion coils, which creates a combination of magnetic fields that push and pull the train along the track. The electric current in these coils constantly alternate to change to polarity of the electromagnets. This change in polarity causes the magnetic field in front of the train to pull it forward, while the magnetic field behind it adds more forward thrust. It is the lack of friction and the train's aerodynamic design that allow for speeds over 500 km/h. All can benefit from the maglev train, and especially those who travel regularly. The benefit extends to individuals, allowing people to reach their destinations quickly and efficiently. In addition, the benefit also extends to the country, by allowing for the employment of engineers in many countries around the world to perfect new construction methods, being a source of revenue for the country, and by reducing energy consumption, air pollution, and noise pollution. Unfortunately, maglev trains have also had a negative impact on society. The track of a Maglev train is small compared to those of a conventional train and is elevated above the ground so the track itself will not have a large effect on the topography of a region. Since a Maglev train levitates above the track, it will experience no mechanical wear and thus will require very little maintenance. Ultimately, maglev trains have the potential to change the lives of people around the world, with unprecedented ground transportation speed.

D. Magnetic Levitation Wind Turbine

Magnetic levitation is a method by which an object is suspended above another object with no support other than magnetic fields. The electromagnetic force is used to counteract the effects of the gravitational force. Magnetic levitation is used to reduce the energy loss due to friction. This energy wasted in friction can be saved by maglev method. Windmill is having maximum overall efficiency of 30%. Energy efficient windmill can operate in the maximum efficiency of 45%. The remaining energy is mainly lost in friction. If the same windmill is operating at 50% of its maximum speed the efficiency becomes very low and the frictional loss gets increased compared to power generated. The drawback of windmill is that it cannot be operated at its full capacity all the time. Wind energy has been identified as one of the green energies, the future world depends. Many countries started investing more money in wind generation. So losses in windmill shall be reduced to tap the maximum power from wind. To reduce the loss, maglev method can be implemented. Moreover, due to friction there will be wear and tear in machines. Due to the wear and tear the performance of the machine will deteriorate. Hence windmill using magnetic levitation has more life than ordinary windmill. Normal windmill can start its generation from wind speed of 3 m/s. But windmill using magnetic levitation can start generation from wind speed of 1.5m/s. Operation of windmill at lower speeds, increases the amount of energy harvested from the windmill. Magnetic Levitation Wind Turbine are also called the Regenedyne. This technique is efficient, frictionless, a single unit capable of producing the power of 500 standard commercial turbines, maglev technology was said to have it all.

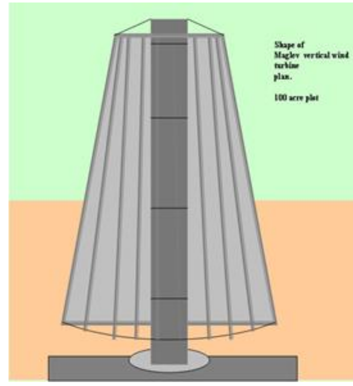

Fig. 3. Magnetic Levitation Wind Turbines

5. Conclusion

Magnetic levitation is a phenomenon that is likely to have considerable potential in the future. Particularly through the use of superconductive levitation. A new idea for magnetic levitation is in the use of storage of energy. Very basically it uses a rotating ring (flywheel) that stores (kinetic) moving energy which can be 'extracted'. It is use of magnetic fields to levitate a metallic object. By manipulating magnetic fields and controlling their forces an object can be levitated. Because of the growing need for quicker and more efficient methods for moving people and goods, researchers have turned to a new technique, one using electromagnetic rails and trains. This rail system is referred to as magnetic levitation, or maglev. Maglev is a generic term for any transportation system in which vehicles are suspended and guided by magnetic forces. Instead of engines, maglev vehicles use electromagnetism to levitate (raise) and propel the vehicle. There is much work to be done in the Maglev industry, but the basic physics argue that these new systems will penetrate the transportation system because of weight and efficiency over the ever present wheel. One other variation that might surface in the near future is a hybrid system, one in which magnets are employed to simply lighten the effective load placed on the wheels. Railways using Maglev technology are on the horizon. They have proven to be faster than traditional railway systems that use metal wheels and rails and are slowed by friction. The low maintenance of the Maglev is an advantage that should not be taken lightly. Energy saved by not using motors running on fossil fuels allows more energy efficiency and environmental friendliness. Maglev will have a positive impact on sustainability. Using superconducting magnets instead of fossil fuels, it will not emit greenhouse gases into the atmosphere. Energy created by magnetic fields can be easily replenished. Maglev will contribute more to our society and our planet than it takes away. Considering everything Maglev has to offer, the transportation of our future and our children's future is on very capable tracks.

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