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Analysis of primary coil voltage on spark ignition engine using flash cable

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Abstract
The efficiency of the ignition system in a spark ignition engine is very important to improve engine performance. This study aims to analyze the use of flash cable on the primary coil voltage in a spark ignition engine applied to an injection motorcycle. There are three types of flash cables (11, 16, and 21 coils) that are made and tested to see the increase in voltage produced. The experimental method is used with a measuring tool in the form of a peak voltage adapter connected to a digital multimeter. The results of the study showed that variations in the length of the flash cable coil significantly affected the primary coil voltage. Flash cable with 21 coils provided the highest voltage increase of 262 V, compared to without using a flash cable which only reached 219 V. The use of flash cable can improve ignition efficiency and spark ignition engine performance.

Keywords
Primary coil voltage, Spark ignition engine, Flash cable

Introduction
The ignition system in a spark ignition engine is a system that aims to generate high voltage for the combustion process of the fuel and air mixture in the combustion chamber [1][2]. The function of the ignition system is to produce sparks on the spark plugs that must be produced at the right time to burn the fuel and air mixture in the combustion chamber [3]. The results of combustion at the right time can generate power to rotate the crankshaft [4]. One of the important factors in generating power or power produced by an engine depends on its ignition system [5]. If the ignition system in a spark ignition engine does not work properly and correctly, then the combustion process of the fuel and air mixture in the combustion chamber is not perfect and causes the power produced by the engine to be suboptimal. Cables are very familiar to all people [6]. The cables used are very many types and sizes according to the needs of electricity. Wires and electrical cables are a medium for transmitting electrical power

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from an electrical power source to equipment that uses electrical power or connecting electrical equipment to other electrical equipment [7][8].

The ignition timing of the gasoline and air mixture is when the spark occurs at the spark plug a few degrees before Top Dead Center (TDC) at the end of the compression stroke [9]. The timing of the spark must be determined precisely in order to perfectly burn the fuel and air mixture to achieve maximum power [10]. After the fuel mixture is ignited by the spark, a certain amount of time is required for the flame to propagate in the combustion chamber [11]. Therefore, there will be a slight delay between the start of combustion and the achievement of maximum combustion pressure. In order to obtain maximum output on the engine with combustion pressure reaching its highest point (around 10° after TDC), the flame propagation period must be taken into account when determining the ignition timing [12].

Air core inductor is a number of coils of wire wrapped around a regular cardboard or plastic that acts as a core [13]. So this gap has nothing but air in it, which is known as an air core inductor [14]. Therefore, air acts as a core [15]. This inductor is applied to the input coil based on its working principle. The working principle of this inductor works on the basis that air has a fairly minimum electrical conductivity [16]. So, the inductance of the air core is also low, resulting in a weak magnetic field [17]. Due to the small magnetic field generation of the air core, it achieves a faster current rise while avoiding signal loss [18].

Peak Voltage Adaptor (PVA) is an adaptor that is connected to a multimeter to measure the peak voltage of the primary coil. Some ignition system components produce short AC voltage pulses [19]. The PVA plugged into a digital multimeter captures and holds the peak value of the AC sine wave long enough for the human eye to see it displayed on the multimeter [20]. Conventional multimeters are not capable of accurately measuring these short duration voltage pulses [21]. The PVA has special circuitry that allows the multimeter to capture the maximum voltage produced during these short duration pulses [19]. The PVA is shown in Figure 1.

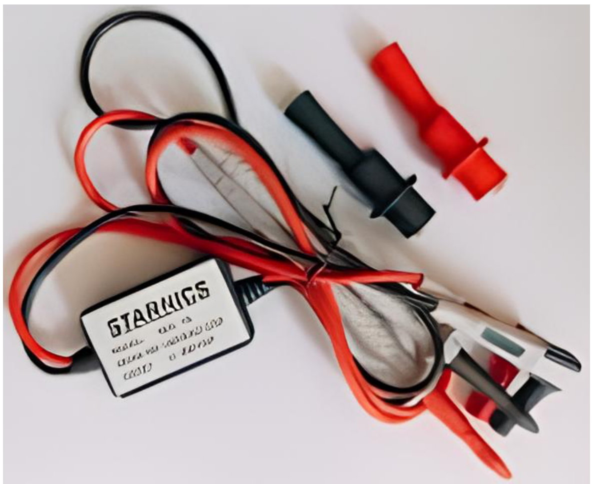

Figure 1. Peak voltage adaptor (PVA)

Voltage or often referred to as potential difference is the work done to move a charge of one coulomb from one terminal to another [22]. If a charge of one coulomb is moved or moved, there will be a potential difference at the two terminals. Electric current is the flow of electric charge that flows in a conducting medium, such as wire or metal. Electric current can be generated from various sources of electrical energy, such as batteries, generators, or other electricity sources. The amount of electric current is measured in amperes (A) [22]. Additional components in the ignition system are often needed to improve efficiency and stability in spark ignition engines, especially for users looking for optimal performance at an affordable cost [23]. Flash cable is an additional cable installed before the input coil which can be an alternative to increase the intensity of the ignition flame and prevent signal loss [24].

The result is a stronger and more stable ignition flame [25]. Flash cable production is carried out with several types of coils, namely 11, 16, and 21 coils. Its use is reported to improve motorcycle performance. The popularity of this product is increasing through user recommendations and more and more parties believe in the ability of flash cable to improve engine performance. This study aims to analyze the use of flash cable with variations in the number of coils against the primary coil voltage on injection motorcycles. The factors to be evaluated include the characteristics of the flash cable in various sizes against the primary coil voltage. The results of the primary coil peak voltage test will be analyzed using PVA to obtain accurate data regarding the effectiveness of using flash cable.

Method

This study uses an experimental method that aims to analyze the use of several types of the number of coils on the flash cable on the primary coil voltage on injection motorcycles. The initial step begins with a literature study to deepen the understanding of the theory related to flash cables and primary coil voltage. Furthermore, the preparation of tools, materials, and research objects is carried out, namely flash cables with different numbers of coils (11, 16, and 21 coils). Each type of flash cable is tested to measure the primary coil voltage produced using a digital multimeter with a PVA adapter, and then compared systematically to see the differences and effects of the variations in coils. The results of this test are further analyzed to gain an understanding of the effectiveness of flash cables in improving the performance of the ignition system on injection motorcycles.

The flash cable design shown in Figure 2 shows the key dimensions to ensure compatibility with the motorcycle ignition system. The total length of the flash cable is 27 mm with a core diameter of 5 mm. The thickness of the winding wire is set at 1.5 mm, while the distance between the coils is designed to be tight to produce optimal electromagnetic induction. Figure 3 provides a more in-depth view of the physical construction of the flash cable. This combination of design and dimensions is designed to improve the efficiency of the ignition system while simplifying installation without the need for major modifications to the vehicle.

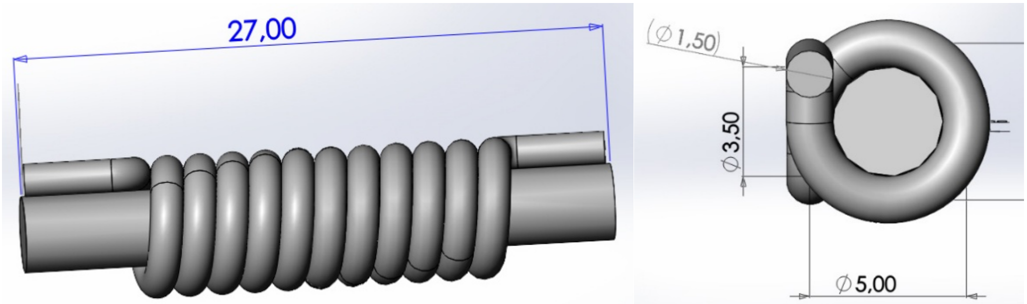

Figure 2. Flash cable design

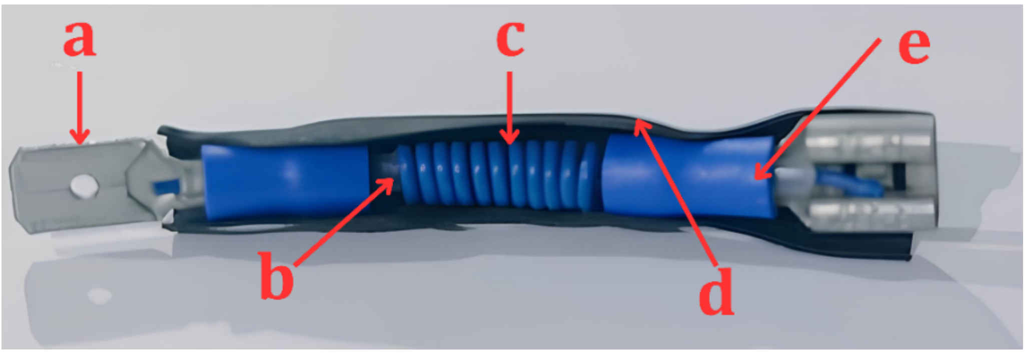

Figure 3. Flash cable construction; a) lug, b) hose, c) cable, d) heat string, e) lug insulator

Figure 4 shows the wiring diagram of the flash cable installation in the motorcycle ignition system. This diagram explains that the flash cable (c) is connected to other components. The flash cable is positioned between the regulator-rectifier and the coil to increase the primary voltage of the coil, which aims to produce a more stable spark at the spark plug. This configuration is designed to maximize ignition efficiency without changing the vehicle's default system, so it can be easily applied to various types of injection motorcycles.

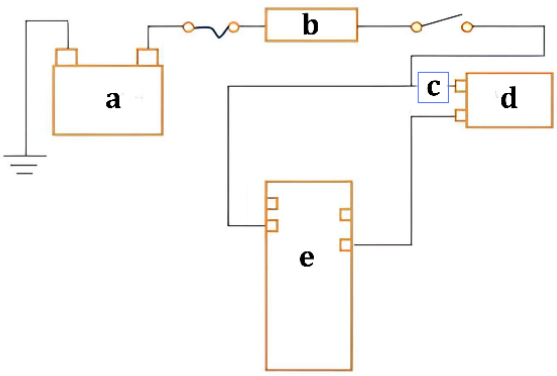

Figure 4. Flash cable wiring diagram; a) battery, b) regulator-rectifier (rr), c) flash cable, d) coil, e) ecu

The percentage change in primary coil voltage due to the use of flash cable is calculated using equation 1 which compares the average voltage value without flash cable with the average voltage after using flash cable to obtain the percentage change figure produced [26].

$$p = \frac{N - n}{N} x\ 100\% \qquad (1)$$

Description: P as The percentage number you want to get; N as Average before being treated without using a flash cable; N as Average after being given treatment using flash cable.

Results and Discussion

Results

The test results of the primary coil voltage on a motorcycle with flash cable variations are shown in Figure 5. This test was carried out at several engine speeds (rpm) to observe the effects of using flash cables with different numbers of coils.

(a) (b) (c) (d)

Figure 5. Voltage measurement data capture; a). Without flash cable, b). Flash cable 11 coils, c). Flash cable 16 coils, d). Flash cable 21 coils

The complete results of the voltage measurements from the test are shown in Table 1.

Table 1. Data of each voltage test result

Engine Speeds (RPM)	Voltage (V)			
	Standard	Flash Cable - 11 Coils	Flash Cable - 16 Coils	Flash Cable - 21 Coils
1500	191	222	227	230
2000	212	233	235	253
2500	218	239	242	267
3000	220	247	250	266
3500	225	251	257	270
4000	228	251	256	269
4500	230	251	254	269
5000	229	250	255	267
Average	219	243	247	262

Table 1 shows that the use of flash cable can significantly increase the primary coil voltage compared to standard conditions (without flash cable). At engine speeds of 1500 to 5000 rpm, flash cable with 21 coils produces the highest voltage, followed by 16 coils and 11 coils. The highest average voltage achieved by flash cable with 21 coils is 262 volts, which shows a substantial increase from the average voltage without flash cable which is only 219 volts. These data indicate that the number of coils of flash cable affects the increase in voltage, which in turn can support more optimal ignition performance.

However, it should be noted that at certain engine speeds, the voltage increase may not be significant or stable, which may affect the stability of the ignition system as a whole.

Discussion

The test results show the measurement of the primary coil peak voltage with variations in the use of flash cable and different number of coils, including without flash cable. When using a flash cable with 11 coils, the voltage increases slowly until it reaches high speed, as seen from the table showing a regular increase in voltage. In this configuration, the voltage increases by 9.88%, from 219 V to 243 V. Conversely, when using a flash cable with 16 coils, the voltage increases too quickly at low speed, then decreases at 4500 rpm and increases slightly again at 5000 rpm, resulting in less stable voltage. The voltage increases by 11.34% from 219 V to 247 V. The use of a flash cable with 21 coils also shows a less than ideal pattern. The voltage increases too quickly at low speed before experiencing fluctuations. The increase in voltage of 16.30%, from 219 V to 262 V shows a significant change.

Based on the test results and theoretical references obtained, more turns produce increased voltage that supports combustion efficiency at high engine speeds, but can cause a lack of combustion at low engine speeds, so that the engine feels heavy because it allows combustion to become too poor due to a significant increase in voltage. High voltage can trigger more aggressive combustion, which may not be in accordance with the characteristics of a standard engine because the mixture supplied to the combustion chamber has been adjusted from the manufacturer. Combustion that is too fast or too slow can cause vibration and potential engine failure, especially at low speeds [27]. In addition, other studies have shown that voltage variations can affect engine current and rotation under various load conditions. When the engine is operating at idle speed, voltage fluctuations can interfere with the current flowing to the ignition system and cause instability [28]. Therefore, an ignition system designed to operate within a certain voltage range will be better and more stable than a system exposed to uncontrolled voltage [29].

It can be concluded that the voltage on the use of flash cable is still categorized as safe on flash cable 21 coils reaching 262 V. Because, the maximum voltage limit on the motorcycle primary coil, especially in the ignition system, can reach between 200 and 400 volts [30]. This is due to the induction process that occurs in the coil, where high voltage is generated to trigger the spark plug to burn the fuel mixture in the combustion chamber. Research shows that the voltage generated by the ignition coil can vary depending on the design and type of ignition system used.

In the ignition system, the coil functions as a transformer that converts low voltage from the battery into high voltage needed to produce sparks at the spark plugs. For example, in a CDI system the voltage produced can reach 300 volts or more, depending on the coil specifications and circuit design [31]. Research also shows that in some ignition systems, the peak voltage produced can reach 400 volts, which is a safe limit for most electronic components in a motorcycle ignition system [32].

Conclusion

This study proves that variations in the number of turns on the flash cable affect the primary coil voltage of injection motorcycles. The more turns, the higher the voltage produced. Flash cable with 21 turns reaches the highest average voltage of 262 V, while without flash cable it is only 219 V. These results indicate that flash cable improves the performance of the ignition system, especially at high engine speeds. The increase in voltage is not always stable, especially at low speeds, so the number of turns needs to be adjusted to driving needs.

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