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RESPONSIBLE DEPLOYMENT OF A PROJECTILE DEVICE IN SOCIETY: THE WAR MACHINE ANALOGY

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ABSTRACT

The superhero genre includes numerous examples of highly advanced technologies such as the Iron Man suit, the trick arrows used by Hawkeye, and the shrinking suit of Hope van Dyne (the Wasp). Another technology is the War Machine suit – an exoskeleton suit worn by Colonel James Rhodes. The War Machine suit is home to a plethora of weapons such as a Gatling gun. In this paper we present a prototype of a projectile device based on coils, which we constructed ourselves, that can replicate the projectile capability of a traditional projectile device. However, unlike traditional projection technologies, we imagine that this device could be used for the benefit of society to improve transportation systems and upgrade space travel.

PROLOGUE

On the streets of Novi Grad – the capital city of Sokovia – the Avengers struggle to deal with Ultron's robotic army. As the city levitates through the clouds, the Sokovians are perplexed by what is happening to their city. Despite striving to save the lives of hundreds of innocent civilians, Steve Rogers and the rest of the Avengers don't have a viable solution. Fortunately, help is on its way in the form of a forgotten SHIELD Helicarrier, and on-board is Colonel James Rhodes – one of Tony Stark's friends who is about to join the cause as the War Machine.

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INTRODUCTION

The War Machine suit worn by Col. James Rhodes is an exoskeleton suit designed and built by Tony Stark, better known as the wearer of the Iron Man suit. Just like Tony Stark and the Iron Man suit, Colonel James Rhodes and the War Machine suit [1] have featured in a number of films from the Marvel Cinematic Universe (MCU) such as Iron Man 2, Avengers: Age of Ultron, Captain America: Civil War, and Avengers: Age of Ultron. Similar to the Iron Man suit, the War Machine suit protects the wearer and contains a multitude of medical and control technologies that can also be found in the Iron Man suit [2, 3]. Nevertheless, Rhodes' War Machine suit differs from the Iron Man suit particularly as it includes a number of additional weapons. One of the main weapons in the suit is a Gatling gun, which is a rapid-fire spring-loaded weapon located on the shoulder of the War Machine suit.

In this paper, we present a method for building a projectile device similar in structure and capability to War Machine's Gatling gun. Unlike War Machine's Gatling gun, our device can fire a projectile without the need for gunpowder. The device has been built using a limited budget of approximately €1,000. Rather than using this technology for destructive means, we contend that the gun's underlying technology can be used for the benefit of society such as in urban transportation and for sustainable space travel. First, we outline the building process for the projection device. Then, we present some results showing the capability of the device. Thereafter, we describe how the device's technology can be used for good and the betterment of society.

BUILDING THE PROJECTION DEVICE

According to Dutch Statutes [4] "a gun is a weapon if it fires a projectile using air pressure or gunpowder." For this work, we have built a device with similar capabilities to a traditional firearm that could fire projectiles without the need for air pressure or gunpowder. We emphasise that we do not wish to promote the use of the technology outlined in this paper for firearms of any kind in the future. Instead, we explore alternative technologies that could be use to project items in a safe manner without the need for explosive matter or gases under extreme pressure.

Our projection device is based on a series of three electromagnetic coils that together act to accelerate a small projectile passing through a tube surrounded by the series of coils (see Figure 1). There are a number of examples of projectile devices based on coils in the literature [5-7]. Our apparatus is built using the following materials and components:

- 15 metres of copper wire;
- One 500 volt (V) power supply unit of 500 volt;
- One PVC (Polyvinyl chloride) tube with a 1.5 cm diameter;
- 6 multimeters;
- 6 switches;
- 6 capacitors (with a capacity of 3300μF and 350 volt);
- 3 Silicon Controlled Rectifiers (SCRs) or thyristors;
- and an Arduino Uno starter kit [8].

To optimise the operation of the coil-based projection system, the electrical resistance of the coils must be minimised since a large resistance leads to a smaller current (as per Ohm's law). This is important since the electrical current is directly proportional to the speed of the projectile. Our configuration consists of three coils that generate a large electric current, which in turn leads to the creation of a magnetic field in the coil. This magnetic field acts to draw metal objects towards its centre. Starting with the first coil, when the projectile reaches the middle of the coil, we switch off the current running through the coil to ensure that the projectile

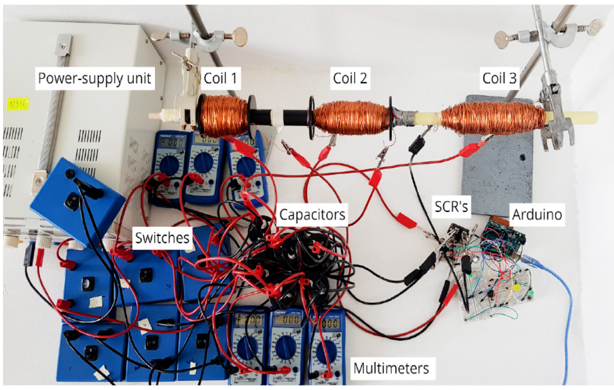

Figure 1: The projectile device with labels for the various parts of the device.

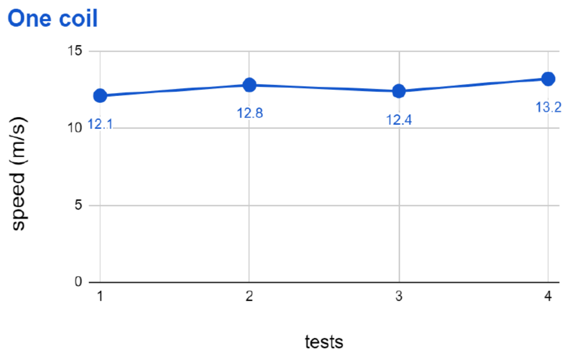

Figure 2: Speed of a projectile accelerated with one coil for four different tests.

continues moving in one direction. We apply the same process to the second and third coils when the projectile moves through the coils. This can result in projectiles exiting the third coil at a speed of approximately 80.46 km/h (22.4 m/s).

To control the activation and deactivation of the coils we utilise an Arduino Uno microcontroller board. The computer program used to control the operation of the projection device is written in s++ (see Appendix for the computer code used to control the projectile device). Operation of the device proceeds as follows. First, the device is turned on using a control switch, which activates an alarm to warn anyone in the vicinity that the device will activate in a matter of seconds. Thereafter an electric current activates the first SCR that completes the electrical circuit. Next, current flows through the coils following the discharging of capacitors. The projectile is forced into the middle of the first coil. Then some milliseconds later the second SCR activates leading to the movement of the projectile into the second coil. Finally, the third SCR activates after the second coil and moves the projectile into the centre of the third coil. The optimum time delays between the activation of adjacent coils (1→2 and 2→3) are explored in the next section.

RESULTS

Although our final design for the projectile device consists of three coils, we also measured the speed of projectiles accelerated using configurations with one coil and two coils.

The speed of a projectile after passing through a coil was measured using two light gates. A light gate consists of an optical transmitter and a receiver where the transmitter emits a light signal that is detected by the receiver. When an object passes between the transmitter and the receiver, the light signal is broken and the time for this interruption is recorded. For our measurement, we set up two light gates (LG_1 and LG_2) a distance d_{12} apart. The projectile then passed through LG_1 and LG_2 at the times t_1 and t_2 respectively. Thus, the speed of the projectile over d_{12} is given as $v_{12} = d_{12}/(t_1 - t_2)$.

Figure 2 shows the speed of a projectile over four individual tests for a device with one coil. The maximum speed reached by the projectile was roughly 13.2 m/s (test 4). Next, we investigated the speed of the projectile in a device with two coils. Figure 3 shows the variation of the speed of the projectile with the time delay between the activation of the first and second coil. The figure suggests that the maximum speed is reached when the delay between activating the coils is between 12 milliseconds (ms) and 14 milliseconds (ms).

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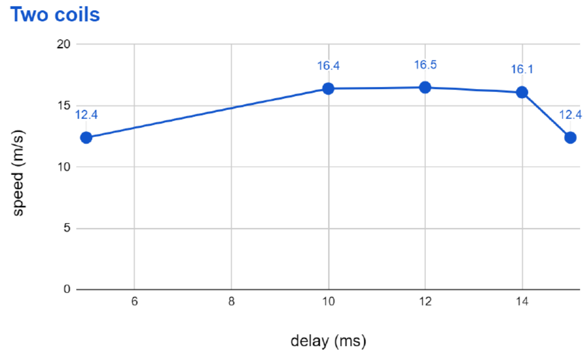

Figure 3: Speed of a projectile accelerated with two coils and different delay times between the activation of the first and second coils.

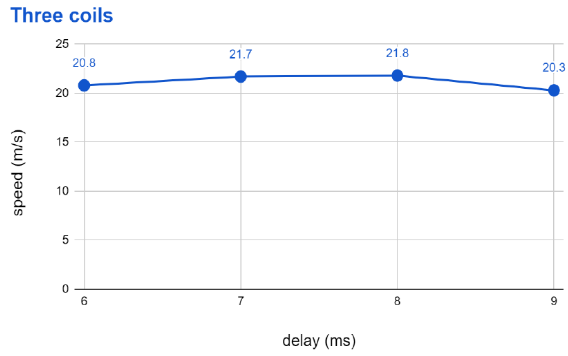

Figure 4: Speed of a projectile accelerated with three coils and different delays between the activation of the second and third coils.

Finally, we tested the projection device with three coils and varied the delay time between activating the second and third coils (Figure 4). For our tests, the projectile reached a maximum speed when the delay between the activation of the coils was 8 ms.

Evidently from Figures 3 and 4, the speed of the projectile increases as the delay between the activation of successive coils increases. However, if the time delay is too long, the speed of the projectile decreases. This takes place because an excessive delay will lead to the projectile being forced back into the middle of the coil that it has just passed through. Hence, the speed of the projectile is reduced.

The operation of this device could be improved by cooling the coils down with nitrogen. This would reduce the resistance, creating a stronger magnetic field and leading to an increase in the speed of the projectile. If there is superconductivity, the speed converges on a maximum value that is limited in theory by air resistance.

RESPONSIBLE USE OF THE PROJECTILE DEVICE

While this projectile device has been fundamentally designed to replicate the operation of a traditional firearm, we do not promote the use of this device as a weapon. Instead we envisage that this device could be used in the design of innovative mobility and transport systems. For instance, if this technology could be safely scaled upwards, this technology could be used as part of future metro systems where electromagnetic coils accelerate and decelerate passenger trains in tubes between adjacent stations. Such a transport system is not reserved for the realms of science fiction. A number of companies around the world are exploring the development of Hyperloop technologies [9] – an idea that is being promoted by Elon Musk [10]. The Hyperloop involves the motion of magnetically levitating passenger pods or capsules through a sealed evacuated (airless) or partially evacuated tube. This approach effectively eliminates contact friction and air resistance during motion, thus allowing capsules to travel at high speeds.

A notable difference between our projectile device and the Hyperloop is that our system does not need a vacuum. Thus, it may be cheaper to operate. However our approach would still have to contend with air resistance and as a result passenger capsules might not reach the speeds predicted for the Hyperloop.

This technology could also be used to deal with some of the space debris and junk that originates

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from the deployment of rockets to space [11]. If the projection device could be suitably adjusted, it is conceivable that it could be used to launch payloads into space without the need for expensive fuel-burning rockets. This is just a proposal and undoubtedly there would be technical issues to be overcome before our device could be used to safely and reliably launch missions to space.

CONCLUSION

In this paper, we have presented details of a projectile device based on electromagnetic coils. Notably, the device does not need gunpowder to fire a projectile, which means that there is no explosion when firing. In the MCU, James Rhodes wears the War Machine exoskeleton suit – a suit that has a Gatling gun on the right shoulder. We believe that our device resembles this Gatling gun. While our device has been designed to fire projectiles, we believe that it should be used for responsible applications in society such as in transport systems or for space exploration.

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APPENDIX

Below is the C/C++ computer code used to control the projectile device.

```
const int buttonPin = 2;
const int buzzer = 8;
int buttonState = 0;
bool done = false;
int reset = 3;
```

```
void Setup()
{
  digitalWrite(reset, HIGH);
  delay(200);
  pinMode(reset, OUTPUT);

  pinMode(13,OUTPUT); //LED
  pinMode(8,OUTPUT);
  pinMode(4,OUTPUT); //ACTIVATE SCR
  pinMode(9,OUTPUT); //ACTIVATE SCR 2.0
  pinMode(11,OUTPUT); //ACTIVATE SCR 3.0
  pinMode(buttonPin, INPUT);
  pinMode(buzzer, OUTPUT);
}

void Loop()
{
  buttonState = digitalRead(buttonPin);

   if (buttonState == HIGH && done == false)
   {

     digitalWrite(13, HIGH);

    OnHold();
    } else {
    //Turn LED off
    digitalWrite(13, LOW);
  }
}

void OnHold()
{
  tone(buzzer, 800);
  delay(1500);
  noTone(buzzer);
  int pitch = 810;
  for(int i = 1; i <= 70; i++){
    int time = 800/(pow(i,0.75));
    pitch = pitch * 1.005;
    delay(time);
    tone(buzzer, pitch);
    delay(time);
    noTone(buzzer);
  }


  tone(buzzer, toonhoogte);
  done = false;
  delay(750);
  ActivateSCR();
  delay(2000);
  noTone(buzzer);

  digitalWrite(reset, LOW);
}

void ActivateSCR()
{
  digitalWrite(4, HIGH);
  delay(2);
  digitalWrite(4, LOW);
  delay(12.85); //DELAY SECOND COIL
```

```
  digitalWrite(9,HIGH);
  delay(2);
  digitalWrite(9,LOW);
  delay(8); //DELAY THIRD COIL
  digitalWrite(11,HIGH);
  delay(2);
  digitalWrite(11,LOW);
  done = true;
}
```

CRediT (CONTRIBUTOR ROLES TAXONOMY)

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