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Decrease of Fuel Consumption and Emission of 4 Stroke Otto Engine due to Ground Strap Installation

This study is to determine fuel consumption and exhaust emissions due to addition of a ground strap to the spark plug coil cable using silver wire material. The silver wire was 0.8 mmdiameter and installed with number of turns of 255. This research was conducted since spark plug disturbance, due to electromagnetic field, decreases engine performance. This electromagnetic field occurs during electric current flows from battery to spark plug. This study applied experimental method with 10 repetitions of data collection. The results showed that the lowest specific fuel consumption reduction by 19.6% occurred at 5000 rpm and the highest one by 29% occurred at 8000 rpm when groundstrap was installed. Meanwhile, HC, CO and CO₂ exhaust emissions decreased by 80.3%, 82.3% and 36.7%, respectively, after installation of groundstrap.

Keywords : Groundstrap, Fuel Consumption, Exhaust Emissions.

1. INTRODUCTION

Of many vehicles in Indonesia, motorcycle is the most extensively used. Registration of new motorcycle rises every years averagely 12% or 7.9 millions annually [1]. On the other hand, high growth of new registered motorcycle causes enviromental effect, i.e. high traffic congestion, air and sound polution, increasing demand of non renewable fosil fuel. In Indonesia, demand of fosil fuel increases by every year [2]. High milleage motorcycle shows performance decrease particularly in its combustion system. In high milleage motorcycle, high exhaust emissions due to unburned fuel occurs due to far from complete combustion. Research to improve combustion system performance is therefore important to decrease both fuel consumption and exhaust gas emissions. Of many solutions, improvement of ignition system offers high applicability.

Electromagentic field (EMF) can be mainly divided in 2 types, i.e. extremely low EMF at frequency of 3 Hz to 3 kHz while the radiofrequency radiation EMF occurs at frequency between 3 kHz and 300 GHz [3]. EMF in motorcycle, occuring when electrical current flows in cable from battery to spark plug, leads to unstable spark on the electrode tip which then unstablizes spark plug peerformance. This causes decrease of ignition point and leads to high unburned fuel [3,5,6].

Specific fuel consumption can be then indirectly show engine performance. Higher off gas emission as hydrocarboni(HC), carbon dioxide (CO₂), karbonimonoxide (CO), and particulate occurs due to incomplete fuel combustion and due to unmixed air and fuel prior combustion [6,7]. In addition, unstable spark on the plug tip contributes also to higher off gas emissions. In order to to overcome this circumstance, groundstrap is installed to minimize electrical current loss which then results in stable spark on plug tip [3,7]. Groundstrap comprises of selected wire materials and number of windings to dissipate elecromagnetic field when high voltage electric current flows from battery to spark plug [8,9]. When groundstrap is installed, stable spark on plug tip is then expected. Hardian *et al.* [4] investigated the influence of groundstrap installation on engine torque and power. Muhammad *et al.* [10] reported focused blue spark on plug tip when groundstrap is used. This corcumstance increases current flowing to plug which leads to higher engine performance. In addition to previous researches, this work investigated the influence of groundstrap installation on fuel consumption and exhaust emission of 4 strokes Otto engine. Fuel consumption in this research is defined as the rate of consumed fuel to produce 1 HP power [1].

2. MATERIALS AND METHOD

This research was worked out in 2 different location. Research of specific fuel consumption (Figure 1) was worked out in *SMK PGRI 2 Badung*, Denpasar, Bali while research of off gas emission (Figure 2) was worked out in *Balai Pendidikan dan Penelitian Transportasi Darat (BPPTD Bali)* Gianyar, Bali. The analysed engine was Jupiter Z 2006 motorcycle. Tachometer TA was used to measure engine rotation (Figure 3a) and Muller Beam 10.000 MX analyzed the exhaust gas composition (Figure 3b). Data gathering and analysis to investigate the influence of groundstrap installation on specific fuel consumption and exhaust gas emission uses descriptive quantitative method [11,12].

The absorbed EMF is changed to heat energy. For this reason, thermal conductivity of ground strap wire as EMF shield is significantly important [12]. Silver is therefore widely used as EMF shield in many engineering application, e.g. [14,15]. Ground strap wire is made off silver since this metal has good thermal and electrical conductivity compared than other metals (Table 1 and Figure 4) [15]. The experiment was conducted in a 4 stroke motorcycle engine of Juptier Z 2006 which has compression ratio of 9.3 : 1 (Table 2) [17]. Peralite therefore served as fuel in this research since its octane number of 92 suits this engine so that no knocking occurred. Its maximum power is 9.0 PS at 8000 rpm and its maximum torque is 9.3 Nm at 5000 rpm. To investigate specific fuel consumption (SFC), 10 data was gathered for each RPM at 3000 to 8000 RPM. Meanwhile, 10 data for each exhaust gas (HC, CO, CO₂ and O₂) was also gathered during investigation of off-gas composition at 4000 RPM.

Figure 1. Set up for specific fuel consumption research

Figure 2. Set up for exhaust gas composition research

Table 1: Electrical resistivity and conductivity of selected metals at 20 °C

Metal	Electrical resistivity [$\mu\Omega\text{cm}$]	Electrical conductivity [$\Omega\mu^{-1}\text{cm}^{-1}$]
Silver	1.63	6.3×10^7
Copper	1.694	5.8×10^7
Gold	2.2	4.2×10^7
Aluminium	2.67	3.4×10^7
Germanium	3.3	2.2

Figure 3: Tachometer TA 303 (a); Muller Beam 10.000 MX exhaust gas analyzer (b)

Figure 4: Temperature dependence of thermal conductivity for selected metals [15]

Table 2: Engine specification of Jupiter Z 2006 [17]

Engine type	2P2, 4 stroke, SOHC
Bore x Stroke	51.0 x 54.0 mm
Cylinder volume	110.3 cc
Compression ration	9.3 : 1
Maximum power	9.0 PS / 8000 rpm
Maximum torque	9.2Nm / 5000 rpm

3. RESULT AND DISCUSSION

Figure 5 shows installed ground strap made from silver. There were 255 coils of silver wire on cable connected to spark plug. The distance between each wire coil should be much closed to effectively minimize electromagnetic field created near the cable from motorcycle battery connected to spark plug. This is to minimize loss when electrical current flows to spark plug.

Figure 5: Addition of silver wire on cable connected to spark plug in this research

In modern Otto engine, voltage flows from battery to spark plug can be up to 40 kV [16]. For motorcycle, spark plug voltage ranges from 10 to 24 kV [20]. Due to this high voltage circumstance, energy loss as EMF can be created in cable connecting motorcycle battery and spark plug. In this research, the installed silver wire seemed to effectively minimize EMF and blue arc on plug tip were seen when ground strap was installed. Almubarak and Albloushi [18] reported that blue arc presents when plug tip works well. In this work, specific fuel consumption (SFC) depending on fuel consumption per unit time (M_f) and generated power (N_e) (eq. 1) decreases after installation of ground strap wire (Table 3 and Figure 6).

$$SFC = \frac{M_f}{N_e} \quad (1)$$

Without installation of ground strap, SFC varies from 0.048 to 0.074 kg/Wh. After installation of ground strap, SFC decreases and varies only between 0.038 and 0.052. In average, specific fuel consumption with and without ground strap installation are 0.059 and 0.043 kg/kwh, respectively. Installation of ground strap can then decrease specific consumption by app. 26%. This decrease is significant and can significantly decrease motorcycle fuel consumption globally. In this work higher SFC both for cases with and without ground strap occurs at 3000 and 8000 RPM. Meanwhile, the lowest SFC occurs for engine rotation of 6000 RPM. Elarvarasan *et al.* [19] informed also that the higher SFC occurs when RPM is excessively low or excessively high.

Tabel 3: Change of specific fuel consumption after installation of ground strap for different engine RPM

RPM	Specific fuel consumption [kg/Wh]	
	Standard coil	Ground strap coil
3000	0.064	0.046
4000	0.058	0.041
5000	0.051	0.041
6000	0.048	0.038
7000	0.056	0.042
8000	0.074	0.052
Average	0.059	0.043

Figure 6. Specific fuel consumption for varied engine rotation

Emission of HC, CO and CO₂ decrease after ground strap installation (Table 4, Figure 7-9). This average value was from 10 measurements at constant engine rotation of 4000 rpm. These emissions value without groundstrap installation can still comply the regulation from Ministry of Environment and Forestry of The Republic of Indonesia, i.e. maximum permitted HC, CO, and CO₂ emissions are 2400 ppm vol, 5.5 % vol and 12 % vol, respectively, for motorcycle engines with conventional combustion system [7]. However, the emissions value still needs to be decreased due to environmental concern. The measurement showed that HC emission significantly decreased by 80% from 172.8 to 33.9 ppm vol. CO emissions decreased from 5.35 to 0.2 % vol, i.e. 90%, after ground strap installation. In addition, CO₂ emissions before and after ground strap installation were 7.80% and 4.99 % vol, respectively.

Tabel 4: Average value of HC, CO, CO₂ and O₂ emissions with and without ground strap installation

Off-gas	Standard coil	Ground strap coil
HC [ppm vol]	172.80	33.90
CO [% vol]	5.35	0.20
CO ₂ [% vol]	7.80	4.99
O ₂ [% vol]	0	0

Figure 7. HC emission without and with ground strap installation

Astane *et al.* [21] reported much lower HC emission when higher quality spark plug was used. Significant decrease of HC and CO emissions in this work was then predicted due to better fuel combustion. This circumstance occurs due to more stable and focused spark created on the plug tip since higher and more stable electrical current flows to spark plug. This is due to less current loss in the cable from

motorcycle to spark plug since energy loss as electromagnetic field could be decreased. This is in agreement with result from Hardian *et al.* [4] and Kurniawan *et al.* [6]. In this research, coil made off silver wire can prevent current leak which convert as EMF. Fryskowski [22] reported that several methods can be applied to prevent current loss, e.g. clean ceramic insulator, improved electric field distribution and cabling system, maintained humidity. In this work, CO concentration, as product of imperfect carbon oxidation, significantly decreases due to better combustion, i.e. due to more stable spark on plug tip. Thus, more carbon can perfectly react with oxygen. Between 1990 and 2017, CO and non-methane volatile organic compound (VOC) from transportation sector had contributed to 87% of total CO and non-methane VOC in EU [23]. Less O₂ concentration in the off-gas after ground strap installation also informs better O₂ use for fuel combustion, i.e. less unreacted O₂ with fuel.

Figure 8. CO emission without and with ground strap installation

Figure 7. CO₂ emission without and with ground strap installation

4. CONCLUSION

Of those transportation systems in Indonesia, motorcycle plays significant role due to its advantages, e.g. low price for new motorcycle, high driving flexibility, etc. Increasing number of new registered motorcycles leads also to environmental effect, e.g. increasing air and sound pollution and higher demand of fossil fuel. This work therefore offers promising future application to address the mentioned challenges by installation of ground strap in the cable connecting motorcycle battery and spark plug. This installation reduces electrical energy loss and increases arc stability created on electrode tip. The investigation showed significant decrease of specific fuel consumption by app. 26% in average when ground strap is installed. In addition, installation of ground strap also decreased emissions of HC, CO, and CO₂ by 80%, 90% and 38%, respectively. HC emission significantly decreased from 172.8 to 33.9 ppm vol, CO emissions decreased from 5.35 to 0.2 % vol, and CO₂ decreased from 7.80% to 4.99 % vol.

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