MODEL OF THE ELECTROMAGNETIC LEVITATION DEVICE

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1. Introduction

From the principal point of view, the magnetic levitation is a method which is used for suspending an object in the air, without any physical contact. There are few main types of the magnetic levitation – electromagnetic, electrodynamic, transformation, superconductive and diamagnetic. All these are usually based on the force interaction between magnetic field and gravitation field. The magnetic levitation is especially used in some hi-tech devices (e.g. MagLev trains, frictionless bearings etc).

The transformation levitation system is used for positioning of electrically conductive materials by electromagnetic forces. This type of levitation is usually utilized by metallurgists and material scientists and the most important practical application is a melting of metals.

The electrodynamic levitation system (EDS) uses the moving of magnets to induce currents in an electrically conductive matrix. The induced currents produce a repulsive levitation force. This system is mostly used in the transportation.

The diamagnetic levitation system is realized by situating a diamagnetic material close to a material producing magnetic field. The both materials will repulse each other. Disadvantage of the diamagnetic levitation is very low repulsive levitation force.

The superconductive levitation system uses the superconductive materials and the source of the magnetic field – the permanent magnet. The external magnetic field is fixated in the superconductor and thereby the place stabilization of the superconductor and permanent magnet is held. At the present time, high temperature superconductors are mostly used.

Our paper is focused on **the electromagnetic levitation system (EMS).** Its basic operating principles are described in the following text. A ferromagnetic object is suspended in the magnetic field of an electromagnet. It is obvious a feedback control circuit is necessary to ensure a stable position of the levitating object. A control unit adjusts the current in the electromagnet. The position is tracked by a sensor; usually photo sensor, Hall Effect sensor etc. are used. According to the signal of the sensor the electromagnet is driven up or down. If the ferromagnetic object is above the desired position, the controller reduces the current in the electromagnet and the magnetic force as well. If the object is below the desired position, the current in the electromagnet increases.

The most usual applications of the electromagnetic levitation are the transportation (MagLev trains) and magnetic bearings.

Maglev train has always been considered to be the high speed passenger transportation between the major population centers. It is often viewed as a sort of super-speed trains which competes with airplanes for inter-city passengers.

Magnetic bearings have specific properties in comparison with mechanical bearings-no lubrication, no abrasion, low vibration and noise etc.

The model of a small electromagnetic levitation device will be introduced in the following text. It has been designed and implemented by the master's thesis at the Department of Electrotechnology. This device has been successfully presented at many occasions at our faculty and it is used for educational aims, too.

2. Arrangement of the levitation device

We have designed and constructed a real working model of the electromagnetic levitation system. The main parts and the arrangement of the levitation device are illustrated in the Figs. 1 and 2.

A suspended object contains a permanent magnet, which is the main difference in comparison with the basic principle of the electromagnetic levitation we have assumed before. The levitating object is repulsived and attracted to an electromagnet so we need the controlled magnetic field. A control unit adjusts the current in the electromagnet and hence the magnetic force acting on the levitating body so that the body is held in the stable position. The functional block diagram of the designed electromagnetic model is shown in the Fig. 1.

This model contains several basic parts. The electromagnet has got a ferrous core (a bolt) with modified end – the pole horn. The arrangement of the pole horn is very important for achieving a required distribution of the magnetic field. Edges and asperities of the pole horn represent the points of inhomogenities of the magnetic field and they can subsequently cause levitating object instability.



Fig. 1: Functional block diagram of the levitation device.

The control system requires the feedback signal from a certain kind of the positional sensor. In that case, the Hall Effect sensor, located on the bolt head (the pole horn), is used. The configuration of the laboratory model is shown in the Fig. 2. The form of the electromagnet and the placing of the Hall Effect sensor are illustrated, too.

The image of the final constructed model is shown in the Fig. 3. This device contains a control button for the adjusting of the levitation distances and an electrical fan for spinning of the levitating object and cooling of electronic circuits located in the base of the device.



Fig. 2: Arrangement of the electromagnet and the placing of the Hall Effect sensor.



Fig. 3: Final image of the device.

3. Principle of levitation model

The operating diagram of the levitation device is shown in the Fig. 4. The electromagnet is controlled in order to hold the levitating object in a stable position beneath it. The power block, which supplies the power to the electromagnet, was made from the H-bridge module. The H-bridge is designed for motion applications and contains MOS power transistors.



Taking away of the levitating object from the eletromagnet





Fig. 4: Operating diagram of the levitation device.

The signal from the Hall Effect sensor is processed by the amplifier with an adjustable gain and controls the PWM (Pulse Width Modulator). As soon as the levitating object moves further away from the bolt the output signal of the Hall Effect sensor increases. It makes the duty cycle of the PWM higher and the electromagnet attracts the levitating object; and vice versa. A repeating pulse changes its width to apply more or less attraction or repulsion forces to the suspended object over time. The written situation is shown in the Fig. 5. The current of the electromagnet can be proportionately controlled by the H-Bridge module from a full reverse to a full forward level. It means that electromagnet can change polarity from attraction to repulsion in the proportional manner.

3. Basic mathematical model

In terms of the design, chosen part of the magnetic levitation model was simulated. We used the software for multidisciplinary system simulation – Dynast [9]. In the Fig. 6, a basic simulation model is shown. One of the significant parts of the model is the feedback circuit. It

means we simulated the output signal of the amplifier with the adjustable gain. According to the Fig. 6, there is a derivation block which is realized by passive components – resistors and capacitors. These components influence stability of the model. On this account, we have optimized the derivation block according to the results of the simulation. After the realization of the electromagnetic levitation device, we have compared real levels of the chosen parameters of the constructed device with the simulation model. The results of the simulation approximatelly correspondence with the real device.



Fig. 6: Basic simulation model of the feedback circuit.

4. Characteristic parameters

We have measured the characteristic parameters of the magnetic levitation device. The basic parameters are distance between the pole horn and the surface of levitating object (the levitation distance), the gain of the feedback circuit and the weight of the levitating object. In the Fig. 7, the gauging fixture for measuring the levitation distances is shown. We have measured the levitatation distances through the use of the light source and the shade. The distances were measured on the shade depending on the gain of the feedback circuit for the specific weight of the levitating object. In the Fig. 8, the operate area of the electromagnetic levitation device is shown.

Fig. 7:Gauging fixture for measuring the levitation distances.

Fig. 8: Operate area of the levitation device.

5. Conslusion

The described levitation system was designed and constructed as a model destined for the demonstrational and the educational aims. The device function was tested in laboratory conditions and i.a. the operating area was established, i.e. an area in which the stable behaviors of the levitating object with assigned weight is guaranteed. In this respect the dependence of the distance, between the pole horn and the surface of levitating object, on the system gain was experimentally checked for defined weights. According to the measured results, the described levitation system assign stable behaviors within the range of distances from 10 mm to 16,5 mm with the corresponding weight from 13 g to 26,7 g.

6. References

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