How Magnetically Suspended Tires Utilizing High-Temperature Superconductivity and Electromagnetism Creates the Most Eco-Friendly Vehicle

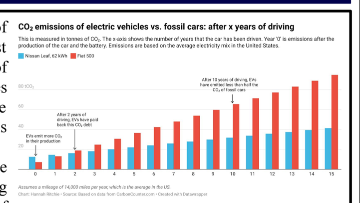
Purpose

The typical emissions by a gasoline car is about 4.6 million metric tons of carbon dioxide (CO2) per year. Gasoline is a fossil fuel; fossil fuels are the most significant contributors to global warming, accounting for over 75 percent of greenhouse gases and 90 percent of all CO2 emissions. CO2 absorbs and radiates heat in the Earth's atmosphere. Although, if too much CO2 is emitted into the atmosphere, it will radiate too much heat and cause global warming. The world is warming faster than ever in recorded history.

The consequences of global warming lead to more frequent and severe droughts, storms, heat waves, and wildfires. Pollution, rising sea levels, melting glaciers, warming oceans, and worse health conditions are also consequences of global warming, which can directly harm animals' and humans' livelihoods and habitats.

Environmentalists and scientists are recognizing the dangers of gasoline cars. In response, car manufacturers are now developing electric cars. Even though electric cars do not give off fossil fuels, they are just as harmful as gas cars because they use many lithium-ion batteries. Lithium-ion batteries are excellent power supplies, but their manufacturing can cause even more damage to the environment than fossil fuels.

There is a limited supply of lithium, and the extraction of lithium involves water-intensive mining practices that cause significant pollution and global warming. Also, the transition metal mix of lithium-ion batteries makes them complex and costly to recycle. As a result, most of these batteries end up in landfills, making them hazardous waste.



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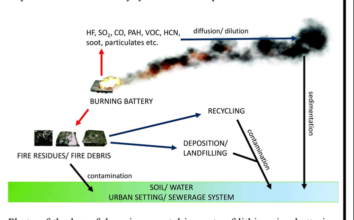

Photo of the harmful environmental impacts of lithium-ion batteries. https://pubs.rsc.org/en/content/articlehtml/2021/ee/d1ee00691f

The purpose of this project is to invent a sustainable car that is environmentally friendly but also efficient, safe. This project invents an electric car with magnetic levitation suspension tires that rotate with high-temperature superconductivity for efficiency and eco-friendliness. Sodium-ion batteries and solar panels are implemented as the power source, making the car exceptionally environmentally friendly. Safety precautions regarding the YBCO superconductors and cryogenic cooling are also considered for the design of the car. This is a theoretical design that does have the potential to be built.

Hypothesis

The research question is: **"Can one invent tires that utilize high-temperature superconductivity and electromagnetism to create the most efficient and eco-friendly vehicle?"**

Suppose I utilize YBCO superconductors into a stator that magnetically levitate a (magnetized) tire so it does not have an axle while also rotating the tire forward and back with electromagnets. In that case, I hypothesize that the tire will rotate. **The superconducting car design is shown in Figure 1, Figure 2, and Figure 3.**

If I were to create a model of the superconducting tire, then I would expect it to accurately demonstrate magnetic levitation suspension, electromagnetic propulsion, and speed control to give a visual representation of how the superconducting tire would work in reality. I also hypothesize that if I increase the resistance of a potentiometer, then the rotor in the model rotor will rotate slower and vice versa. The engineering goal is to invent a magnetic-driven tire and prove it works with a model. **The tire model experiment is what proves if the superconducting car design will work or not. So, the first priority of this project is to create the model before going into how the superconducting car works. The model should also help explain how the superconducting car tire would work.**

Materials for the Circuit

Note: There are two models with identical circuits. This list only accounts for what one needs for one circuit. Doubling the amount of materials on this list will account for both circuits.

- Two 9V batteries
- Two HW 131 Voltage Regulators
- Arduino Mega 2560 R3
- Two seperate Arduino breadboards
- Arduino 8-relay module
- An Arduino jumper set
- An Arduino potentiometer
- Eight Arduino electromagnets

Procedure for the Circuit

- Obtain an Arduino breadboard and insert a voltage regulator on one side of the board so the positive and negative terminals are inserted into the power rails.
- Insert a jumper wire into the ground (GND) connection of the voltage regulator. Connect the other end to the GND of the Arduino MEGA 2560 R3 board. Then, connect a 9V battery to the input of the voltage regulator.
- Insert a jumper wire into the +5V connection of the voltage regulator. Connect the other end to the Vin (voltage input) of the Arduino board.
- Insert four breadboard jumper cables over the power rail divider to connect both sides of the breadboard to a single power rail.
- Insert a potentiometer in the breadboard and hook one breadboard jumper cable to the GND of the power rail to the GND pin on the potentiometer. Hook another breadboard jumper cable to the +5V power rail to the +5V pin on the potentiometer. Then, connect the potentiometer signal pin to the analog pin 0 of the Arduino (A0) via a jumper wire.
- Insert a jumper wire in the GND power rail and connect the other end to the -DC input of an 8-arduino relay module. Insert a jumper wire in the +5V power rail and connect the other end to the +DC input of the 8-relay Arduino module.
- Insert eight jumper wires in 2-9 digital pin slots on the Arduino. Connect the other side of the jumper wires to the 1-8 inputs of the relay module.
- Repeat step one with another voltage regulator. Connect a 9V battery to the input of this voltage regulator, too.
- Insert eight jumper wires into a +5V rail of the second breadboard. Connect the other ends to each output of the eight relays labeled COM1-COM8 (communication).
- Obtain eight Arduino electromagnets and insert jumper wires in each NO pin of the electromagnet (normally open). Connect the other ends to the NO of each relay output NO1-NO8.
- Insert jumper wires in each VCC pin of the electromagnet and connect the other end to the +5V power rail of the second breadboard. Then, insert a jumper wire in each GND pin of the electromagnets and connect the other end to the GND of the power rail.
- Insert a plug into the Arduino and the other end (being a USB) into a computer to upload the program to the Arduino. Disconnect and turn on both buttons from the voltage regulator to power the circuit.

How the Circuit Works

Electricity: Electricity is the flow of electrons through a wire. Copper is a conductor, which means that the valence shell of copper is close to the conductance band. When current flows through copper, it gives enough energy to provide the valence electrons of copper to reach the conduction band and be "free." If one connects a copper wire to a closed circuit with a power source, such as a battery or an outlet, the voltage will force the electrons to move in the same direction in the wire and get back to the power source. By adding applications in the electrons route, they will be forced to flow through them to return to the source.

Voltage Regulator: The purpose of a voltage regulator is to keep a constant output voltage even when the input voltage changes. The unchanging output voltage is due to capacitors. Say a 5V power supply is desired with a current of 300mA (which is what the electromagnets want in this experiment). However, the input voltage is 9V. An integrated circuit with three pins is used to achieve that voltage. Pin 1 is input unregulated voltage, pin 2 is ground, and pin 3 is output regulated voltage. Capacitors are recommended for the input and output pins. The capacitors help smooth out interruptions to the supply and also low-frequency distortions. Diodes help protect the circuit if the power supply is connected the wrong direction. **One voltage regulator powers the Arduino, potentiometer, and the relays for the circuit, while the other powers the eight electromagnets.**

Arduino: Arduinos are a collection of electrical components and microcontrollers that can read and execute programs. Microcontrollers are integrated circuits that are tiny computers. They can run small, simple software programs at extraordinary speeds. Arduinos have a series of microcontrollers called ATMEL AVRs, which give digital control to the system. They are connected to a crystal resonator, which controls how fast the microcontroller runs. The ATMEGA8U2 allows a program to run on the main microcontroller. Once a program is running, this chip allows sending messages back and forth between the computer and the Arduino. A reset button is what allows the program of the Arduino to reboot. Arduino MEGAs consist of multiple pins. 2 GND, Vin, 5V, and 3.3V are the power pins that allow a power source to connect to it and power the board. The TX and RX pins send and receive serial data for wireless communication. Pins 2-52 are digital input and output pins. Digital pins can only read high and low (on and off). Pins A0-A15 are analog inputs that measure continuous voltage from 0V to 5V. Analog pins are used to read the voltage potential of a device.

Potentiometer: When current flows through a resistor, the resistor converts the current to heat and decreases the current until it regains it from the power source after a completed circuit. The resistor makes it hard to pass through due to its internal path blocking the electron flow and causing them to collide with the interior of the resistor and other electrons, converting energy to heat. When the electrons make their way back to the source, they regain their initial current value. **A potentiometer is a variable resistor (a manually controlled resistor). Potentiometers are to adjust the resistance and the current in a circuit.** A potentiometer consists of three pins: a ground pin, a power pin, and a signal pin. The signal pin is connected to an adjustable wiper. The position of the wiper can be manually controlled with an adjustable knob, which determines the resistance value of the potentiometer, hence, controlling the amount of current flowing through.

Relay Module: A relay is an electrically operated switch. Traditional relays use an electromagnet to operate the switch. Relays are used when controlling a circuit using a low-powered signal or where several circuits must be controlled by one signal. **Relays ensure complete electrical isolation between the controlling and the controlled circuits.** When the electromagnet on the primary side is activated, it attracts an armature (its axle is on the barrier that separates the primary and secondary sides), which then pivots down to the electromagnet. On the secondary side, the armature pivots up and pushes a movable contact to a stationary contact, completing the circuit on both sides and permitting current to flow. A normally open relay is when the contacts are initially separated. In the relay module, power flows from the digital pin of the Arduino, through the optocoupler, and to the -DC ground. The primary side of the optocoupler turns on (an LED), and the phototransistor allows current to flow to the ground pin. The 5V from Arduino flows through the +DC pin relay module, the resistor, the phototransistor, and to the ground. The current also flows through the resistor, through the transistor, and to the relay. The relay, being normally open, closes to connect the common pin (which is a voltage source) and the normally open to activate the electromagnet it is connected to.

Electromagnets: An electromagnet is a magnet that can turn off and on. It is a wire wrapped around an iron core that will generate a magnetic field as current runs through it. In the model circuits, the coil wrapped around the iron core in each Arduino electromagnet allows current to flow through it and create a strong electromagnetic field. Therefore, it creates two magnetic poles on either end of the iron core. More electrons flow through the electromagnet by a greater current, creating a stronger electromagnetic field . The circuit of the model first has the signal pin connected to a resistor. The current flows through the resistor, then through another resistor that travels to the ground. Current also travels to the base of the transistor. The voltage from the second voltage regulator travels through the transistor and turns on the electronic switch. Then, the current travels through the electromagnetic coil and diode and back to the source.

The Circuit: The circuit to control the model consists of several parts: a voltage regulator that is connected to an Arduino MEGA, which is connected to a potentiometer, and eight relays in a relay module, which is connected to another voltage regulator, which is both (relay module and voltage regulator) connected to eight electromagnets. The circuit is shown in Figure 4.

First Model Arduino Program

```
/*
The code describes an array of eight relays that activate two at a time in a forward sequence and then repeat. How fast the relays increment is dependent on the value of the potentiometer (pot).
*/

//Define the pins of the relays
int relayPin[] = {2, 3, 4, 5, 6, 7, 8, 9};
//Define the pins of the pot
int potPin = A0;
//Set variable for initial relay value
int relayPlace = 0;
//Set variable for initial pot value
int potValue = 0;

void setup() {
  //Define all the relays as outputs
  for (int x = 0; x < 8; x++) {
    pinMode(relayPin[x], OUTPUT);
  }
}

void loop() {
  //Read the current value of the pot
  potValue = analogRead(potPin);
  //Map pot range with time duration
  potValue = map(potValue, 0, 1023, 200, 2000);
  //Turn on the first two relays
  digitalWrite(relayPin[relayPlace], HIGH);
  digitalWrite(relayPin[relayPlace + 1], HIGH);
  //Relays on until the delay is over
  delay(potValue);
  //Turn off the first two relays
  digitalWrite(relayPin[relayPlace], LOW);
  digitalWrite(relayPin[relayPlace + 1], LOW);
  //Turn on the next two relays and repeat
  relayPlace += 2;
  //Reset cycle when last relays turn off
  if(relayPlace >= 8) {
    relayPlace = 0;
  }
}
```

Second Model Arduino Program

```
/*
The code describes an array of eight relays that activate one at a time in a forward sequence and then repeat. How fast the relays increment is dependent on the value of the potentiometer.
*/

//Define the pins of the relays
int relayPin[] = {2, 3, 4, 5, 6, 7, 8, 9};
//Define the pins of the pot
int potPin = A0;
//Set variable for initial relay value
int relayPlace = 0;
//Set variable for initial pot value
int potValue = 0;

void setup() {
  //Define all the relays as outputs
  for (int x = 0; x < 8; x++) {
    pinMode(relayPin[x], OUTPUT);
  }
}

void loop() {
  //Read the current value of the pot
  potValue = analogRead(potPin);
  //Map pot range with time duration
  potValue = map(potValue, 0, 1023, 200, 2000);
  //Turn on the first relay
  digitalWrite(relayPin[relayPlace], HIGH);
  //Relay on until the delay is over
  delay(potValue);
  //Turn off the first relay
  digitalWrite(relayPin[relayPlace], LOW);
  //Turn on the next relay and repeat
  relayPlace += 1;
  //Reset cycle when last relay turn off
  if(relayPlace >= 8) {
    relayPlace = 0;
  }
}
```

How the Models and Circuits Work Together and Data Analysis

Procedure and How the First Model Works

To make the model, 3D print a hoop (acts as the outrunner rotor) with holes in the interior and sides. Insert cylindrical steel through the holes of the hoop (every four holes). The 3D platform that was used was Onshape and SOLIDWORKS. Next, 3D print a ring with an extended width (ring one). Ring one will have a smaller radius than the hoop, so the hoop can slide over ring one, with a gap between ring one and the hoop. 3D print a second ring (ring two) with a small width with a slightly larger radius than ring one, embedded with holes, that slides onto the exterior of ring one (ring one and two serve as a stator). **The interior of the hoop and ring two are embedded with small permanent magnets that face the same polarity toward each other. As a result, the hoop repels ring two and, hence, magnetically levitates around the stator.** The stator also has a 3D-printed base to hold up the system.

The hoop rotates by the electromagnets attached to the sides of the top of the hoop, held up by the base, and they induce an electromagnetic field in such a way (with programming) that forces the steel in the sides of the hoop to line up with the electromagnets. **There are eight electromagnets, four on each side, that line up with the side holes in the hoop (this is the electromagnet stator). One electromagnet on each side turns on simultaneously as a pair to induce an electromagnetic field in the steel in the hoop. The steel desires to line up with the turned-on electromagnet pair because the ferromagnetic material in the steel is attracted to the turned-on electromagnet pair. Once the steel lines up with the turned-on electromagnet pair, the electromagnet pair shuts off, and the other electromagnet pair in the path turns on to attract the hoop further.** The cycle repeats to make the hoop rotate.

The switching time delays of the electromagnets are controlled by the potentiometer, which control the speed that the rotor gets attracted. The electromagnets have a fixed amount of current running through them. When the potentiometer is at maximum resistance, the current travels to the Arduino at a minimum. The Arduino reads this minimum current flowing through its A0 pin and translates it to the maximum delay time in the electromagnet switching. Therefore, the amount of current flowing through the potentiometer determines the delay time for the electromagnet switching, and hence, the speed of hoop rotation.

Procedure and How the Second Model Works

An unexpected curveball hit the experiment when the initial model levitated but failed to rotate. The concept was present and clear, and the design worked, but the electromagnets needed to be stronger to rotate the weight of the hoop. **I could still perform the calculations and graph the results with the information I was given with the first model, but the rotation concept still needed to be proved.** I decided to break the model into two parts. **The first model demonstrated magnetic levitation because the hoop achieved magnetic levitation around the rotor.** However, the visual representation of how the hoop was supposed to rotate was absent from the model. **Therefore, another model was created to demonstrate rotation.**

The second model only needs to achieve the principle of showing that having electromagnets to the side can rotate the tire. The concept of levitation does not need to be shown again since the first model already proved it. **To show the electromagnets can attract the hoop forward, all that was needed was to attract a steel object forward because that steel material was the same as was in the sides of the hoop.** By creating a railway of electromagnets on each side, each slightly ahead of the other, the steel object (a ball) could be attracted to each magnet as a single magnet fired at a time. **One magnet fired on one side would fire and attract the ball, then it would turn off, and the next electromagnet, being on the opposite side and slightly ahead of the previous electromagnet, would attract the ball.**

The circuit for this design is identical to the first model. Although, only one electromagnet fires at a time instead. The design for the second model is as follows: The 3D-printed model has two rectangular prisms, one on the top and one on the bottom side. Four electromagnets slide into each box. A raised runway is between the two boxes, while one box is half an electromagnet ahead of the opposite side electromagnets, making the ball travel at a lesser distance between pulses. The time delays of the electromagnets are controlled by the potentiometer, which control the speed that the steel ball gets attracted.

Graph Analysis

Note: since the second model worked, it is most likely inferred that the first model would have worked if the electromagnets were strong enough. Therefore, the graph results will be discussed as if the first model was entirely operational.

Distance and electromagnet switching delay are inversely proportional. The hoop rotates quicker when the electromagnetic pulses have a shorter delay between the next electromagnet pair pulse. When given 60 seconds, a shorter delay time for the pulses of the electromagnets will lead to the steel having less waiting time, resulting in more hoop revolutions and a longer distance.

Velocity and electromagnet switching delay are inversely proportional. The hoop rotates quicker when there is a shorter delay between the electromagnet pair pulses. Also, velocity and distance are directly proportional to each other.

Angular velocity and electromagnet switching delay are inversely proportional. The same explanation from velocity applies to angular velocity since angular velocity is velocity divided by the radius.

Acceleration and electromagnet switching delay are inversely proportional. Since the hoop starts at rest, it accelerates to achieve a changing velocity. When the electromagnet switching delay decreases, the hoop has a greater velocity and, hence, a greater acceleration.

Angular acceleration and electromagnet switching delay are inversely proportional. The same explanation from acceleration applies to angular acceleration because acceleration and angular acceleration are directly related since angular acceleration is acceleration divided by the radius.

Current and electromagnet switching delays are inversely proportional. The Arduino reads the value of current flowing through its A0 pin and translates it to the delay time in the electromagnet switching.

Resistance and electromagnet switching delays are directly proportional. When the potentiometer is at a higher resistance, less current flows to the A0 pin of the Arduino. Hence, it increases the delay time of the electromagnet switching.

Electromagnetic field and temperature are inversely proportional. Every superconductor has their own parameters; this project focuses on YBCO. Decreasing the temperature of a superconductor increases the electromagnetic field.

Supercurrent and temperature are inversely proportional. Supercurrent is directly proportional to electromagnetic field in a superconductor. Therefore, when temperature increases, supercurrent decreases.

Calculations for Graph Data Points

The calculations were done using the first model because the purpose of the second model was to prove that the design of the first model still worked (which it did), regardless of whether the electromagnets were strong enough.

Distance vs. Electromagnet Switching Delay	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Angular Velocity vs. Electromagnet Switching Delay	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Velocity vs. Electromagnet Switching Delay	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Angular Acceleration vs. Electromagnet Switching Delay	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Acceleration vs. Electromagnet Switching Delay	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Resistance vs. Electromagnet Switching Delay	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Current vs. Electromagnet Switching Delay	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Temperature vs. Superconductor Electromagnetic Field	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Temperature vs. Supercurrent	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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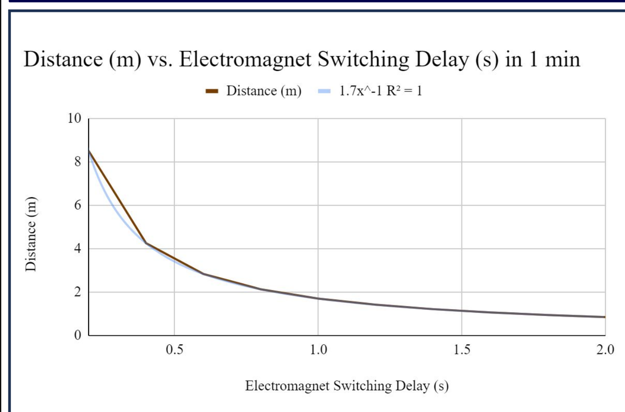
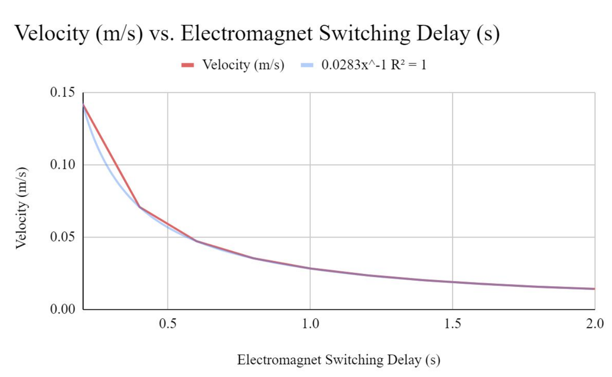
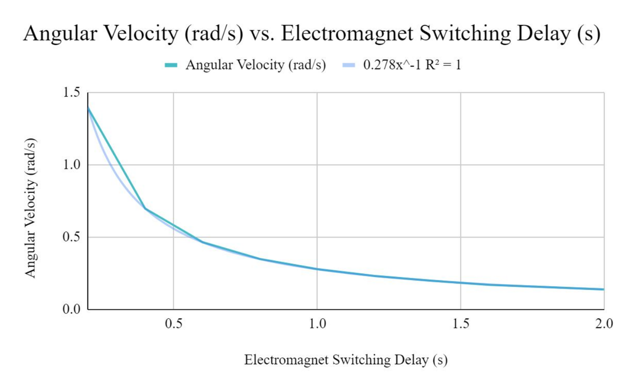
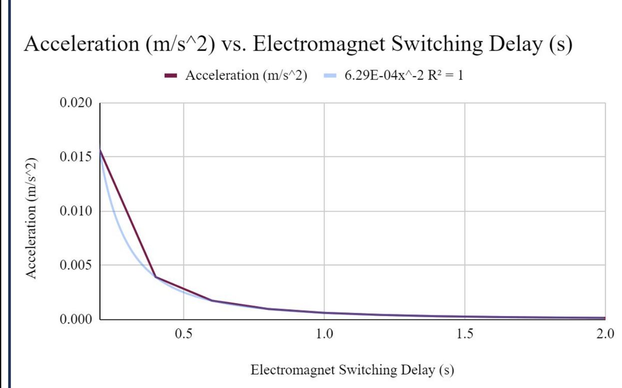
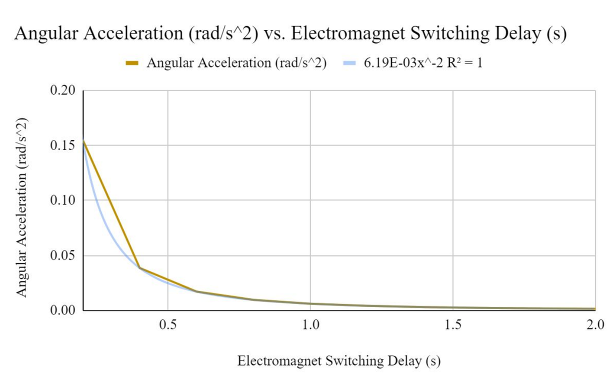
Graph Results

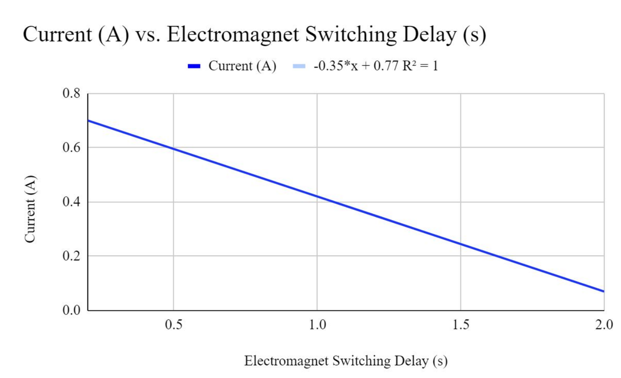


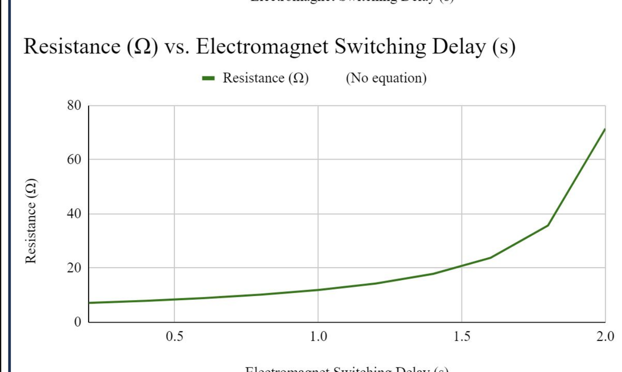


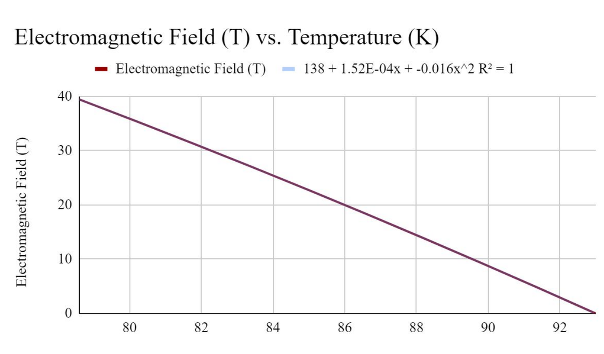


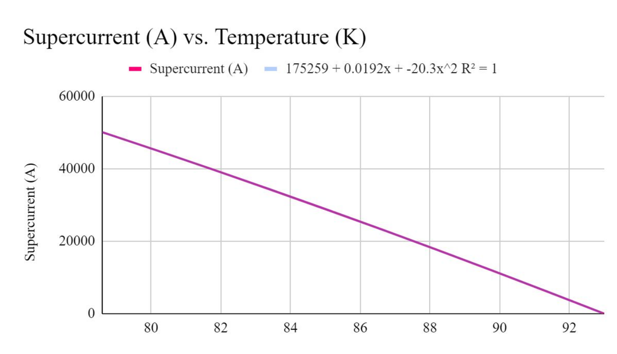












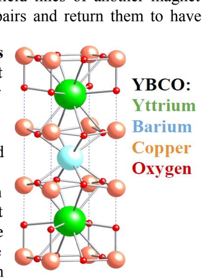
Car Design: High-Temperature Superconducting Tires Discussion

The Quantum Physics of Cuprate Superconductors

When superconductors reach their critical temperature, the lattice of positively charged ions in the superconductor stops moving because their mass is significantly larger than the electrons. The electrons move through this lattice of ions and attract the ions as they move through, which also attract other electrons. It is a long-range force that forms electron pairs called **Cooper pairs, which flow constantly through the superconductor with zero resistance and create a potent magnetic field. This is known as the Bardeen-Cooper-Schrieffer (BCS) theory.**

When a superconductor is close to a magnet, the magnet exposes it to a changing magnetic field. This induces a voltage that pushes electrons around as Eddy currents in a superconductor, creating a supercurrent, which makes it oppose outside magnetic fields. **These characteristics are found in a type I superconductor, which makes it so a magnetic flux cannot penetrate it, also known as the Meissner Effect. A type II superconductor has impurities that allow some magnetic field lines to pass through while also forcing some magnetic field lines around it, known as quantum locking. Quantum locking and the Meissner effect are the reasons for magnetic levitation.** Forcing a type II superconductor perpendicular to the magnetic field lines of another magnet changes its lattice and pins and levitates it in place. Higher temperatures will break apart Cooper pairs and return them to have electrical resistance.

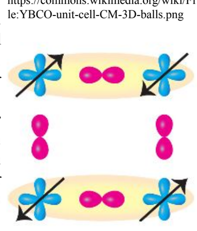
Cuprate superconductors are different from classical superconductors. **Cuprate superconductors are classified as high-temperature superconductors (HTS) because of their ability to superconduct at significantly higher temperatures than traditional superconductors.** Yttrium Barium Copper Oxide (YBCO) is a common cuprate superconductor. **HTSs create stronger Cooper pairs due to superexchange.** The BCS theory is inappropriate for explaining HTSs because conventional superconductivity uses phonons, which only achieve superconductivity up to 30K (HTSs can exceed 100K).



https://commons.wikimedia.org/wiki/File:YBCO-unit-cell-CM-3D-balls.png

Antiferromagnetism is when spins in a material oppose each other. Since both spins point in opposite directions, they cancel each other out. An antiferromagnet can develop a magnetic moment when placed near an external magnetic field because the spins tilt towards it. **Superexchange and the Pauli Exclusion Principle are the reasons for antiferromagnetism.** The Pauli Exclusion Principle states that two electrons paired in the same orbital of an electron shell must have opposite spin directions, eliminating any magnetic fields. Unpaired electrons (only one electron in an orbital) do align.

YBCO has two overlapping copper d-orbitals with one oxygen p-orbital in a Cu-O-Cu fashion. Unpaired electrons in the copper atoms do align. The oxygen between the copper atoms has a full orbital with one electron spin of +½ and the other -½. The copper and the oxygen atoms are bonded covalently, so the oxygen atom shares one of its electrons with one copper and its other electron with the other copper. **The oxygen electrons covalently bond with the copper are from the same oxygen orbital. Hence, one of the two oxygen electrons has the same spin as all the unpaired copper electrons.** However, the other oxygen electron has the opposite spin direction from the other electron in its orbital, and hence, the opposite spin to all the unpaired copper electrons. As a result, the copper atom sharing the oxygen electron with the opposite spin direction will have to spin all of its unpaired copper electrons to match the same spin as that opposite oxygen spin. **Therefore, one copper will have all its unpaired electron spins pointing in one direction while the other copper atom has its unpaired electrons pointing in the other direction. This is known as antiparallel spins, creating antiferromagnetism—superexchange results in antiparallel alignment and antiferromagnetism.**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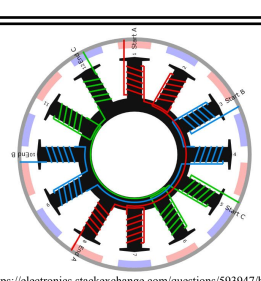
When a cuprate superconductor reaches a critical temperature, antiparallel alignment occurs between neighboring copper atoms, alternating their magnetic moments in an up-down-up-down pattern. When the temperature increases, the magnetic moments vibrate and disorient. The hopping of the oxygen electrons to the copper atoms creates the Cooper pairs. **The pair of oxygen electrons in the same orbital with opposite spins hop over to the Copper atoms to covalently bond with them that are bonded in a Cooper pair.** Also, the easier it is for electrons to hop from oxygen to copper atoms in a cuprate, the higher its critical temperature (and the Cooper pair attraction).

How Brushless DC Motors Work

Brushless DC motors rotate by the permanent magnets of the rotor being attracted to the electromagnetic coil phases of the stator. When a stator phase runs an EMF through it, the rotor and stator are attracted to each other. **The rotor nears one phase, the phase turns off, and the next phase turns on to attract the rotor in a circular path.** Connected to each phase are MOSFETs (electronic switches). **The internal controller receives these pulses and will open and close the MOSFETs in a particular order to energize the phases in the stator.** These pulses cause a rotating electromagnetic field; when the phases energize, the current reverses direction. The polarity alternates to maintain the repulsion and attraction between the rotor and stator magnets to continue the rotation. The faster the MOSFETs can open and close, the faster the rotation. The amount of current let through each pulse also controls the speed of the motor.


https://electronics.stackexchange.com/questions/593947/brushless-drone-motor-with-14-poles-and-12-coil-12-slot-stator

Achieving Magnetic Suspension and Rotation

How the tire works in the superconducting car is nearly identical to how the model works. Ring one and two represent the YBCO superconductor stator; the electromagnets represent the electromagnet stator; the hoop (and steel ball) represent the permanent magnet-based tire, and the potentiometer represents the gas and brake pedal. The superconducting car tire design is essentially a new motor design with two stators to rotate and levitate one rotor. The tire system is shown and explained in Figure 1.

Since YBCO is type II, some of the magnetic fields of the permanent magnets in the tires magnetic fields will penetrate through the impurities of the YBCO in the stator, while most of the magnetic fields of the permanent magnets go around the YBCO. The penetration and repellence of the superconductors with the permanent magnets will lead to the tire magnetically levitating and quantumly locking around the stator.

A rotor rotates whenever the electromagnet phases pulse an electromagnetic field in a brushless DC motor. The same situation occurs for the tire system. When the electromagnet phases pulse a strong electromagnetic field, the electromagnets exert rotational forces on the tire, which causes it to spin. During the electromagnet-induced rotation, the permanent magnets in the tire quantum lock and unlock with the YBCO superconductors in the stator while also repelling the superconductors due to the Meissner effect at extraordinary speeds. The electromagnetic coils would be connected to a controller, such as a pulse width modulator or MOSFETs, to manage speed and power. The time between the electromagnetic pulses determines the speed of the rotor, just as shown in the model.

How the Superconducting Tire Design is Efficient and Eco-Friendly

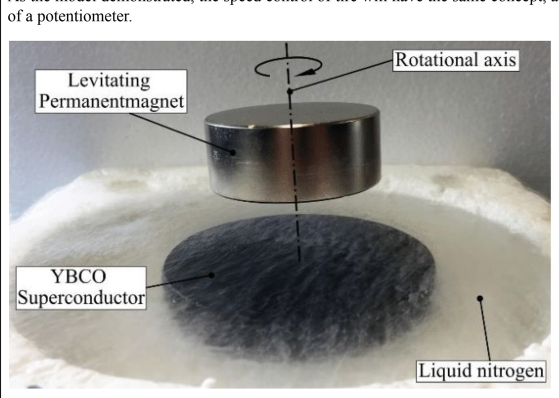
Traditional superconducting motors consist of an interior rotor (made of superconductor coils) and an exterior stator (made of electromagnets). **For a superconductor to become superconductive, it requires two things: to reach critical temperature and to be acted upon by an external magnetic field.** The superconducting coils need to be connected to external circuitry because they need a momentary electrical current running through them to create an electromagnetic field. However, once they reach their critical temperature, the electromagnetic field induced by the electrical current stirs up eddy currents in the superconducting coils. Then, the superconducting coil becomes superconductive, and the electrical current can shut off since a self-sustained supercurrent is running through the superconductive coils. **Electromagnets cannot be used to apply an external magnetic field to the superconductors because they cannot provide the constant external magnetic field needed during the superconductor cool-down process.**

On the other hand, when it comes to the superconductors in the superconducting car, no electrical current is needed to run through them. **Since the tires in the superconducting car are made up of permanent magnets, they provide the constant external magnetic field the superconductor coils require to transition into a superconductive state. In other words, no power source is needed for the superconducting coils, which saves energy, thus making it a more eco-friendly car.**

The superconducting car also has the characteristics of having zero friction. Since the tire does not have contact with the car during operation, the passenger feels no friction since the maglev tire system absorbs the impact of a bumpy road. **With that, the noise of the car and the impacts of the road will be minimized. The reduced bumpiness and lack of resistance also account for a safer operation.**

With zero friction, the electromagnets only have to do a limited amount of work to move the car due to no axles or contacts, versus electromagnets having to overcome the friction and the contact of the wheels with the car. **In theory, this efficiency can lead to decreased work for the electromagnet stator, giving it a longer life and, hence, giving the sodium ion battery a longer life. This also creates a more eco-friendly car since minimum power is being used.**

Also, the speed of the superconducting car is controlled by a control module that reads the gas and brake pedal pressure. As the model demonstrated, the speed control of tire will have the same concept, although the vehicle has a gas and brake pedal instead of a potentiometer.



https://www.researchgate.net/figure/Passive-magnetic-levitation-Levitating-permanent-magnet-above-an-YBCO-superconductor_fig2_335995569


Superconducting motor. https://www.azom.com/article.aspx?ArticleID=20909

Car Design: Keeping Critical Temperature Discussion

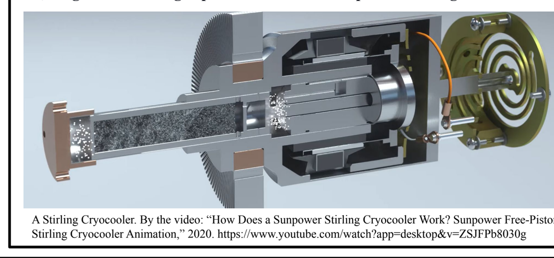
Stirling Cryocooler RS100-77K

I chose YBCO for the superconducting stator because it reaches superconductivity at higher temperatures than traditional superconductors. Because of that, liquid nitrogen can be employed to cool the superconducting stator. Liquid helium is rare and expensive and has to be used to cool traditional superconductors. **The use of liquid nitrogen makes this car even more efficient.**

The YBCO superconductor has a critical temperature of 93K. **The best cryogenic liquid to cool YBCO down to its critical temperature is liquid nitrogen**, which has a temperature of 77K. For the car's superconducting stators to remain in their superconducting state, they must remain cooled during operation. Thus, a cooling mechanism must be utilized.

The best cooler for high-temperature superconductors is the Stirling Cryocooler RS100-77K. It is a new member of the green power Stirling microcoolers family. **The Stirling Cryocooler has a reputation for being one of the best coolers for high-temperature superconductors since it is designed for reliable and eco-friendly liquid nitrogen production by utilizing pressure differences. It is also very compact and lightweight**, making it even more appealing to use in a car. It is a long-term cryocooler that can operate for over 50,000 hours. It is designed to withstand harsh conditions while minimizing vibration and reducing noise levels to ensure optimal functionality.

In the car, liquid nitrogen would coat the exterior of the YBCO superconductor stators to keep them at a critical temperature. YBCO superconductors can still absorb heat from their surroundings through radiation. To avoid further heat absorption, a radiation shield with a vacuum is closed around the superconductor stator. The radiation shield is then cooled by a separate cycle of liquid nitrogen. **Temperature sensors and control systems will continuously regulate and maintain a constant liquid nitrogen temperature.** Also, the magnetic fields of the superconductors can lead to health hazards. **To keep the passengers safe, magnetic shielding is placed between the superconducting units and the passengers.**


A Stirling Cryocooler. By the video: "How Does a Sunpower Stirling Cryocooler Work? Sunpower Free-Piston Stirling Cryocooler Animation," 2020. https://www.youtube.com/watch?app=desktop&v=ZSJFPb8030g


RS100 PRO 77K Stirling Cryocooler. From RIGID® HVAC Co. https://www.rigidhvac.com/77k-stirling-cryocooler

Car Design: Power Supply Discussion

Sodium-Ion Batteries

The superconductor car requires a power supply to power the electromagnets, Stirling Cryocooler RS100-77K, dashboard, lights, and other electronics. Electric cars, like Teslas, use lithium-ion batteries.

Tesla cars use standard lithium-ion cells to power their vehicles. The cells are connected in a combination of series and parallel. Glycol coolant is run through the inner tubes through the gap between the cells. Adequate cooling is achieved using many small cells instead of a few giant cells. The cooling techniques minimize thermal hot spots, leading to longer battery pack life. The cells are arranged as detachable modules. There are 16 modules with a total of 7000 cells. All the modules are laid out flat, covering the entire car floor.

Lithium-ion batteries have a high energy density, lightweight composition, and rechargeability. **However, there is a limited supply of lithium, and the extraction of lithium and other transition metals (cobalt or nickel), essential for these batteries, involves water-intensive and mining practices that cause significant pollution**—lithium-ion batteries are complex and costly to recycle. As a result, most of these batteries end up in landfills, making them hazardous waste.

Sodium-ion batteries can replace lithium-ion batteries. Sodium-ion batteries are recent in production and are currently being implemented for optimal application performance. Because of ocean salt, sodium is one thousand times more abundant than lithium. Chemists have engineered sodium-ion batteries so they do not require cobalt or nickel, making them easier to recycle.

Both the lithium-ion and sodium-ion battery work very similarly. When the electron is given up from the sodium atom in a sodium-ion battery, the electron travels through the salt bridge circuit, flowing as an electrical current. The sodium cation takes a different path through an electrolyte. **The separate flow of electrons and ions is essential to how the battery stores and releases energy.** Recharging the battery is reverse electrolysis.

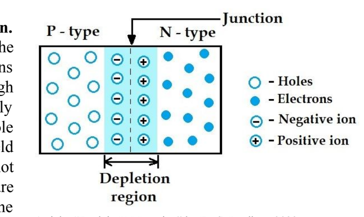
The battery design of the superconducting car is similar to that of the Tesla car. However, the battery cells are sodium-ion versus lithium-ion. The cells can be placed in a block module or on the floor of the car (depending on the counterweight). To keep the cells cool from overheating, a path of liquid nitrogen runs through them from the cryocooler, too.

Solar Panels

A drawback of sodium-ion batteries is that they have a lower voltage compared to lithium-ion batteries. Sodium-ion batteries have enough power to power a car, but larger car applications require extra power.

Adding solar panels to the roof of the superconducting car will help it reach its power requirements. The sodium-ion battery and solar panels form a hybrid power supply system with enough energy to power the car. Solar panels are a highly reliable technology that provides long-term, clean, renewable energy.

Solar panels are made up of solar cells, which are made of silicon. Each silicon atom is covalently bonded to other silicon atoms, keeping all the silicon atoms in place so no current can flow. Light is made up of photons shooting out from the sun. When a photon strikes a silicon cell with enough energy, it can knock an electron from its bond, leaving a hole. The negatively charged electron (creates N-type silicon) and the positively charged hole (creates P-type silicon) are now free to move around. The electric field generated by the P/N junction (where the two types of silicon meet) does not allow the electrons to flow across it, only the holes. Still, the electrons are attracted to the holes. External wires connect to the N side to the P side. The electrons flow through the wires, powering any device in its path to the P side to fill the holes.



Article: "Explain PN Junction" by Er. S. Pradhan, 2022. https://specbee.net/explain-pn-junction/

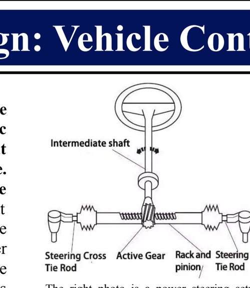
For energy in a solar panel to be stored for when the power is needed, it is stored in a battery. This battery can be sodium-ion. Referring back to the superconducting car, the solar panels can offer additional current when the battery needs it. Another option for solar panels is for them to directly power the Stirling Cryocooler RS100-77K while the battery powers everything else. **If the power from the solar panels ever runs out at night, the sodium-ion battery can supply power to the cooling system so the car does not fail, ensuring safety.**

Combining sodium-ion batteries and solar panels as a hybrid power system to power the superconducting car creates a reliable and sustainable power system. **The hybrid approach allows a renewable energy power source. The power system will last longer than the average lithium-ion battery and be significantly more eco-friendly.**

Car Design: Vehicle Control Discussion

Steering

Rack-and-pinion steering is the mechanism for modern cars. Electric motor assisting power steering is what makes the steering easy and accurate. The superconducting car uses the same mechanism. However, the contacts that provide the steering movement are connected to an arch that extends over the tire versus making contact with the tire (since there are no frames). The ends of the arches are connected the the ends of the superconducting stators. When the stator turns, so does the wheel.



The right photo is a power steering setup. https://www.youtube.com/watch?v=em1O8mz7sF0. The top photo is rack-and-pinion by: https://steeringly.com/steering-system-components/


Power steering (attached to the steering wheel shaft): an electronically controlled motor rotates a worm gear, which rotates a planetary gear set in a ring gear, so planetary gears are not directly connected to the motor; so, if the motor locks, the steering does not.

During the steering, the electromagnets should be strong enough to keep the tires centered to prevent them from smashing into one side of the tire suspension system. Multiple electromagnet pairs fire at the same time to keep a tire center. The electromagnets are vital, especially since they are identical to those used in the brushless DC motors of some electric cars. Thus, the electromagnets should have no trouble keeping the tires centered.

In an electromagnet pair, one electromagnet is on one side of the tire, and the other is on the other. **To guide the tire to stay in the center of the tire system, the electromagnet pair is connected via a wire to always share an equal electromagnetic field strength. Hence, one is not more potent than the other and pushes the tire into one of the sides. This method will work in the superconducting car because the same method is used to keep the L0 Series Maglev train in the center of its path.**

Braking and No Operation

The stopping mechanism for a superconducting car is to slow down the time duration between the electromagnetic pulses. The faster the pulses, the faster the rotation. In order to make the car stop faster, the reverse direction of electromagnetic fields can assist. **Reversing the direction of the electromagnet stator pulses will reverse the direction of the tires, too (backing up).**

Reversing the polarity of a electromagnetic field of the electromagnet stator can slow down, stop, or change the direction of the tires spinning force. There will be situations where one may wish to stop the tires of the car quickly to stop the car quickly, but there is no electric or mechanical brake installed in the superconducting car. **Reversing the polarity of the supply voltage in the electromagnetic stator will produce a force in the opposite direction, helping the tire to stop quickly.** This braking system will be controlled by a controller that reads the pressure from the braking pedal and transfers the signals to the electromagnet stator to either reverse direction (the tire will not achieve complete reverse direction, but it will slow down) or slow down the pulses. This system will especially be helpful downhill.

When the superconducting car is not operating, the superconductors will be off. Hence, the tires will not be magnetically levitating, and the car will crash down on the tires. To prevent this, six linear actuators equally spaced on the perimeter of the car frame will vertically extend out of the bottom of the car and hold it up. This design is similar to the poles that extend out of campers to level them and hold them in place. For the tires to not fall on the stator, actuators will extend out of the car frame horizontally and run through the gap between the tire and the stator to hold the wheel in a fixed position and prevent it from falling on top of the stator and damaging it.

Conclusion

Overview of the Project

This project aimed to invent a more efficient and eco-friendly car to decrease global warming. Global warming is a significant threat to the environment that needs to be mitigated. Gasoline cars threaten the environment by releasing fossil fuels and carbon dioxide into the environment, which gets caught in the Earth's atmosphere and warms it. Electric vehicles are no better than gasoline cars because they utilize lithium-ion batteries, which involve water-intensive and mining practices that cause significant pollution.

The car proposed in this project is built upon the principles of high-temperature superconductivity (HTS) suspension based on the tires. The tires are isolated from the car and make no contact with it during operation. **The tires, which have permanent magnets in their sides and interior, magnetically levitate around an HTS stator for frictionless movement, and electromagnets are also employed as a second stator on the sides, which rotate the tires.**

Model Experiments Conclusion

Two models were built to demonstrate the tires of the car. The first model showed magnetic levitation suspension by having permanent magnets lined in the interior of the rotor (hoop) (demonstrated as the tire) and the exterior of the stator (demonstrated as the YBCO superconductor stator) and rotation with electromagnets (demonstrated as the electromagnet stator) lined on either side of the hoop at the top. The hoop also had embedded steel material on its sides that interacted with the electromagnets to rotate. My hypothesis did not go according to plan, but the concept behind it still held. **Initially, there was only one model, but the first model only demonstrated magnetic levitation suspension rather than the rotation aspect.** The rotation of the hoop did work, but it was not noticeable because the electromagnets were not strong enough.

The second model demonstrated the rotation of the tires by placing electromagnets (demonstrated as the electromagnet stator) on either side of a steel ball (demonstrated as the hoop of the first model and, hence, the tire) to pulse in a sequence that attracted the ball forward. **Since the first model already showed magnetic levitation suspension, the second model just needed to demonstrate the rotation since the first model could not display it. The steel ball being able to be pulled forward by the electromagnets shows that the hoop of the first model would have moved forward if the electromagnets were strong enough, thus demonstrating that the two models as a whole successfully showed that the rotation of the tires in the superconducting car would work.**

For the models to work, both used the same circuit with slightly modified code. Each circuit consisted of two 9V batteries, two voltage regulators, one Arduino MEGA, one 8-relay module, one potentiometer, and eight electromagnets. In this experiment, the potentiometer controlled the electromagnet switching delay to attract the hoop. **The amount of current flowing through the potentiometer determines the delay time for the electromagnet switching.**

Superconducting Car Invention Conclusion

Relating all these relationships to the tires of the superconducting car, the speed is controlled by a control module that reads the gas and brake pedal pressure. The model demonstrated that the speed of the hoop was controlled by electromagnet switching delay. **This design is identical to the design utilized in the car. The potentiometer in the model was demonstrated to be the gas and brake pedal of the superconductor car. Furthermore, the model also demonstrated that the YBCO superconducting stator would work in the car since the permanent magnet stator worked to levitate the hoop in the model; the electromagnet stator would also work because it was able to attract the steel ball forward, which demonstrated the hoop being able to rotate, which demonstrated the tire in the car being able to rotate.**

Based on the models, several relationships were calculated and graphed. Distance vs. electromagnet switching delay, velocity vs. electromagnet switching delay, angular velocity vs. electromagnet switching delay, acceleration vs. electromagnet switching delay, angular acceleration vs. electromagnet switching delay, current vs. electromagnet switching delay, resistance vs. electromagnet switching delay **were all demonstrated by the models and showed how the superconducting car also has speed control and accurate principles that all vehicles have.** Also, electromagnetic force vs. temperature and supercurrent vs. temperature were graphed to show how the YBCO superconductors would work in the superconducting stators of the car.

The superconducting car also has the characteristics of having zero friction. The passenger feels no friction since the maglev tire system absorbs the impact of a bumpy road. **With that, the noise of the car and the impacts of the road will be minimized. The reduced bumpiness and lack of resistance also account for a safer operation.** With zero friction, the electromagnets only have to do a limited amount of work to move the car. **In theory, this efficiency can lead to decreased work for the electromagnet stator, giving it a longer life and, hence, giving the sodium-ion battery a longer life. This also creates a more eco-friendly car since minimum power is being used.**

The superconducting car utilizes the Stirling Cryocooler RS100-77K, solar panels, and sodium-ion batteries to make the vehicle completely eco-friendly. The Stirling Cryocooler RS100-77K (efficient and eco-friendly) cools down the YBCO superconducting stators with liquid nitrogen to keep the superconductors at critical temperature while the car operates. The solar panels and the sodium-ion battery power the car. This hybrid power source is exceptionally sustainable since sodium-ion batteries are far more sustainable than lithium-ion batteries, and solar energy is clean. Like those used in cars today, a steering system is also utilized in the superconducting car. Actuators hold the superconducting vehicle in place when the car is not operating so the car does not crash down on the tires once the refrigeration cycle turns off. The electromagnet stator also keeps the tires centered. Lastly, the braking system utilizes reverse electromagnetic fields to slow or stop the vehicle, similar to how brushless DC motors brake and reverse.

Overall, this project proposed a new theoretical design for a car that was successfully modeled to work. This project aims to one day make this car a reality to help decrease global warming.

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