Study of PWM regulation effect using boost converter on electrolysis injection system based on Fuzzy Logic Controller

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Abstract. The aim of this paper is study the effect of PWM regulation on electric boost converter. The converter was used for electric driver in electrolysis injection system in order to modified the gas flow production. Electric driver will result the modified gas flow that injected into the combustion engine. The proposed scheme was expected to rose the combustion process and reduce the CO emission. The PMW regulation on this paper was developed using fuzzy logic controller that obtained feedback signal from CO gas sensor measurement. The experimental result showed that CO concentration measured about 330 PPM and it’s reduced until 253 PPM after the implementation of PWM variation.

1. Introduction
This paper emphasis on handling of carbon monoxide CO emissions reduction from incomplete combustion process through utilization of electrolysis gas product. Carbon monoxide emission is one of the environmental issues mainly caused by non ideal condition of combustion process, moreover, its also reduce blood function and interfere human health. One of proposed solution that discussed in this paper was mixing electrolysis gas product on the combustion chamber while the burning process occur. The effect of CO emissions has been observed in several research. Yulianti conducted research related to carbon monoxide gas in which the CO in the air around 80 ppm would resulting the difficulty in human breathing, higher concentrations may result in loss of consciousness and even death [1]. According to WHO report in 1992 declared at least 90% of CO in urban air comes from vehicle emissions [5]. In addition, Hill states that 75% of CO gas in the atmosphere comes from vehicle emissions [6]. Based on these data indicate that excess CO gas emissions produced may adversely affect to the air quality and human health.

This paper proposes the reduction effort of CO exhaust gas from motorcycle combustion engine by mixing the electrolysis gas production through the combustion chamber. Electric boost converter was used as a current regulator for electrolysis reactor, therefore, the electrolysis gas flow production would be controlled by electric current regulation of boost converter device. The regulation method was proposed with fuzzy logic control scheme that will change the electric current value depend on the feedback of CO gas concentration measurement.
2. **Experimental Method**

2.1. **System Description**

The electrolysis generator was used to split the water compound into oxyhydrogen gas. The electric current will be supplied to the reactor in order to activated the reaction, its value will be generated by the boost converter which serves the voltage by increasing the duty cycle of electric switching actuation in form of voltage pulse width modulation (PWM) signal. The system was represented in block diagram as shown in Figure 1.

![Figure 1. Block diagram](image1)

The sensor MQ-7 was used in measurement of carbon monoxide gas concentration from exhaust pipe, furthermore, its feed to the fuzzy logic controller (FLC) to regulate the electric voltage. The microcontroller executes FLC algorithm according to CO gas concentration feedback and determine the electrolysis gas outcome indirectly. The system integration is shown in Figure 2.

![Figure 2. System integration](image2)

2.2. **Control Design**

Boost converter is one type of step-up DC to DC converter that produce a voltage output greater than its voltage input, so in this case the converter also has function as switched actuator. The converter will adjust electric voltage output and its value depends on the modified duty cycle value from fuzzy logic controller, so FLC has important role in altering of switching time variable. The boost schematic design is shown in Figure 3. In system integration, the actuator output connected to electrolysis reactor to run the process reaction and its product was influenced by voltage and current outcome of the converter. In this study, fuzzy logic controller was used in electrolysis process regulation. The FLC algorithm was arranged by three section; fuzzification, inference and defuzzification. Before implementation in microcontroller program, the algorithm was simulated first in MATLAB software program in order to obtain the best rule on fuzzy criteria.
Figure 3. Boost Converter Design

The fuzzification logic layer will convert gas concentration into fuzzy value and its was classified in idle, slow and medium criteria in the form of simple triangle membership function as shown in Figure 4.a. That criteria also applied in defuzzification layer but its just different in output value and its will provide the PWM signal for switching actuation. The view of output value could be observed by change the inference function and simulation step will stop after meet the proper criteria. The output illustration is shown in Figure 4.b.

Figure 4. Fuzzy logic simulation.

Pre-study of CO gas concentration needs to determine the rules on fuzzy logic membership functions criteria, this paper use the low level category is lower than 250 PPM, medium category in range of 250 PPM until 350 PPM and high category is more than 350 PPM. The output signals also classified to provide a lowest duty cycle of 0%, 50% as medium, and 100% as highest. Those categories are shown in Table 1.

The sensor feeds gas concentration signal and compare with reference value to provide error signal $e(t)$ as input to the controller, so $e(t)$ value depends on the gas content of CO measurement, after that the incoming signal will process in microcontroller to determine the decision. Gas concentration value was defined as the input to the fuzzy controller to provide the output of duty cycle (%), so the highest CO concentration will trigger the controller to provide more electrolysis gas outcome.
Table 1. Fuzzy category

| CO (PPM) | feedback  | Duty cycle (%) | PWM |
|----------|-----------|----------------|-----|
| 250      | low       | 0%             | 77  |
| 250 < CO < 350 | Medium   | 50%            | 153 |
| > 350    | High      | 100%           | 255 |

3. Result and Discussion

The next step is testing the system before and after the combustion engine is connected with the electrolysis reactor. The system was applied in old motorbike with the production year about 2006. Regarding the limit of sensor measurement so its placed about 15 cm from the exhaust pipe. The throttle withdrawn condition as idle, low throttle, throttle medium, and high throttle opening. The experimental result is shown in Figure 5.

Figure 5. Experiment result

Figure 5.a and 5.b described the experimental result with reference value about 250 PPM. This experiment deal with two condition in which before and after electrolysis activation. The idle condition was obtained the CO gas content associated with electrolysis treatment. Before connected with the
reactor, the sensor observed CO concentration reaches about 330 PPM, and after the electrolysis activated the content of CO reduced about 253 PPM.

According to Figure 5.c and 5.d, set point value is about 350 PPM on the state of throttle opening low. Before the appliance connected to the reactor, the CO value was reach about 456 PPM and after that its reduced about 349 PPM while reactor active. The set point about 330 PPM as shown in Figure 5.d and 5.e was observed about 488 PPM and 324 PPM before and after the reactor activation respectively.

4. Conclusion
The fuzzy logic control was successfully developed in effort of CO reduction on motorbike combustion engine that meet minimum reduction about 253 PPM. However, the performance in reducing of error value still need to be improved by considering the aspects of instability of chemical reaction in reactor and interference of sensor measurement.

5. References
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