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HOVER BOARD

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Abstract

In this project, electromagnetically levitating hoverboard is built. The levitation is made possible by feeding alternating current through a coil, which is placed over aluminium sheet. The coil creates alternating magnetic field when alternating current is fed to it and this magnetic field induces alternating eddy current to the aluminium sheet. Eddy currents create opposing alternating magnetic field and the interaction of magnetic fields produce lifting force. During project, a feasibility study was conducted by researching requirements to produce enough lift for given mass so levitation is achieved. Project also included designing and constructing planar coils, inverter and body for the hoverboard. Design process consisted of drafting schematics and plans as well as selecting components and materials for construction. Hoverboard testing was conducted to validate simulations and designs. Tests consisted of system turn-on tests, full system tests, failure analysis and problem solving. In the short business aspect exercise hoverboard was given product name "HoveBev" from the business idea that hoverboard could be used to levitate beverages. The hoverboard was never fully realized as per to project plan. Project itself was successful as a university project in teaching students practical project work, teamwork and problem solving skills. It also gave practical experience in fields of electromagnetism, power electronics, electronics, power systems and mechanical design.

Introduction

Final goal of this project was to build a battery-operated Hoverboard, which can levitate up to 8 kg of mass in addition of itself. Operating principle of the device is based on electromagnetism and inducing eddy currents. A coil is fed with alternating current (AC) to produce alternating magnetic field. This alternating magnetic field induces eddy currents in the conducting surface below the coil. Eddy currents in turn produce magnetic field of their own and these magnetic fields repel each other, creating a force called levitation. Figure 1 illustrates a simulated coil fed by AC which generates magnetic field and eddy

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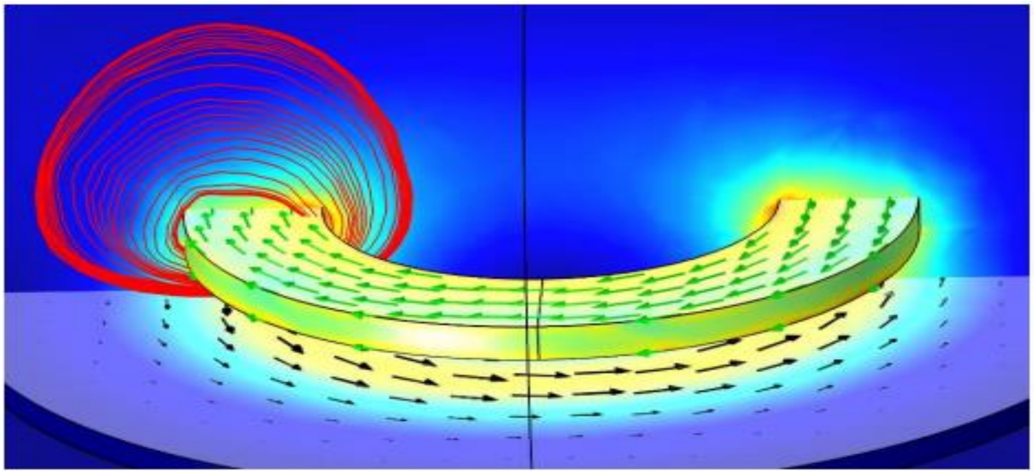
currents.



Other devices, such as Hendo Hoverboard, are inspiration to this project. However, Hendo Hoverboard way of producing alternating magnetic field is vastly different. Hendo Hoverboard utilizes permanents magnets attached to rotor of electric motor to produce alternating magnetic field [1]. Since this project is limited in both time and budget, a mechanically simpler machine is chosen for implementation. Hoverboard consists of planar coils, batteries, inverter and body. There are total of 10 individual planar coils. To improve safety and to enable 50 V operation required by batteries, the coils are connected so that there are five sets of coils connected in parallel and each set has two coils connected in series. As energy storage, the hoverboard uses two 5500 mAh Lithium Polymer (LiPo). Because the batteries provide only direct current (DC), inverter is required to produce alternating current (AC) which is required for producing alternating magnetic fields. Finally, the body is the frame to which all modules and systems are fastened. Because of masses involved the body material needs to be light but strong, it must be heat resistant due to coil heat generation and it cannot be conductive or magnetic material because of the electromagnetic physics involved in the operation. Only the levitation height can be controlled electrically when a single coil is used. However, it can be easily moved around by pushing it since there is no friction. Further development in the device can result in significant improvements and increase in features. As such, this project can serve as proof of concept and prototype which could be used as starting point in future projects.

Definition

Prof. Barata tasked me with designing a concealed device which would allow Jibril to move slowly and eerily across the floor. Due to the angel's long and wide costume, it would be possible to hide it from sight beneath the loose fabric. The most important consideration for the device is balance. It is important that the performer will not fall off from the device. The impact of such a blunder during the performance would not only harm the scene in which the angel is present. The entire show's integrity would be compromised and harshly received by the audience, potentially as a comedic act, which would seriously damage the performance's reputation.

Objective

There were two main objectives for the project. Because the project is part of university course, primary objective was learning practical skills required in industry, team working skills and project work skills. Secondary objective was creating a functioning device corresponding to instructors demands and requirements. Original goal of the project was to build hoverboard that is capable of levitating equivalent mass of adult human being between 50-80 kg. As described in the feasibility study section of this document, this was proven to be infeasible and goal was reduced to levitating 18 kg total. The device itself was estimated to weigh 8-10 kg and during the progress of the project the goal was set to levitating 8 kg of load in addition of the device itself.

Project plan

At the start of the project the intent of project plan was to create tasks that could be divided among group members and to form a logical path and guideline which could be used and followed throughout the entire project. The project was divided into five phases: Feasibility Study, Design, Part Acquisition, Implementation and Testing. These phases also served as milestones of the project.

All phases and their purposes are listed below:

● The goal of phase one, the Feasibility Study, was to find out what is possible and what would be infeasible to implement. Feasibility study also explored different features for the device such as control, remote control and safety mechanisms.

● Objective of second phase, called Design phase, was to find out all the necessary components that would need to be acquired as well as prepare schematics and plans for all components and subsystems that were meant to be implemented.

● During third phase, called Part Acquisition phase, all the necessary parts were listed and it included finding retailers from whom the parts could be purchased from.

● All the building and manufacturing was done during the fourth phase, called Implementation phase.

● Final phase, called Testing phase, was intended to be part of the project where most intensive tests would be performed and when any major issues would be solved through iteration.

Project plan also included risk assessment and the point of it was to evaluate, estimate and predict potential risks that project group could be facing. The risk of electrocution was raised as prime concern and this was one of the reasons why 50 V was chosen as operating voltage, since it is regarded as extra low voltage (ELV) and therefore the risk of electrocution is low albeit present.

Feasibility Study

Since this project was a proof of concept prototype and no documentation or evidence of similar devices or products were found, a feasibility study was deemed necessary. The feasibility study began with examining and researching what is possible for project group to create. The study was begun by confirming if the levitation of human being was possible with the project group skills, time and budget.

The following limitations were placed upon the project group at the start of the project and were the starting point of the feasibility study:

● Parts which are not available from university, and thus much be acquired, shall not exceed the 1000 € budget

● It should be possible to complete the project within 4 months of time, with 1200-1400 hours total time spent working from 6 group members

● Hoverboard shall operate at extra low voltage of 50 V, to minimize the risk of electric shock

● Hoverboard must be able to lift adult person, equivalent to approximately 60-80 kg of mass

● Hoverboard must be safe to operate Feasibility study was mainly conducted using COMSOL Multiphysics simulation software. COMSOL has built in magnetic physics package and coil tool that allowed project group to research and study the project and the physics behind its operation with relative ease. Simple 2D models were enough to determine almost all requirements for this project

Design

With more feasible and more realistic goal, the project group set out to optimize a hovering system to get as efficient hoverboard as possible with the given budget. Desired characteristics included high levitation height (5 to 10 cm) and high lift of around 8 to 10 kg of load. Because the hoverboard was intended to be battery operated so that it can be moved around, the project required an inverter to be designed. This process would include selecting components for H-bridge, creating control circuitry for the H-bridge and programming microcontroller to produce signals for control circuitry.

Concept Generation

It was clear to me that the final product would involve motorized wheels and at least one surface for the user to stand and balance on. The device must also be powered by batteries due to power cables being aesthetically displeasing and a potential hazard for other performers on stage.

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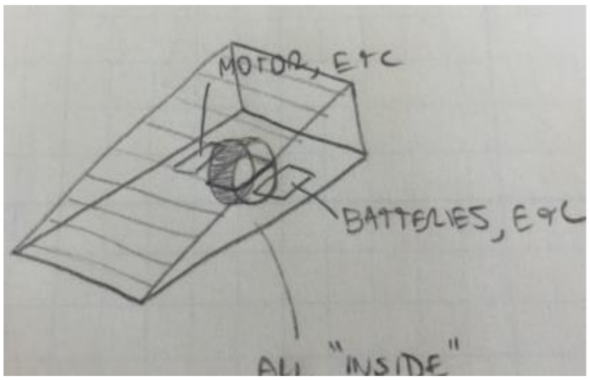
Structure One design

Concept involved two separate motorized devices, one for each foot. This design was inspired by Heelys . Each device would be similar to a box, with the electrical 2 components (battery, motor, wiring) inside. A wheel would be embedded on the underside of the pyramid-shaped "box", and the user would rest their feet on the top, with the forefoot poking past the front of the device, resting on the floor while standing still. The devices would be separate, with each motor and battery having its own circuit (left and right feet independent of each other). Each device would be controlled via a momentary switch in the user's hand, with wiring up each leg and arm, concealed by the costume.



The primary advantage of this design is that it allowed the user to change directions easily and intuitively by lifting their heel (which is attached to the device) and pivoting with their forefoot. With practice, the user turn smoothly and be barely noticeable in the loose costume. Balancing issues may arise as the user would be The design would also allow the user to correct their posture easily and quickly in case they were losing balance simply by placing their forefoot down and turning the switches off. However, it was unclear whether there was enough room in the "box" to store the battery and motor. There was also a concern during movement when the forefoot is lifted from the ground, as the pressure exerted by the heel of the foot on the device could be too great to bear, and catastrophic failure may result. A simpler design concept was also considered. The design incorporated all of the components into one structure, requiring the performer to stand on one platform with both feet. The platform would be attached to two motorized wheels on its underside and one caster wheel to allow for turns. All electrical components including wiring would be attached to the underside of the platform, next to the wheels

Platform Details

Seeing as the device would use four wheels in total, it made sense for the platform to be rectangular. The chosen dimensions were 15"x12". The 15" width allowed for comfortable feet placement on the platform, with the user placing their heels together and pointing their feet slightly outward. The 12" length allowed for more room on the underside of the platform for electrical and other structural components. As for the material, simple plywood was selected due to its high strength and resistance to cracking and bending. Its light weight was also a positive factor as it helped exert a lower load on the wheels. A 23/32" plywood height was selected.

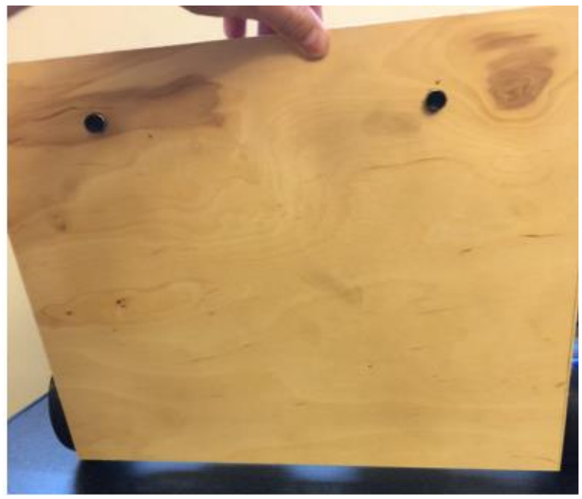


Figure 1 : Plywood Platform

Structural Details The motor and motorized wheels were attached to the underside of the platform by connecting them with an aluminum channel. This channel ran alongside the width of the platform. It was connected to 90° brackets and attaching those to the underside of the plywood with wood screws. The total height of the device had to be considered. It should be kept as low as possible due to costume concerns. Increasing the height would make it more difficult to conceal the device using the angelic cloth costume. 4" diameter wheels were selected for the

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Figure 2:Aluminum Channel

motorized wheels. 3” diameter swivel casters were selected. The casters were directly attached to the underside of the platform by screwing the attached metal plate to the plywood.

Figure 3: Diameter Motorized Wheel

Figure4 ; Diameter Swivel Caster

Gear: —

- A gear or cogwheel is a rotating machine part having cut teeth, or cogs, which mesh with another toothed part to transmit torque, in most cases with teeth on the one gear being of identical shape, and often also with that shape on the other gear.
- Two or more gears working in a sequence (train) are called a gear train Geared devices can change the speed, torque, and direction of a power source.
- The most common situation is for a gear to mesh with another gear — The gears in a transmission are analogous to the wheels in a crossed belt pulley system. An advantage of gears is that the teeth of a gear prevent slippage.
- When two gears mesh, and one gear is bigger than the other (even though the size of the teeth must match), a mechanical advantage is produced, with the rotational speeds and the torques of the two gears differing in an inverse relationship.

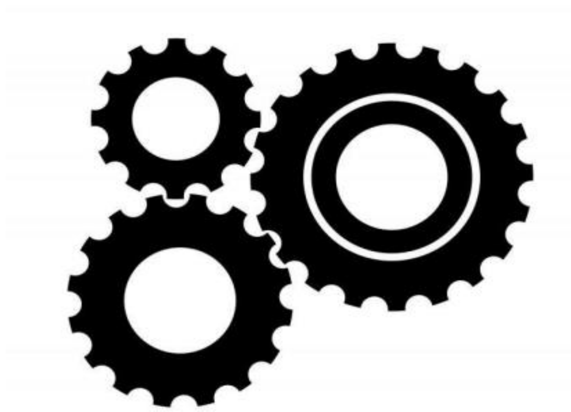

Figure5 : Spur Gear

Electrical Details

Appropriate motor selection depended on the intended speed of the device and the load the motorized wheels would bear. An appropriate velocity for the angel would be walking speed. This speed was approximated to be 5 mph. RPM requirement with 4” diameter wheels was calculated as follows:

$$V = \frac{5\, miles}{hr} = \frac{5280\, in}{min}$$

$$RPM = \frac{5280\, in}{min} \cdot \frac{1\, rotation}{4\pi\, in} = 420.17\, RPM$$

A 437 RPM brush motor was selected with a maximum torque of 305.5 oz-in at a rated voltage of 12 VDC. The selected motor’s rated voltage was 12VDC, so a battery capable of producing 12V was required. The scenes in which Jibril appeared did not require him to move too often, so a 3700 mAh battery

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pack was selected as the motor did not have to run for too long. A NiMH type battery was deemed to be appropriate for the device seeing as the motor did not require a high amp load. The battery is rechargeable with a universal smart charger, which was ideal seeing as the show was to be performed on two separate occasions. Two of these batteries were purchased, one for each motor. As stated earlier, the switches' height had to be considered due to it being controlled by the toes. Small SPST momentary switcher were selected, mountable on half-inch holes which were to be drilled into the plywood platform. The switches were default off, momentary on in order for the user to press down with their toes in order to move forward. Two of these switches were purchased, one for each circuit. The electrical components were connected with 14 AWG wires taped on the underside of the platform. The wiring formed two circuits, one for each motor (left and right).

Figure 6 : Selected Switch

Construction

Once the plywood was acquired, the 15"x12" platform was created using a table saw. The edges were sanded in order to prevent wood splinters, as the device was to be picked up from its sides and moved during blackout scenes in the production. In order to find the best placement of the switches, I stood on the platform with my feet slightly pointed outwards. I marked the location of my big toes on the platform. A rotary tool was used to drill a half inch hole through the wood on the marked locations. The switches were then fitted through the holes, with the button poking out of the surface and the terminals on the underside of the platform. The switches were then attached to the platform with super glue. The channel was attached by connecting it with three 90° brackets which were then screwed onto the underside of the platform on the opposite edge of the casters. The casters were attached to the device by screwing the attached metal plate onto the underside of the platform, half an inch from the edges.

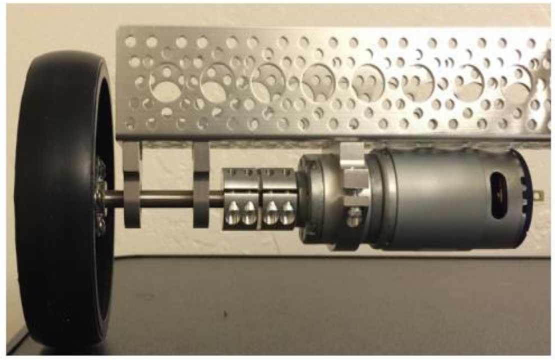

Figure 7: Channel Attachments

The motors were attached to the channel with clamping mounts, which were then screwed into the channel. The motor's shaft was connected to a 1/4" shaft with a coupler. The 1/4" shaft was attached to the channel with two pillow block bearings. The shaft was finally connected to the heavy duty wheel with a clamping hub. Figures 14 and 15 below help visualize this process.

Figure 8 : Top View

Motors:

Motor is fixing with the chassis through screwed bolt and it is the main source of power with is to drive the vehicle. There are two motors, each for one wheel. Each motor is driven by a separate 12v battery. Motor Specification:• 1) DC gear motor (Wheel chair motor). 2) Voltage range- 12V-24V. 3) Current- 2-5 Amp. 4) Gear ratio- 1:50 5) Power- 150Watt 6) Motor RPM- 100-3200 RPM 7) Noise- 60dBA 8) Weight- 1.75kg 9) Brake- DC 24V, 0.45A & 30kgf-cm

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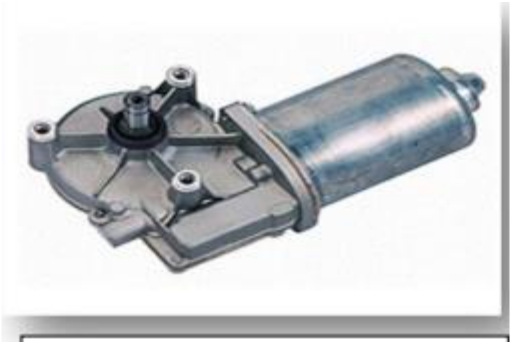

Figure9 : Motor

Battery:

Battery is a main power source. Two 12V DC batteries are used in Mechanical Segway. Each battery connected with each motor. Battery supplies power to each motor to run the wheels. Battery is rechargeable in both ways electric socket and solar plates. Battery Specifications:• 1) Voltage range- 12V-24V DC (22Ah) 2) Current – 2-5Amp. 3) Battery weights- 5.9kg 4) Grid alloy lead- Calcium tin Alloy 5) Container cover- ABS resin 6) Electrolyte- diluted sulfuric acid 7) Size- 181*76*167mm 8) Battery type- AGM (Absorbent Glass Mat)

Figure10 : Battery

Mechanical Segway tyres:

In mechanical Segway two tyres is used in both the sides. Scooter wheels are used in Segway reason behind that cost is less, easy to available and friction property is also less. Also higher amount of weight gaining capacity and movements is also very smooth. Tyre Specifications:• 1) Wheel diameter- 177.8mm 2) Material- Combination of rubber and leather. 3) Casing material – combination of fiber and plastic. 4) Thickness of tyre- 100mm

Figure 11 : Tyres

Motion control potentiometer

Rotatory type potentiometer is used in Mechanical Segway. Purpose of potentiometer is to turn the Segway right and left by using rotary potentiometer. Rotary potentiometer specifications

1) Size- 22.225 to 76.20mm

2) Range of motion- 3200 to 3580

3) Drive interface- Round solid shaft

4) Standard operating temperature- -550 to 1250C.

5) Extreme environment- Extended temperature.

Figure 12 : Motion control potentiometer:

Supporting Wheel:

Supporting wheel is used on Mechanical Segway. The purpose of small supporting wheel is to balance properly; there is no need to gyroscope for the balancing purpose. Also easy to assemble and dis-assemble. Supporting small wheel Specification:• 1) Wheel diameter- 63.5mm 2) Material - Plastic hard rubber 3) Metal casing is used to supporting the wheels and one fixing socket is provided.

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Figure 13 : Supporting Wheel:

Recommendations for Future Manufacturing The following section recommends design changes in order to improve the device. 5.2.1 Noise Reduction The device was designed to be hidden from sight by covering it with the loose fabric of the angel's costume. This provided a small amount of noise reduction to the motors while the device is moving. In order to further suppress the sound of the operating motors, I recommend adding other means of sound insulation to the device. 5.2.2 Wheel Protection During testing, the wheels collected any dust and small materials on the ground. This prevented the device from working to its full potential. The casters were more reluctant to swivel due to debris and random dust they collected. I suggest adding some way to easily brush off these inconveniences when not in use, or some way to prevent the dirt from becoming attached to the wheels. 5.2.3 Backwards Movement It was not necessary for the purposes of the production for the device to move backwards. However, in the case that is desired, one could design more elaborate circuitry to make it happen. Using the remote-control idea would alleviate some pressure on the performer 4 by giving them less things to think about while performing.

Tool Kit:

1. Spanner

2. Pliers

3. Wire Cutter

4. Screw Driver

5. Fitter

6. Hammer

7. Scissor

8. Adjustable Wrench

9. Fix Wrench

Figure 14 : Tool kit

COMPONANTS USED IN SEGWAY & ITS SPECIFICATION:

It consists of following mail points:

chassis and material properties:

Chassis is made up of aluminum section and four aluminum bars is used to make the frame. To make the chassis to balanced, four aluminum bars of equal weight are used. It is engaged firmly with the help of aluminum welding. Aluminum welding is used to connect all the bars. Wheels are attached to the middle of frame in order to withstand the load capacity. Handle is also made up of same aluminum material to which DPDT switch is fixed.

1) Atomic Weight (g/mol) - 26.98

2) Thermal Conductivity(0-1000C) (cal/cms.0 C) - 0.57

3) Electrical Resistivity at 200C (Ω.cms) - 2.69

4) Density (g/cm3) - 2.6898

5) Modulus of Elasticity (GPa) - 68.3

Details of chassis:•

1) Base Plate Thickness - 10mm

2) Aluminum Rod Diameter –

3) Rod Height – 1016mm

4) Normal Cycle Handle Bar used for balancing purpose.

5) Width* Length – (304.8 mm *508 mm)

RESULT AND DISCUSSION:

Mechanical Segway presents the results of the project. First comes a short discussion on the implementation of the balancing without using any type of programming and sensors. This is followed by some initial driving results and why the vehicle did not behave in satisfactory manner and what was done to improve performance without using programming and sensors. Initial driving results:• When testing the vehicle for the first time the controller gains were significantly lower as a precaution. This test was mainly performed to see that the system functioned as intended, spinning the wheels in the right and left direction etc. after this was confirmed the first riding test was conducted, and already with this controller the vehicle was drivable. The control strategy with the remaining error serving as a source for speed turned out to be a success and speed control by using DPDT switch forward and backward worked well.

CONCLUSION:

Basically this investigation is successful achieved the objective with the acceptable outcome. The main goal of this project was a build a functional two wheels and one supporting wheels transporter and this goal has been fulfilled. The overall functionality and performance of the vehicle has been evaluated thoroughly by a number of test drives. The vehicle has been tested by a number of different weights. This project is implementing with an idea to find an effective solution to transportation problem.

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