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Construction Of A Manually Operated Ignition System Circuit Display

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ABSTRACT
This study presents the design, construction, and testing of a manually operated ignition system circuit display for educational purposes in automotive technology programs. The research addresses the critical need for practical teaching aids in technical education by developing a functional model that demonstrates the principles of automotive ignition systems. The constructed display successfully simulates key ignition system operations while allowing step-by-step visualization of the process, making it an effective teaching tool for automotive technology education.The shortage of modern practical facilities in automotive technology education presents a significant challenge to effective teaching and learning. This research focuses on developing a manually operated ignition system circuit display to bridge this gap. The system demonstrates fundamental ignition principles, including voltage transformation, spark generation, and timing mechanisms, through a hands-on approach that enhances student understanding.
Keywords: Automotive education, ignition system, technical education, practical demonstration, educational model.

INTRODUCTION
Automobile technology is an educational program that focuses on teaching students the skills and knowledge needed to work in the automotive industry. It is offered by several institutions of learning in Nigeria such as technical colleges, colleges of education (technical), polytechnics and universities. The course covers a wide range of topics related to automotive technology, including design, diagnostics, repair, maintenance, and service (Denton, 2020). The students are thought how to troubleshoot and fix various issues that arise in vehicles, from engine problems to electrical issues. They are prepared for the modern workforce by covering emerging trends in electric vehicles, automation, and sustainable energy sources, making it a crucial area for vocational and technical training. However, lack of funding and poor facilities have limited the use of models to effectively teaching automobile technology concepts and system (Okoye & Arimonu, 2016). As a practical oriented course, most of its concepts and systems are better understood when taught with the use of models. Such systems that require models for effective teaching and learning include breaking system, suspension, transmission system, ignition system among others.

The ignition system of an automobile is a crucial component responsible for initiating the combustion process in an engine, allowing it to start and run efficiently. This system ignites the air-fuel mixture in the engine's cylinders, setting off a series of controlled explosions that power the vehicle (Trombley & Toulson, 2023). In spark ignition versions of the internal combustion engines (such as petrol engines), the ignition system creates a spark to ignite the air-fuel mixture just before each combustion stroke (power stroke). According to Pischinger and Heywood (2018), explaining how this system operates is much easier when the process is visualized or demonstrated through the use of an ignition system model or circuit display. These models or display circuits could be manually operated or automated, giving the students an opportunity to visualize how the system operates. Different types of ignition systems have evolved over time, with the primary types being mechanical, electronic, and coil-on-plug systems, each with a designed circuit to enhance reliability and efficiency in modern engines.

The ignition system circuit display is an essential component of a vehicle's electrical system. It controls the flow of electricity, allowing the engine to start and run smoothly (Trombley & Toulson, 2023). By monitoring the ignition system circuit display, engineers can diagnose and troubleshoot any issues that may arise, ensuring optimal performance and safety. The ignition system circuit display plays a crucial role in the overall functionality of a vehicle, and it is important to understand its intricacies for the advancement of automotive technology. In a manually operated display circuit constructed for educational purpose, each phase of the ignition process can be controlled and demonstrated individually, making it possible to study the system in detail (Pischinger & Heywood, 2018). Basic components in the ignition system are a storage battery, an induction coil, a device to produce timed high-voltage discharges from the induction coil, a distributor, and a set of spark plugs.

Each component performs a peculiar function in the system to achieve the collective goal of allowing the engine to start and run smoothly. Batteries supply the necessary low-voltage electrical power to the ignition system. The ignition coil transforms the low voltage from the battery into the high voltage needed to produce a spark. Distributor as the name imply, distributes the high-voltage current to the correct spark plug (used in older systems). Spark plug then creates a spark across its gap, igniting the air-fuel mixture in the engine's combustion chamber. In an electronic ignition system, there is an ignition control module which regulates the timing of the spark, ensuring optimal combustion timing. Though each component can function separately but the ignition system is constructed such that these functions are harnessed in an automobile (MacLean & Lave, 2023). Construction of a manually operated ignition system circuit display require professional expertise in assembling these components in a manner that each step can be observed, analyzed, and tested for educational purposes.

A manually operated ignition system circuit display is a scaled-down, interactive model that demonstrates the basic principles of an automotive ignition system without the need for a full engine. This educational setup allows users to manually control each stage of the ignition process, making it ideal for training and experimental purposes. In a classroom or workshop setting, this type of display enables students to understand the interrelated functions of each ignition component by manually operating and observing them in real time. When the students visually observe the ignition process, they can grasp complex concepts more effectively than they might from textbook explanations alone (Clark & Lyons, 2019). Such a display circuit is not constructed to be as compact as it appears in an actual automobile engine but with the exact operational principles.

Constructing a manually operated ignition system circuit display is a project that requires a good understanding of the functions of the components and the working principles on the ignition system of automobiles (Denton, 2019). The construction process involves securing a 12-volt battery on the mounting board and identify the positive and negative terminals. Then connect the positive terminal of the ignition coil to the positive terminal of the battery through the fuse. The ignition coil will step up the low 12 volts from the battery to a much higher voltage needed to produce a spark at the spark plug. Place the switch between the battery and the ignition coil in the positive line to manually control the flow of current. Connect one end of the high-voltage output from the ignition coil to the center electrode of the spark plug. A distributor is then connected between the ignition coil and the spark plug(s) to direct high voltage from the ignition coil to multiple spark plugs at specific intervals. Whenever the switch is turned on all working principles are activated.

The ignition system functions on the principle of electromagnetic induction within the ignition coil, a fundamental aspect of all ignition systems. When the switch is turned on, the battery sends low-voltage current to the ignition coil's primary winding, creating a magnetic field (MacLean & Lave, 2023). As the switch is rapidly turned on and off, the magnetic field in the coil collapses and then re-establishes, inducing a high voltage in the secondary winding of the coil. This high voltage is directed to the spark plug, where it arcs across the gap between the center and ground electrodes, creating a spark. In a real automobile, the ignition system operates automatically based on engine timing. However, in this display, manual operation allows the user to control when the spark occurs, demonstrating the essential concepts of ignition timing and voltage transformation.

The construction of a manually operated ignition system circuit display serves as a powerful educational tool, providing a simplified yet effective way to understand the ignition process of an automobile. By manually operating the ignition steps, students can observe the sequence and functions of each component within the ignition system. This project, however, aims to construct a manually operated ignition system circuit display, offering a practical representation of the ignition process while providing a controlled environment where each step can be observed, analyzed, and tested. This setup is invaluable for educational purposes, allowing students to gain hands-on experience with the mechanics and electrical principles behind ignition systems.

Problem Statement

The inadequacy of modern practical facilities in Technical Vocational Education and Training (TVET) institutions, particularly in automotive technology programs, presents a significant challenge to effective technical education. Despite the critical role of hands-on training in automotive education, many institutions operate with outdated equipment that fails to reflect current industry standards (Akanmu et al., 2022). This gap between educational resources and industry requirements results in graduates lacking essential practical skills, potentially affecting their career prospects and professional development.

Aim and Objectives of the Study

The aim of this study is to construct a manually operated ignition system circuit display that effectively simulates key automotive ignition operations. The study addressed three specific objectives:

1. Design a circuit demonstrating high-voltage spark generation and control
2. Identify essential components for constructing the ignition system display
3. Develop a functional manual ignition system that accurately simulates automotive operations

Research questions

The following research questions were formulated to guide the study.

1. What is the design of a circuit that demonstrates the generation and control of high-voltage sparks?
2. What are the components of constructing a manually operated ignition system circuit display?
3. What is the procedure of constructing a manually operated ignition system that simulates the key operations of an automotive ignition system?

LITERATURE REVIEW

The ignition system is a critical component of the internal combustion engine, responsible for igniting the air-fuel mixture in the engine's cylinders. Over the years, ignition systems have undergone significant technological advancements to improve reliability, efficiency, and performance. In the early 19^{th} century internal combustion engines were experimental and did not have dedicated ignition systems (Ferrari, Onorati & D'Errico, 2022). Instead, they relied on manual ignition methods, such as a heated tube or open flame, to ignite the air-fuel mixture. These methods were rudimentary and highly unreliable, often resulting in misfires or engine inefficiencies. The invention of the electric spark ignition system is credited to Étienne Lenoir, who developed a spark-ignited internal combustion engine in 1860. This innovation laid the groundwork for future developments in automotive ignition systems.

In the late 19th century, the magneto ignition system was introduced, primarily used in stationary engines and early automobiles. The magneto generated electrical energy without a battery by using a rotating magnet to produce a high-voltage spark for ignition (Enz, 1982). The magneto system became widely adopted in the early 1900s due to its simplicity and ability to function without external power sources. However, it had limitations, including inconsistent spark timing and performance issues at low engine speeds. Later on this was advanced to the development of the battery and coil ignition system which marked a significant improvement in reliability and efficiency. This system utilized a battery to provide a consistent power source and a coil to step up the voltage required for the spark plugs. Introduced around 1910, the Delco ignition system, developed by Charles Kettering, became a milestone in automotive engineering (Leslie, 2024). This system incorporated a distributor to control spark timing and allowed for more precise and reliable ignition. It became the standard for most gasoline-powered vehicles during this period.

Throughout the mid-20th century, ignition systems relied on breaker points and condensers to regulate the electrical current to the ignition coil. The distributor included a mechanical cam that opened and closed the breaker points, creating the electrical pulses necessary for ignition (Dietsche, 2014). Despite its widespread use, the breaker point system required regular maintenance to replace worn-out points and adjust the timing (Leslie, 2024). It was also prone to performance degradation over time, prompting the need for further innovation. This was followed by the introduction of electronic ignition systems in the 1970s represented a major technological leap. These systems replaced mechanical breaker points with electronic sensors and control units, significantly improving reliability and reducing maintenance requirements.

In the 1990s, Distributorless Ignition Systems (DIS) emerged, further enhancing efficiency and reliability. These systems eliminated the traditional distributor, instead using individual ignition coils for each cylinder or coil packs for groups of cylinders. DIS relied on electronic control units (ECUs) to manage spark timing, improving precision and engine performance (Dietsche, 2014). This technology also reduced moving parts, lowering maintenance needs and increasing system durability. The first commercially successful electronic ignition system was Chrysler's Electronic Ignition, introduced in 1972. By the 1980s, most automakers had adopted electronic ignition systems, which offered better spark timing, improved fuel efficiency, and reduced emissions. The future of ignition systems is closely tied to advancements in automotive electrification and hybrid technology. While traditional spark ignition systems remain relevant, ongoing research focuses on alternative methods, such as laser ignition and plasma ignition systems, to further enhance combustion efficiency and reduce environmental impact. With the rise of electric vehicles (EVs), the importance of ignition systems in conventional internal combustion engines may diminish (Dietsche, 2014). However, for hybrid and plug-in hybrid vehicles, ignition system innovations will continue to play a crucial role in optimizing performance and efficiency. This trend in transformation of ignition systems has resulted to significant change in the main parts of ignition system circuit.

MATERIALS AND METHOD

The manually operated ignition system circuit display is built using several components including 12 volts Battery, Ignition Coil, Distributor, Spark Plugs and Ignition switch. The components are assembled accordingly to construct a manually operated ignition system circuit model for educational purpose.

Operation Principles of Manually Operated Ignition System

The mode of operation of a manually operated ignition system circuit display is based on the principle of electromagnetic induction within the ignition coil, a fundamental aspect of all ignition systems. When the switch is turned on, the battery sends low-voltage current to the ignition coil's primary winding, creating a magnetic field. As the switch is rapidly turned on and off, the magnetic field in the coil collapses and then re-establishes, inducing a high voltage in the secondary winding of the coil. This high voltage is directed to the distributor which distributes it to the spark plugs, where it arcs across the gap between the center and ground electrodes, creating a spark. In a real automobile, the ignition system operates automatically based on engine timing. However, in this display, manual operation allows the user to demonstrate the essential concepts of ignition timing and voltage transformation.

Major Components Used

1. **Battery:** The battery serves as the primary energy source for the ignition system. Typically rated at 12 volts in most vehicles, its function is to supply direct current (DC) to the ignition system and ensures consistent power delivery, enabling reliable engine startups.
2. **Ignition Switch:** The ignition switch is the user interface for the driver to control the ignition system. The function of this component is to enables or disables the flow of electrical current from the battery to other ignition components. Ignition switch also acts as a gateway to engine operation and overall vehicle electrical control.
3. **Ignition Coil:** The ignition coil is an electromagnetic transformer that amplifies the low voltage from the battery to a high voltage necessary for creating an electric spark. It steps up battery voltage to between 12,000 and 45,000 volts. It ensures that sufficient voltage is provided to bridge the spark plug gap, initiating combustion.
4. **Distributor:** The distributor ensures the correct timing and distribution of high-voltage current from the ignition coil to the spark plugs in the engine's cylinders. The distributor allocates high-voltage electricity to spark plugs in a specific firing order. It also ensures optimal timing for combustion, improving engine efficiency and performance.
5. **Spark Plugs:** Spark plugs are the endpoint of the ignition system, where high-voltage electricity creates a spark to ignite the air-fuel mixture within the combustion chamber. They are positioned at the top of each engine cylinder and it produces the spark necessary for combustion by creating a high-voltage arc across a small gap.
6. **Wiring:** The wiring system connects all components of the ignition system, enabling the seamless transmission of electrical signals. Insulated wires are used to prevent energy losses and protect against short circuits.
7. **Baseboard:** A wooden board to mount components for display.
8. **Mounting Materials:** Screws, clamps, or adhesive.
9. **Resistors:** For smoothing current if necessary.
10. **Protective Components:** Such as fuses for safety.

Construction Process

Manually operated ignition system circuit is made up of different components joined, fixed and couple together to act as a simple unit for the purpose of demonstrating the fundamental function of an ignition system in an automobile. Various equipment/instrument were used, construction processes were adopted and sequences of operation taken for the construction. Also, quality control measure and safety precaution were considered. The construction process involved assembling, connecting of wires, drilling of holes, measuring and screwing components to a firm wooden surface.

Equipment/Tools used for the Construction

The equipment/tools used in this construction are as follows

1. **Screwdriver Set:** to mount components and tighten screws.
2. **Drill Machine:** to create mounting holes in the baseboard.
3. **Wire Strippers:** to strip insulation from wires.
4. **Soldering Iron:** to solder connections (where needed).
5. **Multimeter:** to test connections and measure voltage/current.
6. **Electrical Tape**: for insulation of connections.
7. **Cable Ties**: to organize wires neatly.
8. **Clamps or Adhesive**: to secure components to the baseboard.

Construction phases

Designing the circuit diagram

1. Designed a detailed circuit diagram showing connections between the components: battery, ignition coil, spark plug, and switch as shown in figure 3.1.
2. Included safety features like fuses to prevent damage.

Preparing the baseboard and mounting of components

1. Cut the baseboard into a suitable size and fitted as the top of a table.
2. Marked positions for components like the battery, ignition coil, switch, and spark plug.
3. Installed the battery and secure it under the baseboard using clamps or adhesive. Made sure the terminals are accessible for wiring.
4. Mounted the Ignition Coil on the baseboard and labeled the primary and secondary terminals for easy connections.
5. Fixed the spark plug vertically into drilled holes on the baseboard, positioning it visibly so that the spark is easy to observe.
6. Mounted the switch on the baseboard in a convenient position.

Wiring of components

1. Primary Circuit:
   - Connected the positive terminal of the battery to one terminal of the switch.
   - Connected the other terminal of the switch to the primary input of the ignition coil.
   - Connected the ignition coil's primary output to the terminal of the distributor.
2. Secondary Circuit:
   - Connected the distributor's high-voltage terminal to the spark plug.
   - Connected the spark plug's ground terminal to the battery's negative terminal.
   - Used appropriate wire gauges to handle the current and voltage (at least 1.5mm copper wire).

Testing of the circuit and safety features

1. Ensured all connections are secured.
2. Activated the switch to check if the spark plug generates sparks.
3. Included a fuse in the circuit to protect the battery and components.
4. Encased high-voltage parts to prevent accidental contact.

Additions for educational purposes

1. Clearly labelled each component on the baseboard for educational purposes.
2. Used a transparent casing for aesthetic appeal and safety.
3. Created an instruction sheet or placard explaining how the circuit works.
4. Include details about the role of each component and the ignition process.

Construction process safety tips

1. Always wear insulated gloves while working with electrical circuits.
2. Keep high-voltage components covered to avoid shocks.
3. Do not connect the circuit for extended periods to prevent overheating.

Test and Result

Experiment I: Testing

Aim: Testing to know the capacity of the component used

Determined the total power output per current in the circuit.

Formula: $P = I \times V$

Where:

P: Power (Watts)

V: Voltage (Volts)

I: Current (Amperes)
The circuit operates at 12 V and when it consumes a current of 2.2A, the power was
P = 12 V×2.2 A = **26.4 Watts**

4.1.2 Voltage boosts produced by the ignition coil to generate a spark.

Turns Ratio: $\frac{V_{Secondary}}{V_{Primary}} = \frac{N_{Secondary}}{N_{Primary}}$

Where:
$V_{Secondary}$ = Output voltage
$V_{Primary}$ = input voltage
$N_{Secondary}$ = Secondary winding turns
$N_{Primary}$ = Primary winding turns

The coil boosts 12 V to 10,500 V and it has $N_{Primary}$ = 100 turns. Hence its secondary winding turns is

$$\frac{10{,}500}{12} = \frac{N_{Secondary}}{100}$$

$$N_{Secondary} = \frac{10{,}500 \times 100}{12} = \mathbf{87{,}500\ turns}$$

4.1.3 Voltage needed to ionize the air in the spark gap

Breakdown Voltage: $V_{gap} = d \times E$

Where:
V_{gap} = Voltage (Volts)
d = Gap distance (meters)
E = Electric field strength (V/m) its constant value in air is 3×10^6 V/m.
The spark plugs used had a gap of 1mm (0.001m)
Therefore $V_{gap} = 0.001 \times 3 \times 10^6$ = **3000Volts**

4.1.4 Fuse Current Rating

The fuse should protect the circuit by blowing if the current exceeds a safe limit.
$I_{Fuse} > I_{normaL}$
I_{normaL} of the circuit is 2.2A, hence the fuse used was 3A

4.1.5 Heat Dissipation from **coil**

Power Dissipated: $I^2 \times R$

The circuit had a current of 2.2A and a coil of resistance approximately 1Ω.
Therefore, P = $(2.2)^2$ x 1 = 4.48W

4.2 Experiment II: Assembling

Aim: Assembling of the manually operated ignition system

First stage

1. Cutting the baseboard into a suitable size and properly fitted as the top of a table.
2. Marking positions for components like the battery, ignition coil, switch, and spark plug.
3. Drill holes on the board where wires will pass through

Second stage

4. Installing the battery and securing it under the baseboard using clamps on wooden frame. Making sure the terminals are accessible for wiring.

5. Mounting the Ignition Coil on the baseboard and labeling the primary and secondary terminals for easy connections.
6. Fixing the spark plugs through drilled holes, positioned visibly so that the spark is easy to observe.
7. Mounting the switch on the baseboard in a convenient position.

Third stage

8. Connecting the positive terminal of the battery to one terminal of the switch.
9. Connecting the other terminal of the switch to the primary input of the ignition coil.
10. Connecting the ignition coil's primary output to the negative terminal of the distributor.
11. Connecting the distributor's high-voltage terminal to the spark plug.
12. Connecting the spark plug's ground terminal to the battery's negative terminal.

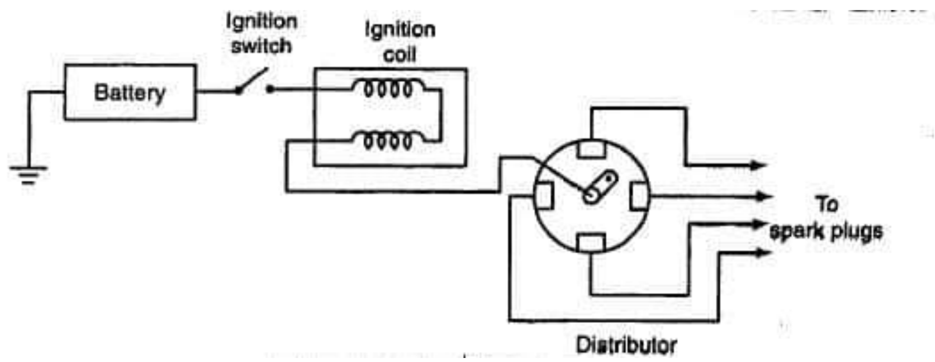

Figure 1 Circuit diagram of primary and secondary connection

Circuit Safety Features

1. Appropriate wire gauge was used that can handle the current and voltage (at least 1.5mm copper cable).
2. Ensuring all connections are secured.
3. Activating the switch to check if the spark plug generates sparks.
4. Installing a fuse in the circuit to protect the battery and components.
5. Encasing high-voltage parts to prevent accidental contact.

List of Materials, Tools and Equipment

Materials, tools and equipment used for the construction of a manually operated ignition system circuit display.

S/N	Materials/Tools	Quantity
1.	12 volts battery	1
2.	High tension cable	2
3.	Ignition coil	1
4.	Ignition switch	2
5.	Conductors (wires)	40 meters
6.	Distributor cap	2
7.	Distributor	1

8.	Condenser	1
9.	Sparking plugs	4
10.	Rotor	1
11.	Contact breaker	1
12.	Sheet metal	1
13.	Black Square Pipe	3
14.	Plywood	1
15.	Round pipe	1
16.	Bolts/ nuts	25 pcs
17.	Screws	12 pcs
18.	Black paint	4 liters
19.	Emery cloth (sand paper) (R&S)	2 yards
20.	Bearings	4
21.	Helical gears	1
22.	Alternator	1
23.	Belt/pulley	1
24.	Hack saw & blades	2 frames & 5 blades
25.	Try squares	2
26	Hammers	2
27	Mallets	2
28	Cramps/clamps	2
29	Power hand drilling machine	1
30	Filing machine	1
31	Measuring tape	2
32	Scribers	2
33	Chisels	2
34	Sharpening stone and oil	1
35	Welding machine	1
36	Complete tool box	1
37	Electrodes	4 packs
38	Spraying machine	1
39.	Laptop computer	1
40.	Generator	1
41.	Spark plugs wires	4
42..	Fuel	40 liters
43.	Riveting machine	1
44.	Paint Thinner	4 liters
45.	Multimeter	1
46.	Resistor	1
47.	Fuse	1

RESULTS

The experiment and testing shows that:

i. The ignition system circuit constructed gives a total power of 26.4 Watts
ii. The ignition coil of the circuit has an output of 10,500Volts with 87,500 secondary turns.
iii. The voltage needed to ionize the air in the spark gap of the spark plug is 3000Volts. The circuit that is constructed produces up to that amount of voltage.
iv. A fuse of 3A is required to protect the components of the designed circuit from been damaged by high current or voltage.

v. The ignition coil used in the designed circuit dissipates 4.48Watts of power.

The manually operated ignition system circuit display is constructed based on the principle of electromagnetic induction which occurs within the ignition coil. When the switch is turned on, the battery sends 12Volts and 2.2 Ampere current to the ignition coil's primary winding which is 100 turns, creating a magnetic field. As the switch is rapidly turned on and off, the magnetic field in the coil collapses and then re-establishes, inducing a high voltage of 10,500Volts in the secondary winding of the coil. This high voltage is directed to the spark plug that needs 3000Volts to ionize the air in the spark plug gap, where it arcs across the gap between the center and ground electrodes, creating a spark. In a real automobile, the ignition system operates automatically based on engine timing. This display demonstrates the essential concepts of ignition timing and voltage transformation.

CONCLUSION

The construction of a manually operated ignition system circuit display has successfully demonstrated the fundamental principles of ignition systems, showcasing how electrical energy is converted into high-voltage pulses to simulate spark generation. Through careful component selection, circuit design, and rigorous testing, the project achieved its objectives of illustrating the ignition process in a safe and controlled manner. This circuit display serves as an effective educational tool, providing insight into the operation of ignition systems used in internal combustion engines. It also highlights the importance of precise calculations, safety considerations, and practical implementation in electrical circuit design. The project lays a solid foundation for further exploration into advanced ignition systems, including automated and electronic variations.

RECOMMENDATION

For proper efficiency and effectiveness of this manually operated ignition system circuit, the following is strongly recommended.

1. The circuit display should be incorporated into technical and engineering training programs to provide students with a hands-on understanding of ignition systems. Comprehensive documentation and an operational manual should be developed to accompany the display.
2. Explore ways to reduce energy consumption by optimizing components such as the ignition coil and power source. Energy-efficient designs can make the system more sustainable for prolonged demonstrations.
3. Diagnostic tools like LEDs or digital meters should be added to monitor system performance in real time, making it easier to troubleshoot issues during operation.
4. Further research should improve the design, focusing on miniaturization and durability. It should also consider recent innovations in automobile ignition systems.

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