Improved Electromagnetic Can Crusher

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Introduction

We have improved the previous model of the Electromagnetic Can Crusher. Its intended purpose is, to crush aluminum cans using an electromagnetic field. The device does so by releasing current through a conductive coil (solenoid) wrapped around the can in a short period of time. We have achieved our main goal by improving its functionality and safety. The previous design failed to do more than pinch the can. We have enhanced the machines' can crushing capability.

Theory

The electromagnetic can crusher relies on Faraday's law of induction. Faraday's law, as shown in Equation(1), states that the induced electromotive force in a closed circuit is equal to the negative time rate of change of the magnetic flux ($\frac{d\Phi_B}{dt}$) through that circuit. The negative is sign is required by Lenz's Law, which states an EMF always gives rise to a current whose magnetic field opposes the original change in magnetic flux. This is due to the circuit obeying Newton's third law ($F = \dot{p}$) and the conservation of energy. N Is the amount of loops within our solenoid.

Faraday's Law of Induction

$$\boldsymbol{\varepsilon = -N\frac{d\Phi_B}{dt}} \quad \text{Equation (1)}$$

$$\boldsymbol{V_b = \frac{apd}{ln(pd)+b}} \quad \text{Equation (2)}$$

In Paschen's law, shown in Equation 2, p is the pressure in atmospheres, V_b is the breakdown voltage given in volts, d is the gap distance in meters and a, b are constants for air at standard atmospheric pressure. The four capacitors we are using are rated for 450 V and have 15,000μF. When the capacitors reached maximum safe capacity at 410 V. They were discharged as quickly as possible using a hammer trigger that we designed. This voltage will create a current, and a magnetic field that will rapidly increase with time within the coil. This rapid change in the magnetic field with respect to time will create an electromotive force that will induce another current within the can. These two currents, will also induce magnetic fields opposing each other, creating a Lorentz force pushing inward on the can and outward on the coil. Once this force is overcomes the cans natural structural resistance the can will be crushed.

Methods

Our first step was to test original model, we tested the previous can crusher to observe the existing mechanics and begin the process of designing a new and improved system. We started taking data of the magnetic flux within the solenoid, the resistance within the wiring as well as the physical appearance of cans. When we discharged the system we measured the change in magnetic flux with respect to time using a fluxmeter and DataStudio. We also measured the time it took for all the energy to be discharged from the capacitors. Given the amount of loops in the previous model, it was easy to calculate the induced electromagnetic force on the system.

The changes we made to the electrical circuit was in its triggering mechanism and the addition of another capacitor. The addition of the extra capacitor (as seen in Figure 1) increased the capacitance of the system to 60,000μF from 45,000μF more charge to be released.

S1	Power Switch	
DB1	Diode Bridge	25A, 600V
T1	Transformer	120V-300V 75mA
R1	Risistor	3,750 ohms, 25W
R2	Risistor	3,900 ohms, 25W
C1, C2, C3, C4	Polarized Capacitors	15,000 microfarads, 400V
L1	Copper Coil	3 Turns
V1	Voltage Source	120V
V2	New Spark Gap	
V	Internal Voltmeter	

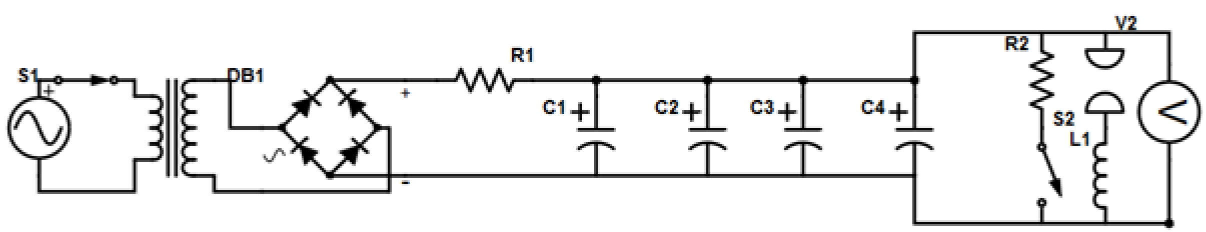

Figure 1. Circuit Schematic

The preexisting trigger was a simple switch, and it was felt that this triggering system was unsafe. We attempted to implement a spark gap trigger system consisting of a bolt facing a fender washer mounted by two L-brackets, as seen in Figure 2.

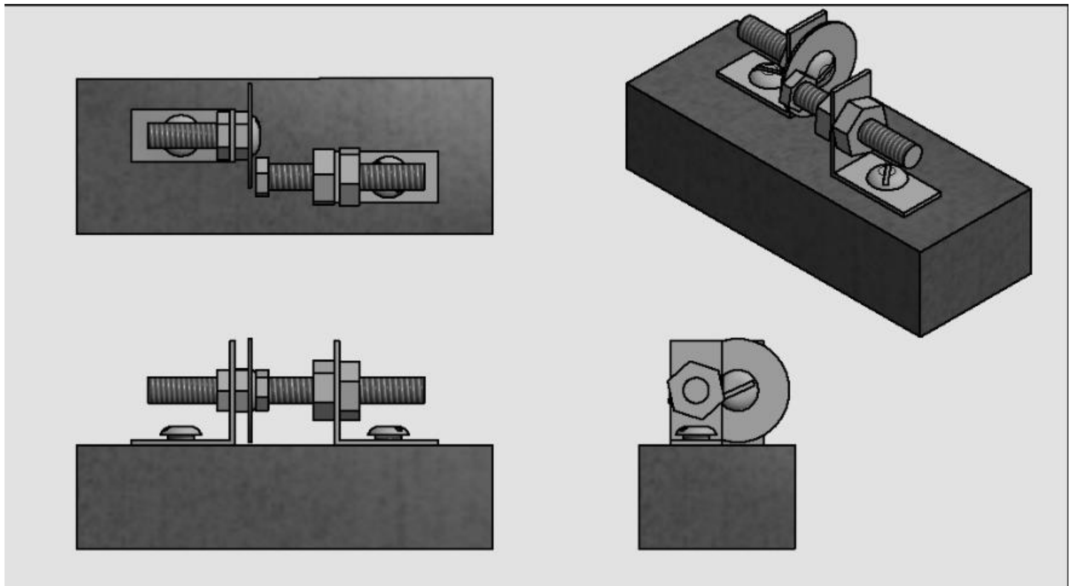

Figure 2. Spark Gap Schematic

The washer remained stationary while the bolt was adjustable to allow less or more distance in the spark gap. The gap was calculated based on the desired voltage and the breakdown field of air. See Equation 2. When we attempted to set off the system using our originally designed spark gap, no plasma was able to arc the calculated gap: a tenth of a millimeter. We tried two techniques to get the current to arc the gap: The adjustable bolt was changed to a screw hoping that concentrating the charge at a point would encourage a spark. We added an ultraviolet light to attempt to induce a photoelectric effect. When neither of these changes induced a spark, we replaced the spark gap with a switch system. We installed two hammers: one connected to the solenoid and the other hammer connected to the positive side of the capacitors. The hammer connected to the solenoid remained stationary while the other was able to pivot, acting as the switch. The moving hammer rested on a plastic pin which was pulled away, allowing the hammer to drop and complete the circuit.

The housing system was reconstructed from five pieces of plywood and a sheet of Plexiglas. The five pieces of plywood are mounted in each of the four corners by a two by four that is cut to fit. On the front side of the structure is the sheet of Plexiglas which allows one to view the circuit inside. We mounted the Plexiglas to the plywood at the bottom using two door hinges. At the top of the window, we attached a hinge lock. This adds a safety feature to the system which allows the user to know if the circuit inside is safe to access or not. We had to drill holes within the back side of the plywood so that we could attach our power and discharge switches. At the side of the plywood we had to drill two holes for the wiring of the solenoid.

Some issues we encountered while doing this project was while testing our design we were unable to trigger the system by the sparkgap. Also, when we tested the hammer triggering mechanism the terminals would rip off of the wiring due to excessive amount of current. At this point we are still unable to stop the ripping of the terminals during activation.

The safety procedures that we followed was to never test the can crusher without the presence of at least both of us. To wear ear and eye protection. The system has an easy to reach discharge switch. We have a working fire extinguisher within the lab. We also added an internal voltmeter to decrease the danger dealing with an open circuit.

Data:

We tested the old circuit and checked whether the addition of an extra turn in the solenoid would improve the system's production of electromotive force. We used a fluxmeter and DataStudio to create a graph (Firgure 3) of the change in magnetic flux over time.

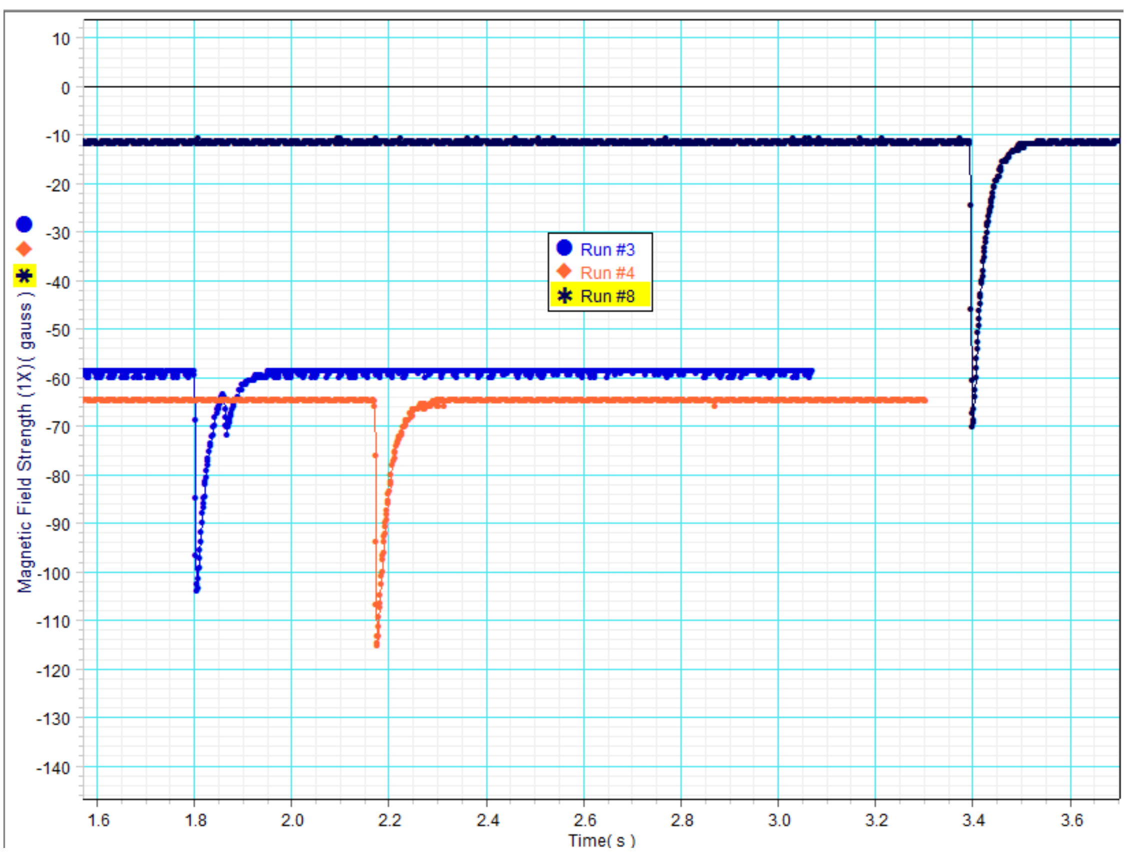

Figure 3. Magnetic field strength of previous and new design

As Figure 3 shows, Run#3(in blue) is the run we did with a three loop solenoid while Run#4 (in Red) was done with a four loop solenoid. Run#4 gives us a magnetic flux of 50 gauss over a time of 0.13 seconds this gives us an, electromotive force of 1,538V. While Run#3 has 45 gauss magnetic flux over a time of 0.14 seconds, this gives us an, electromotive force of 964V. This tells us that using four loops will produce a greater electromotive force then the three loops, which will allow us to see better results when crushing cans with the device. Run #8(in Black) was a measurement of the magnetic strength of our new design: It shows an increase in magnetic flux, the physical results reflect this improvement of magnetic flux.

The results include six semi successful discharges shown below in Figures 4 through 9. Figure 4 was our first successful run; the circuit took 45 minutes to charge to approximately 410V before being triggered. The system then discharged to 123V a difference in voltage of 287V. This resulted in a fair result with the can showing minor cringes and indents. Some of the wiring was blown out of their terminals and had to be repaired so the next test could be done. The second run is shown in Figure 5 which charged to 400V in 35 minutes. The system was then set off, and discharged 337V to a final charge of 63V. This result was again a fair result appearing more crushed then the previous run. After the second run minor repairs had to be made due to a similar problem encountered in run 1. In Figure 6 we tested the system on a smaller can hoping the smaller can would be easier to crush then the normal sized canes we had been using. The system again took 35 minutes to charge to 400 but due to an error in records the final discharge of this run was lost. The result of this run was again fair showing less crinkling the both previous runs. The wiring came undone again and had to be repaired before further testing. Our fourth test, as seen in Figure 7, was charged to 400V and then discharged to 101V. This discharge of 299V produced another fair result similar to the result achieved in the first test. The wiring needed more repairs after this test. Figure 8 shows the fifth test where the circuit discharged from 406V to 245V, a difference of 161V, this yielded a result slightly better than test one with more defined field lines present. Minor repairs required to the wiring after this test. The sixth and final test showed no improvement from the previous tests. The circuit was charged to 402V and then discharged 110V to 292V. Some of the wiring was again blown from the terminals.

Figure 4. Run 1

Figure 5. Run 2

Figure 6. Run 3

Figure 7. Run 4

Figure 9. Run 6

Figure 8. Run 5

Discussion and Conclusions:

After Setting off the Can Crusher several times we found a recurrent problem. The wiring would continually escape the terminals they were connected to, disconnecting the circuit and not allowing the system to fully discharge. This problem did not allow us to achieve maximum results because the magnetic flux was not able to reach its maximum potential since all the current was unable to flow through the solenoid in the time before the wires would break. Due to this issue, we have only been able to achieve what we considered fair results.

To fix the issue of the wiring disconnecting from their terminals, we threaded the wire in the terminal and then looped it back around upon itself and crimped it. This prevented any additional magnetic fields, force or energy to disconnect the circuit.

Some improvements that could be made to the system include the addition of capacitors that could withstand higher voltages, allowing the spark gap triggering system to work more effectively. The larger capacitors would also allow the system to generate more energy and ultimately crush the can. Other improvements to be made would include a housing made from a less flammable and sturdier material, as well as the addition of a discharge switch that could be activated at lower voltages to discharge the system faster.

Appendix:

DigiKey Scheme-it Software

Schematic software was used to create a schematic of our circuit.

AutoDesk Inventor Software

The Inventor CAD program was used to create Technical Drawings for the box and original Spark gap design.

DataStudio Software

DataStudio was used to measure and graph the magnetic flux produced by the system.