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A Motor-Free Elevator for Emergency Downfall

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ABSTRACT

In case of unpredictable events such as fire and explosion of gas pipes in apartments and sky scrapers, due to electrical failures, using elevators is not recommended. Moreover, due to smoke and its consequences such as suffocation and lack of eye vision, staircases are not safe and usable. Furthermore, the use of emergency stairs is a slow procedure with limited capacity. Therefore, such emergencies may result in heavy human casualties. This is while the invention of a human emergency downfall system in aluminum or copper tubes with magnet helps save lives in such emergency situations very easily. In this paper, we propose an electromagnetic downfall system with no need for electricity or fuel which can be used in such situations easily and safely while we will prove our work's excellence and helpfulness in real life with simulations and lab experiments.

Keywords: *Electromagnetic Brake, Faraday's Law, Lenz's Law, Magnet, Copper, Aluminum, Emergency Elevator*.

1. Introduction

In case of unpredictable events such as fire and explosion of gas pipes in apartments and sky scrapers, using elevators is not recommended because of electrical failures. Also, staircases due to smoke and its consequences such as suffocation and lack of visibility are unsafe and not usable. Moreover, emergency stairs is a slow procedure with limited capacity to be used. So, such emergency events sometimes result in death of dozens of people. Magnetic braking of a falling magnet inside a conductive pipe [1-3] and the Thomson jumping ring [4, 5] are experiments frequently shown in lecture demonstrations. The subject of magnetic braking has received considerable attentions and is addressed in scientific journals repeatedly [1-3, 6, 7]. Also, recent technology has provided many important applications for magnetic braking [8]. Besides jumping ring [4, 5], the vertical motion of a small magnet inside a non-magnetic conductive tube are manifestations of Faraday magnetic induction which have recently found their way to laboratory experiments [1-3] for their pedagogical value. The magnetic drag force on a strong magnet falling inside a vertical non-magnetic conductive tube is re-examined here with the idea of saving people in emergency cases by invention of a human emergency downfall in aluminum or copper tubes with magnet.

2. Theory

Consider a copper tube with a cylindrical magnet over its top aperture. The tube can be divided to many hypothetical parallel rings. When the permanent magnet is released, the magnetic flux starts to change in every ring. According to Faraday's law the change in the magnetic flux leads to induction of electromagnetic force and electric current flows through the ring. The magnitude of the induced current depends on two factors; first the velocity of the falling magnet and second, the distance of each ring from the falling magnet. Faraday's law states that an electric current produces its own magnetic field. The direction of this current according to Lenz's law is such that it will resist the phenomenon that induced it originally, in this case the movement of the permanent magnet. Based on Lenz's law, during the falling, when the permanent magnet's distance to a given ring is about to increase, an attempt to try to attract it back to the ring is made by the induced field. Conversely, when the permanent magnet's distance to the ring is decreasing, the attempt by the induced field will be made to keep it away. The exact calculation of these forces is a cumbersome task. However, using Finite Element Analysis and summing the magnetic interactions with all the rings, the net force on the magnet can be calculated. The electromagnetic force is an increasing function of the velocity and will decelerate the falling permanent magnet. At a certain velocity the gravity force and the magnetic force will become equal, leading to zero acceleration. Essentially, the acceleration from the beginning of downfall decreases until it is zero at a certain velocity. The stronger the permanent magnet the faster the constant velocity is reached.

According to [9], an expression for the magnetic braking [10] force on a strong small permanent magnet falling inside a tube is obtained by Equation (1) by using Faraday's induction law.

$$F = \left(\frac{\pi f \sigma e \mu^2}{a^4}\right) v \qquad (1)$$

Where, v is velocity, a is magnet's inner radius, μ is the magnitude of the magnetic dipole moment of the magnet, σ is the conductivity of the material of the tube's wall, e is the tube's thickness and f is a constant value of $\frac{5\pi}{256}$.

According to Equation (1), the thickness is directly effective on the force, and thus with the increase of thickness the force increases and therefore it takes more time for permanent magnet to fall.

3. Proposed Solution

As shown in Figure 1, we install a thick tube with thick walls made of aluminum or copper to the highest point of the high-rise building to the surface of the earth (Figure 1, No.1). This tube passes through each floor (Figure 1, No. 5 and No. 6). Individuals can be guided through the tube to the ground. In front of the entrance of each floor and in the near-tube area, a number of strong magnets are installed. In emergency situation, people at risk (Figure 1, No. 3,), put a strong magnet underneath their feet (Figure 1, No. 2) and with its support (Figure 1, No. 4) they will be conducted into the tube. Thanks to Faraday's law, during the fall in the aluminum or copper tube, the strong magnet will induce electricity in the body of the tube which is like short-circuited coil circles. According to the Lenz's law, the electricity induced in the tube creates a field that opposes the movement of the magnet and reduces the velocity of the magnet and thus the person riding it down the tube. By reducing the speed of the magnet in the tube, the intensity of the induced electricity and consequently the resulted magnetic field and the opposite force will decrease. Increasing the speed again leads to more induction, more magnetic field and stronger opposite force, which itself reduces the speed of the collapse of the magnet and the rider. The exact calculation of the acceleration and speed depends on strength of the magnet and the thickness of the tube wall. Nevertheless, this ongoing increase and decrease in the speed insures a relatively slow movement to the ground (Figure 1, No. 10).

With precision calculations and engineering, it is possible to accommodate several persons at specific intervals and simultaneously into the tube. At the end of the tube, rubber material is fitted with bumpers to prevent people from suffering from the impact (Figure1, No. 7).

There are documentary photos and films from all the experiments conducted in the university campus.

4. Experiment and Simulation Results

Two metal tubes of different kind of non-ferromagnetic materials namely Copper and Aluminum are chosen. A very strong magnet (NdFeB) is used and released through the tubes separately (Figure 2). The magnet starts to fall very slowly, despite what is usually expected when something is dropped. In the experiment that was conducted the aforementioned tubes had different widths.

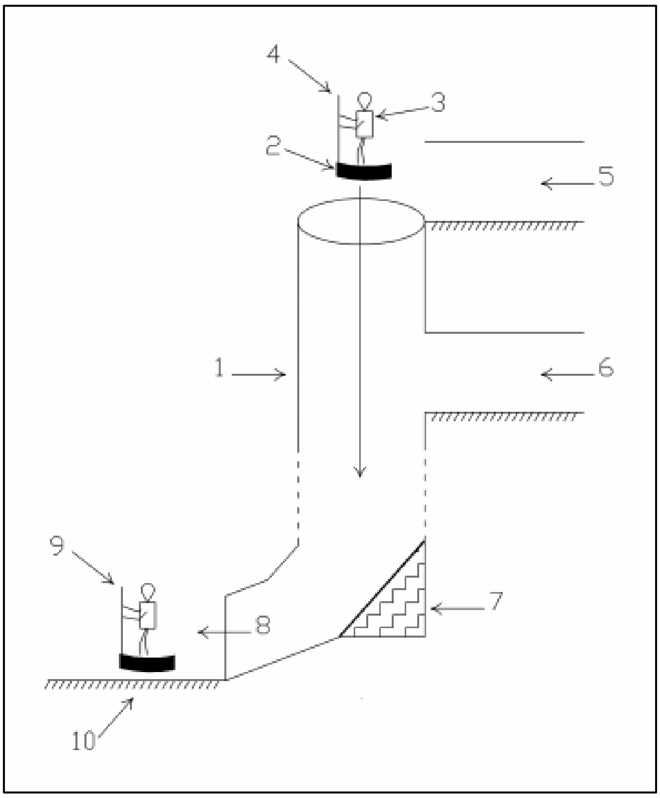

Figure 1: Schematic of the proposed method

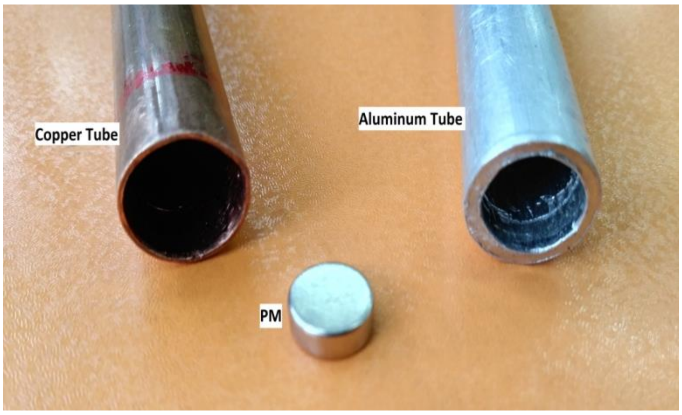

Figure 2: Tubes and the PM

In this section a fully featured simulation of the experiments is described, and the results match the downfall time of the physical experiment. As shown in Table 1 the specifications of the aforementioned tubes are presented. In order to be able to closely observe the effect of thickness, for both tubes the same permanent magnet (PM) was used. The remnant flux density of the selected PM is 0.52T and the relative permeability is 1.12.

Material	Aluminum	Copper
Length (mm)	520	560
Inner radius (mm)	4.5	5.575
Outer radius (mm)	6.5	6.175

Table 1: Tube Specifications

The tube's dimensions were used in order to simulate the experiments using finite element analysis (FEA). For 2D simulation the Flux FEA software [11] was used. As shown in Figure 3 the magnet and the tube were simulated axisymmetrical.

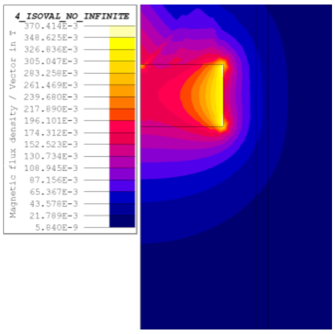

Figure 3: Copper Tube Flux Density Distribution

In this simulation the parameters needed to be chosen carefully, in order for the simulation results to match that of reality. The falling condition includes the initial velocity which is zero and taking into account the gravity and of course the electromagnetic force impact in opposition to moving direction because of the induced current in tube. The falling time, for aluminum tube is longer, as the air gap between the tube and the magnet is smaller.

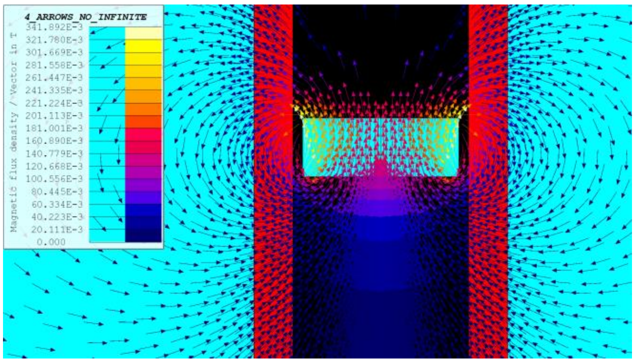

Figure 4: Aluminum Tube Flux Density Distribution and Direction of Magnetic Flux

Considering the same size for magnet and different dimensions for inner radius of the tubes, the smaller the air gap the more flux flows in the tube thus the eddy current is more and leads to a larger induced electromagnetic force compared to the copper tube with larger air gap. Also, it can be explained by direct relationship between the thickness and the force based on Equation (1). The calculations for forces were conducted in software load inputs; in that case the gravity acceleration constant was considered to be 9.8 and the magnet's weight as 0.88g. Figure 4 and 5 show the direction of magnetic flux with its density by color. As can be seen for copper tube since its equivalent area that passes the flux is smaller the density of flux is larger.

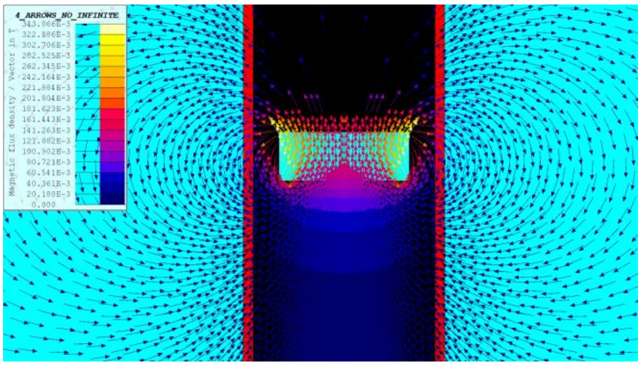

Figure 5: Copper Tube Flux Density Distribution and Direction of Magnetic Flux

As was mentioned before, the electromagnetic forces are calculated and are shown in Figures 6 and 7 for aluminum tube and copper tube respectively.

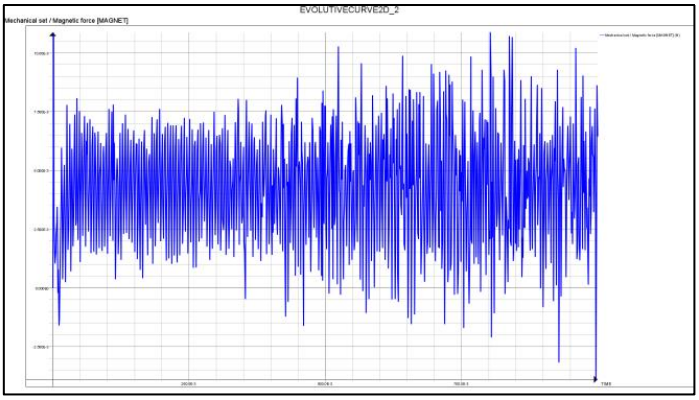

Figure 6: Aluminum Tube Electromagnetic Force

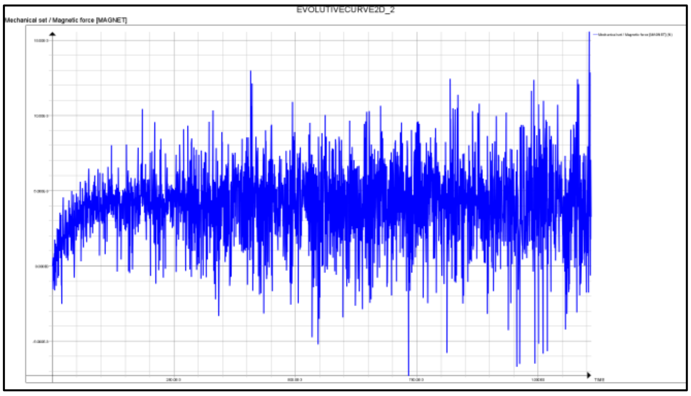

Figure 7: Copper Tube Electromagnetic Force

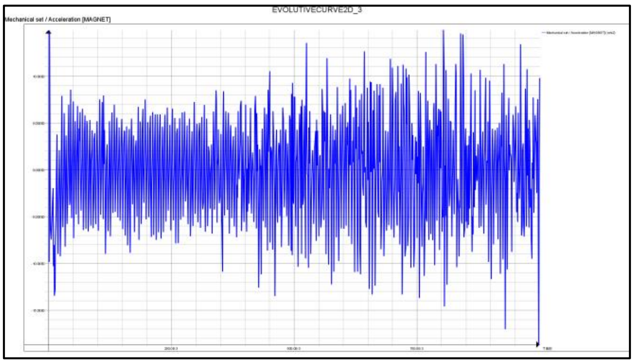

Figure 8: Linear acceleration of PM in Aluminum Tube

The results show that for aluminum tube the mean value of Electromagnetic force is 0.00427 N while this value for copper tube is 0.00402 N. In previous sections it was mentioned that because the acceleration after a while becomes zero the velocity will become a constant value and Figures 8 and 9 for copper and aluminum tube, confirm this. As can be seen for both tubes, the acceleration is decreasing in time until the velocity reaches its final value.

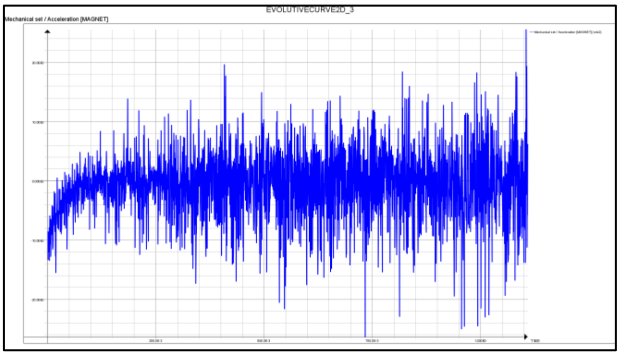

Figure 9: Linear acceleration of PM in Copper Tube

5. Conclusion

In emergency situations such as fire and explosion of gas pipes in apartments and sky scrapers, neither elevators nor stairs are safe and practical; so, such emergencies sometimes result in death of dozens of people. In this paper, we proposed an electromagnetic downfall system with no need for electricity or fuel which can be used in such situations easily and safely. In other words, the invention of a human emergency downfall system in aluminum or copper tubes with magnet helps more people to save their lives in such emergency situations very easily and quickly. Also, we proved our work's excellence and helpfulness in real life with simulations and lab experiments.

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