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The Analysis of Exhaust Gas Characterization in Reducing CO and HC Gas Pollution on the EFI Engine of Daihatsu Luxio 1500 CC

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Abstract

Air pollution from highways, particularly in urban area which density and mobility are already on the verge of solid boundaries, resulting in environmental and human health problems. This is due to the lack of standardization of testing exhaust gas by the governmental body. Accurate results form the test and technology standardization on exhaust system which is one important components for gas pollutant elimination from vehicle. In the present work, we examined the role of some modified exhausts on the level of pollutant exhaust, i.e. CO, HC, NOx gas. Experimental design for controlled variable is the speed, torque of the wheel, and gear position. Several modification of exhaust gas was tested were tested, i.e. Standard, 3-way catalytic converter, racing and 2-ways catalytic converter. The data is gained through dynamometer and exhaust gas Analyzer as a speedometer gauges, torque Wheels and levels of exhaust gas that comes out of the tailpipe. Statistical analysis of the results uses one-way ANOVA. The result showed that the order in reducing exhaust gas CO and HC are: (1) two-way exhaust gas and 3 Way Catalytic Converter exhaust gas, (2) standard and (3) modified exhausts. 3 Way catalytic converter was the best to eliminate NOx than other three exhaust gas system

Keywords: Exhaust Gas, Pollutants, Modify, Standard Exhaust Gas, 2 way Catalytic Converter, 3 way Catalytic Converter

1. Introduction

Urban air pollution which occurs in major cities in Indonesia has been very alarming for the nowadays society. Some researches on air pollution with all the risks have been published, including the risk of blood cancer. However, it is rarely recognized who knows how many thousands of city residents who die each year from respiratory infections, asthma, and lung cancer due to urban air pollution. City air has been filled with soot and gases that are harmful to human health. It is estimated that in the next ten years an increasing number of patients with diseases of the lungs and respiratory tract. Not only acute respiratory infections which now ranks first in the disease pattern in many areas in Indonesia, but also the growing number of people with asthma and lung cancer.In large cities, the contribution of motor vehicle exhaust gas as a source of air pollution reaches 60-70%. While the contribution of the exhaust gas from industrial chimneys is only about 10-15%, the remainder coming from other combustion sources, for example from households, waste burning, forest fires, etc. Everything is emitted by motor vehicles. WHO estimates that 70% of the urban population in the world ever breathe dirty air due to emissions of motor vehicles, the remaining 10%, while breathe air that is marginal. Consequently fatal for infants and children. Adults who are at high risk, such as pregnant women, the elderly, and people who have had a history of lung disease and chronic respiratory tract. Unfortunately, the patients and their families are not aware that most of the negative consequences derived from air pollution caused by vehicle emissions are increasingly alarming. The increasing air pollution today is very alarming. Sources of air pollution in road motor vehicles, especially during traffic jams or congestion occurs on some streets to traffic light. Various congestion is the biggest contribution to air pollution is discharged into the atmosphere [1].

The attempts to suppress levels of toxic exhaust pollution that has been done in three ways such as to improve the processing technology of fuel, combustion process and exhaust gas catalytic [2], the quality of combustion engine technology with EFI [3]. Development and application of mathematical models for 3-way catalytic converters was defined bravely, and the exhaust gas discharge technology [4]. Due to the variety of disposal of waste gas technology in the market, including standard exhaust, modified exhaust and exhaust with catalytic converter, the researcher needs to conduct research to determine the quality of the exhaust in particular to the effects of toxic gases released from the tailpipe (exhaust emissions)

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2. Theoretical Review

2.1. Air-Fuel Ratio (A/F)

It is important to know how much oxygen or air must be supplied for complete combustion of a given quantity of fuel. This information is required in sizing fans and ducts that supply oxidizer to combustion chambers or burners and for numerous other design purposes. The mass air-fuel ratio, A/F, or oxygen-fuel ratio, O/F, for complete combustion may be determined by calculating the masses of oxidizer and fuel from the appropriate reaction equation [4]. Let.s return to equation 1. The A/F for methane is [(2)(32) + (2)(3.76)(28)]/(12 + 4) = 17.16 and the O/F is 2(32)/(12 + 4) = 4. Thus 4 kg of O2 or 17.16 kg of air must be supplied for each kilogram of methane completely consumed. While oxygen atom weight is 32, Nitrogen dioxide atom weight is 28, carbon atom weight is 12 and hydrogen is 1.

2.2. Equivalence Ratio

A measure of how much fuel is actually supplied, called the equivalence ratio (Lamda), is the ratio of the actual fuel-air ratio to the theoretical fuel-air ratio shown in equation 2. Thus 100% theoretical air corresponds to an equivalence ratio of 1, and 20% excess air (17.16 x 120%), to θ = (100x17.16)/ (120x17.16) = 0.833. When the equivalence ratio is less than 1, the mixture is called lean; when greater than 1, it is called rich. $\theta < 1$; $\theta =$ 0.833; (A/F) actual = 120%(17.16) then following equation 1 we develop equation 3. $\theta > 1$; θ = 1.200; (A/F) actual = 80%(17.16) then following equation 1 we develop equation 4, where X,Y,Z and W depend the quality of combustion process to investigated in this research chapter 3:

$$\mathrm{CH_4 + 2O_2 + 2\,(3.76\,)N_2 \longrightarrow CO_2 + 2H_2O + 2\,(3.76\,)N_2} \tag{1}$$

$$\theta = \frac{(F/A)_{actual}}{(F/A)_{theory}} = \frac{(A/F)_{theory}}{(A/F)_{actual}} \tag{2}$$

$$\mathrm{CH_4 + 120\%(2O_2 + 2\,(3.76\,)N_2) \longrightarrow CO_2 + 2H_2O + 2\,(3.76\,)N_2 + 20\%(2O_2) + X\%(N_2) + Y\%(NOx)} \tag{3}$$

$$\mathrm{120\%(CH_4) + 2\,O_2 + 2\,(3.76\,)N_2 \longrightarrow X\%(CO_2) + Y\%(H_2O) + 2(3.76\,)N_2 + Z\%(CO) + W\%(HC)} \tag{4}$$

2.3. General Rules of Emission Engine Analysis

The output of combustion in the form of composition of exhaust gas can be conclude generally as follow Figure 1:

1. If CO goes up, O_2 goes down, and conversely if O_2 goes up, CO goes down. Remember, CO readings are an indicator of a rich running engine and O_2 readings are an indicator of a lean running engine
2. If HC increases as a result of a lean misfire, O_2 will also increase
3. CO_2 will decrease in any of the above cases because of an air/fuel imbalance or misfire
4. An increase in CO does not necessarily mean there will be an increase in HC. Additional HC will only be created at the point where rich misfire begins (3% to 4%CO)
5. High HC, low CO, and high O_2 at same time indicates a misfire due to lean or EGR diluted mixture
6. High HC, high CO, and low O_2 at same time indicates a misfire due to excessively rich mixture.
7. High HC, Normal to marginally low CO, high O_2, indicates a misfire due to a mechanical engine problem or ignition misfire
8. Normal to marginally high HC, Normal to marginally low CO, and high O_2 indicates a misfire due to false air or marginally lean mixture

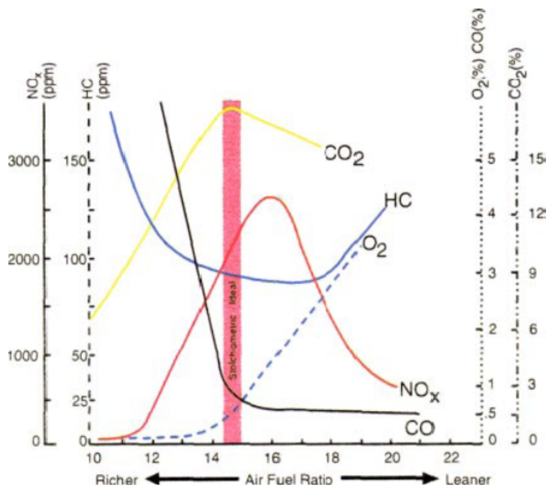

Figure 1. A/F ratio versus Exhaust Gas

2.4. Exhaust Gas Pollutants Elimination

In this research we have listed the pollutant and non-pollutant as follow, Pollutants in the standard exhaust gas are CO, HC, NOx while Non-pollutant gas in the exhaust standard are CO_2, H_2O, O_2, N_2. To eliminate pollutant there are two solution namely oxidation for hydrocarbon, carbon monoxide and reduction for NOx.

2.4.1. Through Oxidation

Regarding to [5], there are two stages in the process of two-way catalytic converter which are Figure 2:
Stage 1: Oxidation of Carbon Monoxide (CO) into carbon dioxide such as equation 5.

$$2\mathrm{CO} + \mathrm{O_2} \longrightarrow 2\mathrm{CO_2} \tag{5}$$

Phase 2: The oxidation of unburned hydrocarbons (HC) into carbon dioxide and water such as equation 6.

$$\mathrm{CH_4} + 2\,\mathrm{O_2} \longrightarrow \mathrm{CO_2} + 2\mathrm{H_2O} \tag{6}$$

Phase 3: The oxidation of unburned hydrogen (H2) into water such as equation 7.

$$2\mathrm{H_2} + \mathrm{O_2} \longrightarrow 2\mathrm{H_2O} \tag{7}$$

Reaction rate of oxidation conducted by 2 way catalytic is formulated as equation 8 :

$$R_i = \frac{k_i C_i C_4}{G} \quad \left(\frac{mol.C_i}{cm^2 pt.s}\right), R_4 = \frac{1}{2}R_1 + \frac{9}{2}R_2 + \frac{1}{2}R_3 \tag{8}$$

Where : CO i=1, HC i=2, H_2 i=3, O_2 i=4
G = $(1 + K_1.C_1 + K_2.C_2)^2.(1 + K3.C_1^2.C_2^2).(K_4.C_{NO}^{0,7})$
C_i = concentration of ith species (mol/cm^3)
C_{NO}= concentration of NO (ppm)
Rate constant: $k = A.e^{(-E_a/RT)}$

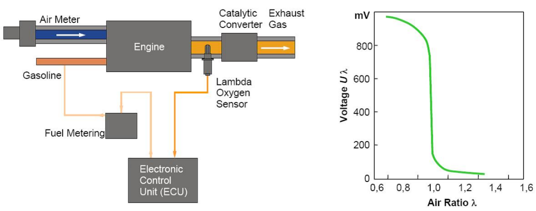

Figure 2. The Two-Way Catalyst

2.4.2. Through Chemical Reduction

For 3 way catalytic converter is shown in Figure **??** and 4, Reduction of NOx , namely nitrous dioxide (NO2) into nitrous and oxygen can be formulated as equation 9.

$$2\mathrm{NO_2} \longrightarrow \mathrm{N_2} + 2\mathrm{O_2} \tag{9}$$

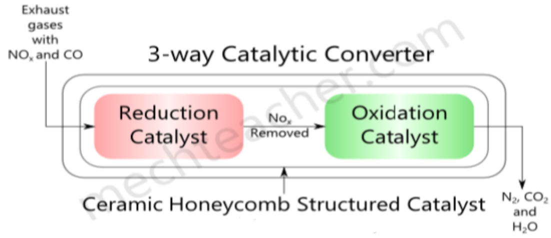

Figure 3. 3 Way Catalytic Converter Scheme

2.4.3. Through Exhaust Gas Recirculation Reduction

EGR is one of the most effective ways to reduce NOx emissions. Yet, not all cars have the EGR system. Cars that do not use EGR to reduce NOx emissions must rely more on that catalytic converter to reduce NOx [6]. These cars may require catalytic reduction efficiency of 90% or more. Only the highest quality catalytic converters, operating under conditions intended to achieve this kind of efficiency. EPA certification only indicate that the converter can reduce NOx emissions by 60% [7]. Their camshafts (valve timing) is often reduce the flow of EGR. Both of these design features increase the emission of NOx and require NOx reduction efficiency is much higher than the catalytic converter [8, 9] .

2.4.4. Catalytic Converter Properties

1. Oxidation reactor constructed from Platinum (Pt), Palladium (Pd) or Rhodium (Rh) [18]. 2. Reduction reactor constructed from material.

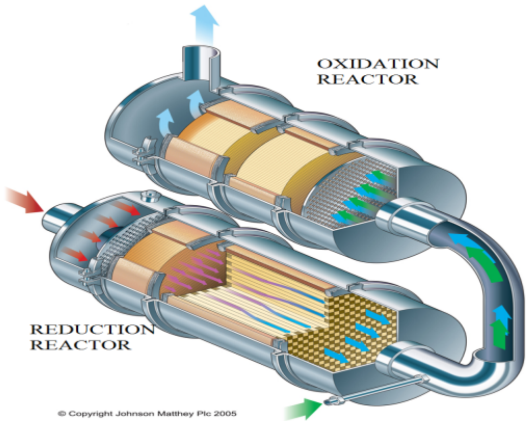

Figure 4. Construction of 3 Way C.C. in Cutting Section

3. Methods

3.1. Experimental Setup

This research falls under the category of quantitative research. Some previous researchers have much to conclude about the exhaust gas treatment technology in both Diesel and petrol, but has not yet reached a significant difference against 4 types of exhaust system technology, which is the standard exhaust, modified, 3 Way Catalitic Converter and two-way catalyst. To the authors have done a performance test 4 to the technology in order to eliminate the pollutant gas vehicle exhaust gas. Test object and fuel with the same conditions that EFI Luxio Daihatsu vehicle with non-lead fuel (pertamax). Test equipment used endeavored that have high validity, namely, vehicle dynamometer and Hanatech Ultra 4/5 Gas Analyzer (13627-84) exhaust tester sown in Figure 5.

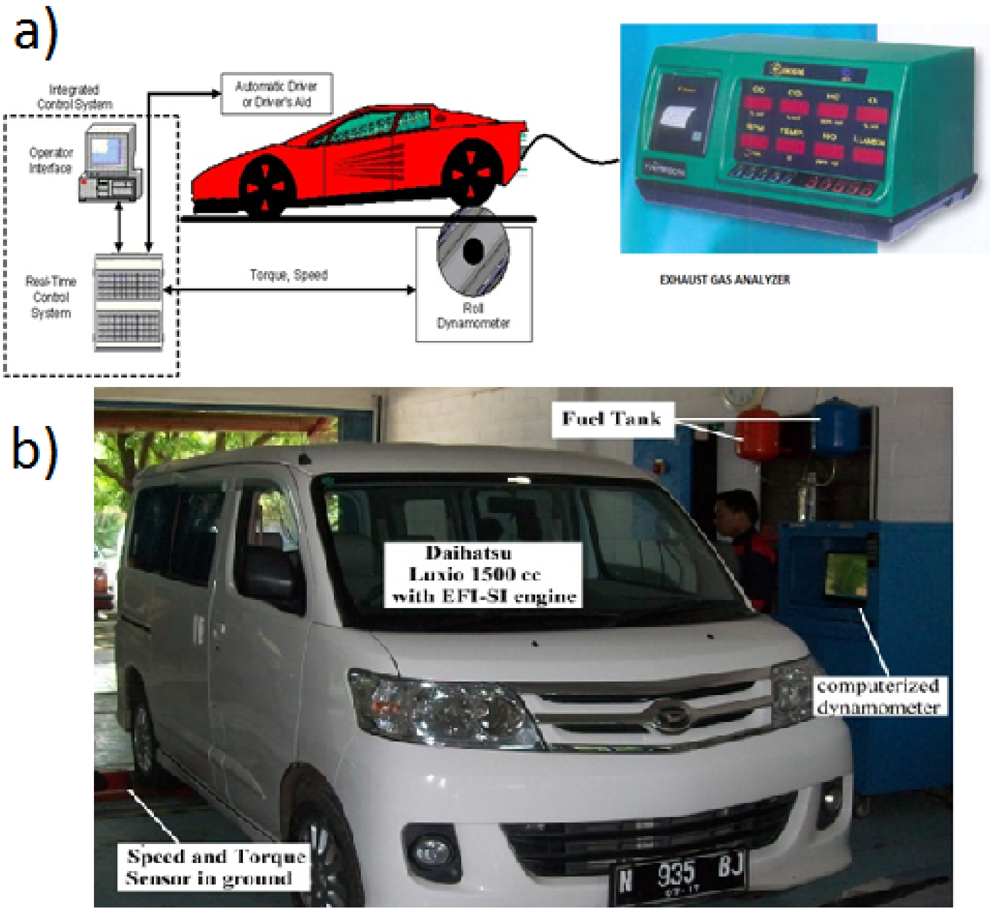

Figure 5. a) Experimental Setup (b) Our Data sampling realization in VEDC Malang

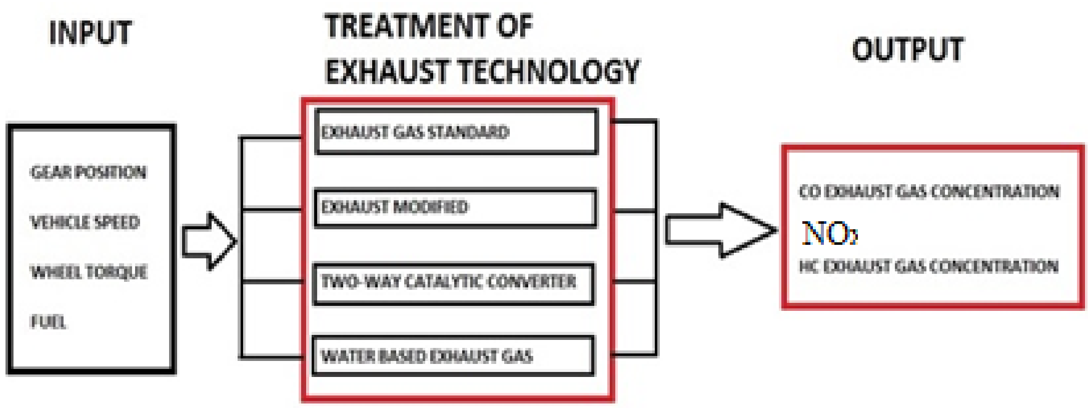

Figure 6. Data sampling scheme

3.2. Data Sampling and Validation

Quality research results depends on the accuracy / validity of the sampling and the number of sampling of the population. In this study, data collection was obtained through experimental testing on real-time data on the results of pollutant gases petrol engines with a variety of field operations. Implementation of the sampling data is not performed on a test drive on the highway, given the diversity is not complete. For that then tested on a replacement dam complex highway complete with vehicle dynamometer. Dynamometer allows it to be set in accordance with a variety of road conditions / load. To achieve the validity of the data is good then all objects and equipment testing standards must be met through a step called for the calibration of test equipment and conditioning of normal for the vehicle. Based on input variables (independent) and a variable output (dependent) and the condition of constraint conditions that have been setup in chapter 1 introduction, it has been created with the data collection instrument as follows (Figure 6).

a. Input Variable (Independent) as follows:

1. The position of the transmission gear in 2nd gear, 3rd gear and 4th gear
2. Vehicle speed (speedometer) in kilometers per hour
3. Torque cog in Newton meter
4. Variation of Exhaust gas Type

b. Output Variable (dependent) as follows

1. Levels of Carbon mono-oxide (CO) in
2. Levels of Hydro Carbon (HC) unburned in PPM
3. Level NOx

4. Results and Discussion

4.1. CO, HC and NOx with Equivalent Ratio

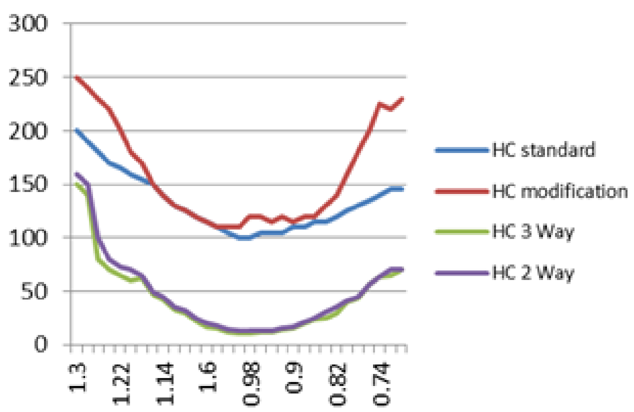

Figure 7. HC concentration (ppm) vs Equivalent Ratio

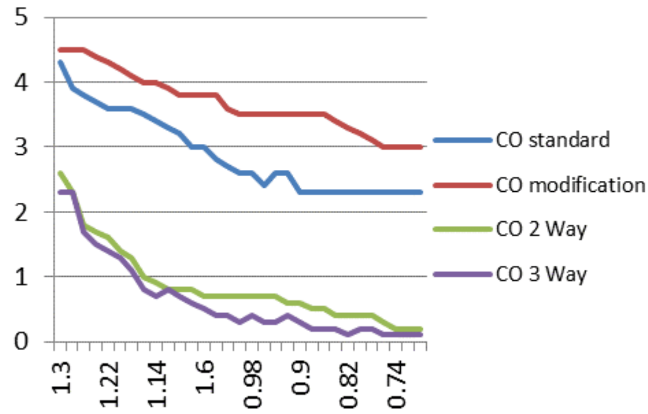

Figure 8. CO concentration (%vol) vs Equivalent Ratio

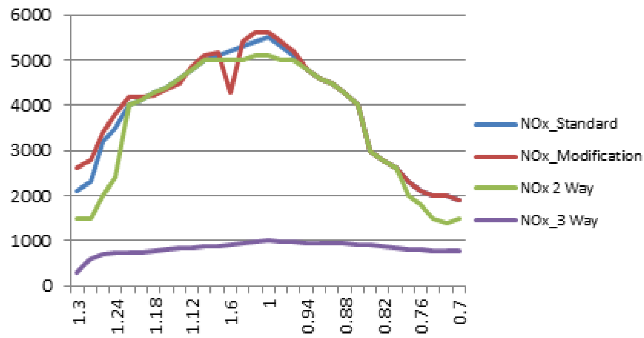

Figure 9. NOx concentration (ppm) vs Equivalent Ratio

Several points can be figure out from the data:

a) Equivalent ratio 1,0 HC and CO concentration 2 way and 3 way the best value namely 25 ppm for HC and 0,4% for CO, because of oxidation process was conducted very good by both of catalytic. HC-concentration standard and modification higher in average value namely 100 ppm for HC and , 2,3% for CO because there no oxidation process was conducted by both of catalytic (Shown in Figure 7 and 8)

b) Equivalent ration 1,0, NOx concentration 2 way, standard and modification were 5000 ppm, because of EGR cannot do well, while 3 way can eliminate NOx at minimum value namely 960 ppm, because it was reduced in its Bank 1 catalytic converter (shown in Figure 9)

4.2. Data CO, HC dan NOx with Wheel Torque

After going through a series of input and output of data retrieval that has generated the data - the data significant in accordance with the independent and dependent variables in research methods as follow, data on vehicle speed, torque and power as well as an independent variable, while CO, HC and NOx in the standard exhaust, modified exhaust, 2-Way and 3-Way catalytic converter are dependent variable. Research result can be shown as

Figure 10,11 and 12.

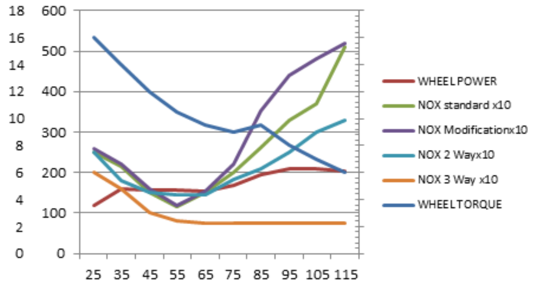

Figure 10. Interaction between Wheel Speed,Torques, Power with Exhaust NOx

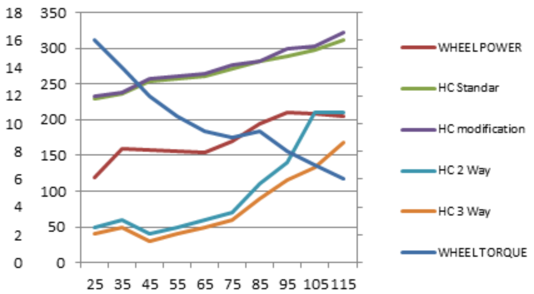

Figure 11. Interaction between Wheel Speed, Torque, Power with Exhaust CO

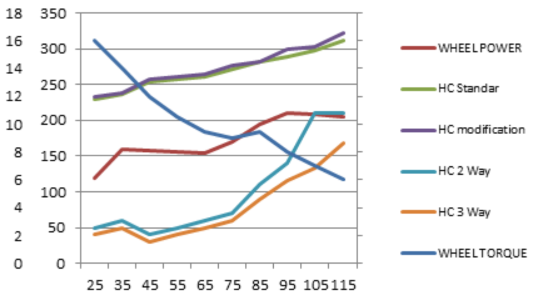

Figure 12. Interaction between Wheel, Speed, Torque, Power with Exhaust HC

a) There are not significant differences in the use of the standard exhaust and modified exhaust to the levels of exhaust gas pollutants CO and HC, when wheel torque at 12 Nm.

b) There is a significant difference in the use of the standard exhaust with exhaust 3 way catalytic converter on levels of exhaust gas pollutants CO and HC, CO eliminate 3 way better than 2 way, HC eliminate 3 way better than 2 way, when wheel torque at 12 Nm.

c) There are significant differences with the standard exhaust use 2 way on levels of exhaust gas pollutants CO and HC. CO eliminate 3 way better than 2 way, HC eliminate 3 way better than 2 way, when wheel torque at 12 Nm.

d) There are significant differences with the use of modified exhaust and 3 way catalytic converter exhaust on levels of exhaust gas pollutants CO and HC, when wheel torque at 12 Nm.

e) There is a significant difference using a modified exhaust (racing) with 3 way catalytic converter exhaust pollutant levels of exhaust gas pollutants CO and HC. CO eliminate 3 way better than modified, HC eliminate 3 way better than modified, when wheel torque at 12 Nm.

f) There are significant differences in the use of 3 way exhaust and 2 way exhaust pollutant levels of residual gas CO and HC on. CO eliminates 3 way better than 2 way, HC eliminate 3 way better than 2 way, when wheel torque at 12 Nm.

g) There are significant differences with the use of exhaust modified exhaust pollutant levels 2 way flue gas CO and HC on. Eliminating CO, 2 way better than modified one, when wheel torque at 12 Nm.

5. Conclusions

- Exhaust ranking in reducing CO and HC gas are: (1) 3-way exhaust, (2) 2 way exhaust gas, (3) standard and (4) modified exhaust, when wheel torque at 10 up to 12 Nm
- Exhaust ranking in reducing NOx gas are: (1) 3-way exhaust, (2) 2 way exhaust gas, (3) standard and modified exhaust, when wheel torque at 10 up to 12 Nm.

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