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Characteristics of Exhaust Emissions of Two Wheel Motorcycle Based on the World Wide Motorcycle Testing Cycle for Euro 4 Standard in Indonesia

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Abstract

Good air quality is an absolute requirement that must be met to promote healthy lifestyle. Air pollution, however, can cause adverse effect on air quality. One of the main sources of air pollution comes from transportation sector. The unburned hydrocarbon (HC), carbon monoxide (CO), Oxides of Nitrogen (NO_x), smoke opacity, carbon dioxide (CO2) and particulate matter (PM) are main constituents of the exhaust gas from vehicles. In order to reduce the emission from transportation sector and meet the requirement of Euro-4 emission threshold, all new motorcycle has to undergo the World Wide MotorCycle Test Cycle (WMTC) which will be implemented in Indonesia. In addition to the level of CO, HC, NO_x and CO_2 emission parameters that must be maintained, it is necessary also to measure the level of particlulate emissions in the engine exhaust.

Hence, the purpose fo this study is to conduct emission measurements from a new type of motorcycle with a cylinder capacity larger than 250 cc, Bsed on the measurement results, it was found that the Euro-4 emission requirement for CO, HC, NO_x can be easily fulfilled. However, an in-depth measurement on Particulate Matter (PM) indicate that the motorcycle produced higher concentration of nano-particulates (particulate with size less than 2.5 μm). The number concentration of $PM_{2,5}$ is around 734.08 /cm^3 , which is around 99% of the total particulate emission. Given this fact, the PM value should be be taken into account in determining roadworthy motor vehicles.

Keywords: Motorcycle, Emission, Euro-4, World Wide Motorcycle Testing Cycle (WMTC), Particulates

1 INTRODUCTION

Air pollution today shows a very poor condition. Sources of air pollution can come from various activities, including industry, transportation, offices and housing. These various activities are the biggest contribution from air pollutants that are discharged into the air. The air pollution can cause a decrease in air quality, which has a negative impact on human health. Though the growth of development in industry and transportation brings positive impact on human lifestyle, it also has a negative impact in the form of air pollution that occurs both indoors and outdoors which can endanger human health and the occurrence of disease transmission.

Currently, the parameter used to describe air quality in Indonesia is by looking at the level of the Air Pollutant Standard Index. This index is illustrated by the number of ambient air quality conditions at a certain location and time based on their effects on human health, aesthetic values and other living things. The parameters used according to Government Regulation Number 41 of 1999, which include: Sulfur dioxide (SO2), Carbon monoxide (CO), Nitrogen dioxide (NO2), oxidants (O3), Hydrocarbons (HC), PM_{10}, $PM_{2.5}$, TSP (dust), Pb (Lead), Dust (falling dust), Total Fluoride (F), Fluorine Index, Chlorine & Chlorine dioxide, Sulfate index. For PM emission in particular, epidemiological studies have consistently found associations between ambient air particulate concentrations and adverse human health effects. PM2.5 has been most closely associated with excess cardiovascular mortality , lung cancer and cardiac arrhythmias, and such effects vary in strength with sampling location, season and size fraction. Coarse PM has been associated with respiratory disease and cardiopulmonary morbidity, although some research studies have not been able to show any clear associations with health effects . Many of the contradictions from epidemiological work on coarse PM arise from findings that are confounded by the co-presence of fine PM, low exposure levels, and/or the lack of statistical power in single city or regional studies **[1, 2]**.

From the source point of view, these parameters can be generated from both a moving source and a stationary source. Control related to the emission produced is an absolute must, so that ambient air quality is maintained.

The growth of motor vehicles in Indonesia today certainly has a direct and significant impact on air quality levels. From AISI data for Semester 1 of 2019, the number of units produced is 4,350,158 units. Making motorbikes as the main means of transportation in Indonesia. The Emission Threshold Level that is currently used in most regions of the world and which will be used in Indonesia for motorbikes is Euro-4 with the WMTC method where only the parameters of CO, HC and NO_x are used as benchmarks for contributing to the air quality standard **[4]**.

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However, other exhaust emissions such as Particulate Matter(PM) of motorbikes may also have effect on air quality. The value of particulates with a certain size must be considered, considering that it has a very large effect on health. The size of the dust particles that are harmful to health generally ranges from 0.1 micron to 10 micron. In general, the dust particle size of about 5 microns is airborne particulate which can directly enter the lungs and settle in the alveoli. This does not mean that particulate sizes greater than 5 microns are harmless, as larger particulates can irritate the upper respiratory tract and cause irritation **[3]**.

2 METHODOLOGY

2.1 Vehicle and Fuel Specification

The main specifications of the motorbikes used in the testing are summarized in Table 1. The tested motorbike were a new type of motorized vehicle equipped with a four-stroke engine, with a cylinder capacity larger than 250 cc.

Table 1: Motorcycle Specification

ITEM	SPECIFICATION
Engine Type	4-Stroke, 8-Valve, Parallel Twin Cylinder
Engine Capacity	250 cc
Fuel Supply	PGM-FI
Bore X Stroke	62,0 x 41,4 mm
Transmision	Manual, 6 Speed
Compression Ratio	12,1:1
Maximum Power	30 kW (41 PS) /13.000 rpm
Maximum Torque	25 Nm (2,5 kgf.m)/11.000 rpm
Starter	Electric
Clutch Type	Multiple Wet Clutch with Coil Spring
Engine Cooling System	Liquid Cooled With Auto Electric Fan
Liquid Cooled With Auto Electric Fan	1-N-2-3-4-5-6
Frame Type	Diamond (Truss) frame
Front Suspension Type	Inverted Telescopic Front Suspension
Rear Suspension Type	Aluminum Swing Arm (5 Adjustable Mono Suspension with Pro-Link System)
Front Tire	110/70 – 17 54S (Tubeless)
Rear Tire	140/70 – 17 66S (Tubeless)
Dimension	2.060 x 724 x 1.098 mm
Curb Weight	168 kg

The motorbike used has been pre condition before the test. checking condition of the engine, lubricants and has been running in procedure within a minimum of 1000 km as a requirement test that needs to be done.

Although engine design features must always be the prime factor in reducing undesirable exhaust emissions, the fuel can play significant role. Most of the fuel quality factor that are important such as Unleaded gasoline, Oxygenated blend components, Gasoline Volatility and also Additives **[5]**. For this sampling fuel we use Highest RON Indonesian Fuel Market which is PERTAMAX TURBO RON 98.

Table 2: Fuel Specification

NO	CHARACTERISTIC		PERTAMAX TURBO	TEST METHOD
1	Octane number	RON	min. 98	D2699
2	Induction Period	minute	min. 480	D525
3	Sulfur	% m/m	max.. 0.05	D2622/D4294/D7039
4	Lead	gr/l	max. 0.013	D3237
5	Oksigen	% m/m	max. 2.7	D4815
6	Washed gum	Mg/100ml	max. 5	D381
7	Unwashed gum	Mg/100ml	max. 70	D381
8	Vapour preasure	kPA	45-60	D5191/D323
9	Specific Gravity at 15 °C	Kg/m^3	715-770	D4052/D1298

2.2 Emission Test Cycle

Before Testing Emission, Vehicle sample should be classified based on engine capacity and Maximum Velocity (VMax) to judge the class of emission testing mode as shown in Figure 1 **[6]**.

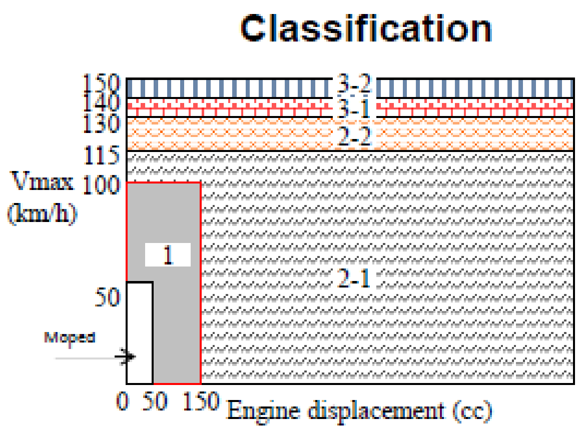

Figure 1: Clasification Mode Type [6]

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The driving cycle based on the World Wide MotorCycle Test Cycle (WMTC) are used in a series of test to determine the emission behavior of the new motorcycle. The test cycle used is Mode Test Type 1 and Idle Test Type 2. This cycle has been established in Indonesia through Minister of Environment Regulation No. 23/2012 and is also used in EUROPEAN Directive (European Council Directive 2002/51 / EC) **[6]**. The cycle start under cold conditions and represents the rural, general road and also highway driving conditions. This speed profile is then applied to a motorbike during the dyno test with further consideration based on the basic vehicle specific classification of the engine and the maximum speed of the motorbike

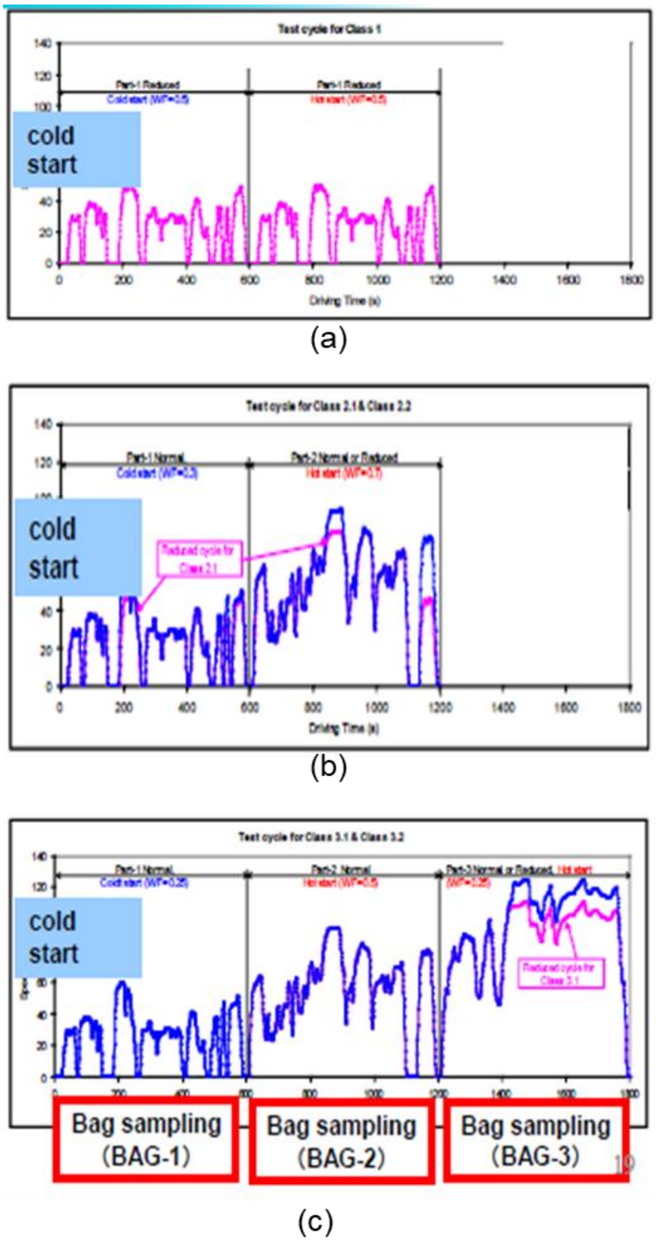

Figure 2: Test Cycle Class 1 (a), Test Cycle Class 2-1 & Class 2-2 (b), and Test Cycle Class 3-1 & Class 3-2 (c) [6]

In addition, the gear calculation procedure was based on the power-to-mass ratio of the motorbike. The individual gear points were then used to determine the profile speed in Worldwide Motorcycle Testing Cycle (ECE / TRANS / 180 / Add. 2 / Annex 1 / Rev 1).

2.3 Experimental Procedure

Preparation of chassis dyno roller test are applied in accordance with the provisions of Directive 2002/51 / EC. The inertia setting is selected based on the flywheel class, and the soaking room conditions are set at 23 C and also 50% relative air humidity. The CSC cycle was also carried out at low speed conditions of ambient temperature of 7 C and air relative to 50% humidity.

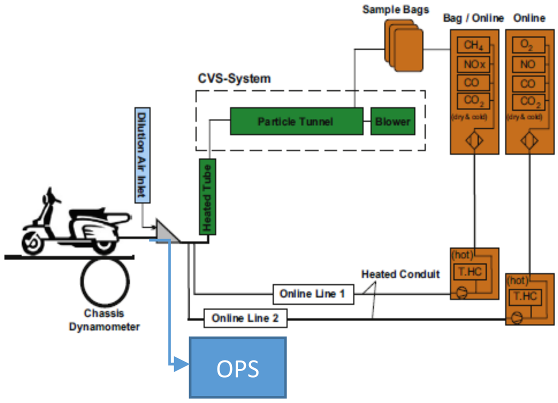

Figure 3: Emission Testing

Standard fuel with a minimum research octane rating of 95.9 and a low sulfur content (<10 ppm) was used for all motorbikes to mimic real world conditions **[7]**. Testing equipment and setting are shown in Figure 3. To ensure the optimum performance from the testes motorbike, a specifically designed sampling of the exhaust system was used throughout the testing period.

2.4 Sampling, analyzing and data processing

Horiba Emission Analyzer MEXA ONE C1 was employed to measure the exhaust emissions of CO, HC, NO_x. Particulate size measurements are done using TSI Optical Particle Sizer model no. 3330. The Optical Particle Sizer (OPS) spectrometer measures particle concentration by counting individual pulses from the photodetector. This works well when particle concentrations are low, but when particle concentrations are high, pulses start to overlap each other. Because of this, particle concentrations based solely on the number of pulses underestimates the number of particles entering the viewing volume.

When a particle is detected entering the optical viewing volume, no other particles can be counted. As the particle concentrations increase, the amount of time blocked by the presence of particles becomes significant. If the particle concentration is computed using elapsed time, the value will be under reported.

3 RESULTS

3.1. Results of Gaseous Emission Measurements

The test is carried out by following the measurement rules according to the provisions of Directive 2002/51 / EC. Whereas before the test was carried out, the unit had been preconditioned in a soaking room with a temperature of 25 ± 3 C, for more than 8 hours. These conditions are needed to obtain test conditions that are considered capable of producing / representing the worst emissions from the test. The results of the Emission Test Type 1 are summarized in Table 2.

Table 3: Emission Result From Test Mode Type 1

EMISSION MODE	CO (gr/km)	HC (gr/km)	NOx (gr/km)
Regulation Standard Euro- 4	1.140	0.170	0.090
Emission Gas Mass	0.794	0.136	0.017
Judgement	**OK**	**OK**	**OK**

From the results of the data above, it is clear that the vehicle produced emissions that are lower than the required threshold of Euro-4 which is expected. In addition, the exhaust emission measurements were also conducted for idle condition (Type 2 Test) as shown in Table 3. Similarly, the motorbike was able to achieve emissions that are lower than the required threshold value. Based on the current regulation in Indonesia for 2-wheeled motorized vehicles, the sampled motorbike unit has adhere to the Euro-4 standard, which legally mean that this new motorbike can be put for sale on the market.

Table 4: Emission Result From Test Mode Type 2 (Idle)

GAS CONCENTRATION		CO (%)	HC (ppm)	CO2 (%)	Speed (rpm)	
Regulation Standard EURO 4		0.5	-	-	1500	
Result (idle)		0.004	12.88	16.17	1508	
Result (high idle)		0.004	1.14	16.87	2087	
Judgement	**OK**	**-**			**-**	**-**

3.2. Result of Particulate Matter Measurements (WMTC Mode)

The results of the particulate size and number concentrations measurements from TSI Optical Partcle Sizer (OPS) are shown in Table 4 below.

Table 5: Particulate Number Concentration

Size (ɥm)	Number (#/cm3)	Surface (ɥm2/cm3)	Mass (ɥg/m3)
0.337	424.9	152.2	8.62
0.419	169.9	94.3	6.65
0.522	73.7	63.4	5.56
0.650	22.2	29.5	3.23
0.809	12.3	25.4	3.45
1.007	12.5	40.0	6.77
1.254	3.57	17.7	3.73
1.562	5.99	46.1	12.1
1.944	5.49	65.5	21.4
2.421	3.53	65.3	26.6
3.014	1.99	56.9	28.8
3.752	1.10	48.9	30.8
4.672	0.531	36.6	28.7
5.816	0.180	19.2	18.8
7.241	0.0847	14.0	17.0
9.015	0.0402	10.3	15.6

From the measurement results, it can be observed that the 250 cc motorcycle generates significant number of particulates in the size range of $PM_{2,5}$. Based on the data, it can be seen that the total number concentration of PM ≤ 2.5 µm was 734.08 #/cm3 while the PM ≥ 2.5 .5 µm only contributed 3.93 #/cm3. In other word, almost 99% of particulates generated from the engine exhaust can be categorized as nano-particulates. It is suspected that the smaller particle generated by the 250 cc motorbikes is due to the latest engine technology applied in which has been recorded as capable of improving engine performance and reducing gaseous emissions at the expense of breaking down particulate matter into smaller sizes druing the combustion phase. This is also supported by the observation on the muffler of the exhaust pipe which showed cleaner (smokeless) exhaust emission.

Based on the fact that smaller particles tend to have more adverse effects on human health, the higher PM 2.5

concentration generated from the new motorbikes may bring unintended negative effect. Up to 99% of the particles smaller than PM ≤ 2.5 μm (often identified as particulate matter with very small / ultrafine sizes) found on the motorbike exhaust emissions can directly enter human lungs without being able to be filtered by organs or even medical masks and increase the risk of lung cancer if inhaled.

Current weakness arises in terms of statutory provisions where the government as a regulator and stakeholders should be aware of the dangers posed by the various existing emission sources. The source of emissions from motorized vehicles is no exception. The current emission standard is good, but it is not perfect without regulating the PM 2.5 level generated by the motorized vehicle. One of the suggested improvements that can be done is to regulate the emission level of particulates below 2.5 microns produced by motorized vehicles so that later ambient air quality can be maintained clean. This can be simply achieved by introducing stringent emissions threshold for both gaseous as well as particulate emission.

4 SUMMARY AND CONCLUSION

Current experimental research offers insight into the environmental impact of a new type of Euro-4 category motorcycle. In general, the new motorbikes can safely fulfill the emission requirement of the Euro-4 motorcycle emission standard which limits the Carbon Monoxide (CO), Hydro Carbon (HC) and Nitrogen Dioxide (NO_2) emissions prior to the launching of motorbikes into the market. CO emission level of 0.794 gr / km, HC level of 0.136 gr / km and NO_x level of 0.017 gr / km was obtained for the the WMTC Test 1 mode; while the CO level of 0.004% was measured during idle and high idle condition are all lower than the threshold limit for the Euro-4

Further research on particulate size measurement conducted in this study, however, show a troubling finding, It was found that the around 99% of particulate was in the size of 2.5 μm or smaller with the number concentration of $PM_{2.5}$. is measured at the level of 734.08 #/ cm^3. It becomes a major concern considering that smaller particles are more dangerous to human health

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