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The Role of Vehicle Speed Management in Urban Air Pollutant Emission Reduction

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Abstract— **Lack of mass transit facilities in urban area leads motorcycle to become the most chosen vehicle mode in Indonesia. It accounts for approximately 80% of the total motorized vehicle population. Increasing in motor vehicle population causes traffic congestion and lower traffic speed, hence higher emissions that worsen urban air quality. This paper aims to investigate relationship of vehicle travelling speeds and CO_2, CO and HC emission profiles of the typical motorcycle used in Indonesia. Exhaust emissions of 20 motorcycles were tested using autocheck analyzer on idle and speed variations of, 10, 20, 30, 40, 50, and 60 kph on a chassis dynamometer. For idle condition average emission rates of CO_2, CO and HC were 0.16, 0.03 and 0.002 g/s, respectively. The results show that the highest CO_2 and HC emissions of 82.30 g/km and 0.55 g/km, respectively, found at 10 kph. The lowest emissions were found at 60 kph speed with CO_2 emission rate of 27.03 g/km and HC of 0.10 g/km. Carbon monoxide (CO) showed slightly different emission pattern, with 12.85 g/km found at 20 kph and 4.18 g/km at 50 kph. In general, the result shows that the higher the speed the lower the CO_2, CO, and HC emissions. Emission profiles indicate that the speed between 30-50 km/h could be recommended as the most suitable traffic speed in urban area to ensure mobility, safety as well as the lowest emissions. The results are valuable as input to transportation management as a part of environmentally sustainable transportation.**

Keywords— *traffic congestion, transportation management, speed-related emission, air quality management, vehicle emission, air pollution*

I. INTRODUCTION

Traffic congestion become a serious problem in many city around the world. Many research was conducted to quantify its cost which associated with many factor. There are many factor affecting traffic congestion cost which associate with the disruption of unpredictable traffic delay, inconvenient schedule to avoid traffic congestion, extra fuel charge, accidents and air pollution [1]. Furthermore, some other researches were conducted to investigate emission during traffic congestion, which found that emission tend to be higher when congestion happened [2-4]. This findings give insight that traffic congestion, which cause low speed vehicle mobility, have negative impact for the population.

This issue should become a concern, while the Sustainable Development Goals (SDGs) program has goals to make cities inclusive, save, resilient and sustainable. One of the target is reducing the adverse per capita environmental impact of cities, including by paying special attention to air quality [5]. One of concept that could be used to manage this issue is environmentally sustainable transportation (EST). EST can facilitate the recent need of transportation while preserves the environment for the next generation needs. That concept integrating many aspect including roadside air quality monitoring and assessment. The result of monitoring and assessment will become the input to for better transportation management strategy [6].

As the lack of mass transit facilities, Indonesia faced many transportation problem. One of the biggest problem is the rapid growth of private motorized vehicle on the road especially motorcycle. Those increasing population cause traffic congestion and lower traffic speed, hence worsen the urban air quality. On average, 7 million motorcycles are sold to Indonesian citizen annually [7] and this count 80% of total private motorized vehicles population in Indonesia [8].

There are many previous study conducted to investigate traffic induced air pollution in Indonesia. Some of the studies found many compounds polluted urban air including, criteria pollutants, heavy metals, and some toxic compound such as benzene [9-11]. Others study tried to predict traffic-induced air pollution from available data [12-15]. Most of these study focusing on the ambient air quality, only few study conducted to investigate the pollutant on emission level.

This study aims to investigate the role of motorcycles speed to emission reduction. Motorcycle becomes object of this study since it is the most chosen transportation mode in Indonesia. There are some special condition on

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motorcycle utilization in Indonesia that become the reason for further investigation. Motorcycle emission is worth investigation due to its large population number, the outdated technology, and the variation of fuel used. According to the government regulation, the minimum technology requirement for motorized vehicle including motorcycle is EURO III. However there is no vehicle scrapping policy in Indonesia, so Euro II and older technology are still operated in the road. There is not just single fuel specification sold in Indonesia but various type of gasoline. Fuel used for motorcycle in Indonesia is differentiated by its octane number which are RON 90, RON 92 and RON 95.

II. METHOD

Simple method is used for this study. Twenty sample of motorcycle were tested on this study, selected based on 2 latest technology which are Euro III and Euro II and 2 most common fuel type used which are RON 90 and RON 92 Gasoline. Detailed sample number for each category is presented on Table 1.

Table 1. Motorcycle Samples

	RON 90	RON 92
Euro II	5 unit	5 unit
Euro III	5 unit	5 unit

CO_2, CO, and HC measured using portable emission analyzer named Autocheck from SPTC USA Corp. Chassis dynamometer, which one of the approved technologies emission measurement was utilized on this study. It is used to obtain emission in idle condition and speeds of 10,20,30,40 and 50 km/h. Emission concentration is measured simultaneously from the minimum to the maximum speed, and the sample was taken on steady engine condition. Stability of exhaust temperature and emission concentration gave assumption that engine has reached steady condition. CO_2, and CO were measured on % unit and ppm unit for HC. To simplify the analysis, all concentration data obtained were converted into g/m^3 unit (see formula (1))

$$C\left(\frac{g}{m^3}\right) = \frac{C_{ppm} \times M}{24.45 \times 10000}$$

In which:
$C\ (g/m^3)$ = pollutant concentration in g/m^3
Cppm = pollutant concentration in ppm
M = molecular weight

Formula (1) is used to convert concentration on ppm to g/m^3. This formula also can be used for converting pollutant concentration on % unit, which 1 % is equal to 10000 ppm

Velocity pressure and static pressure were measured to calculate exhaust gas velocity for gas volume estimation. This measurement method is derived from EPA method

1a, which is standard method measuring gas velocity from small stack [16]. Gas velocity measurement conducted with utilization of additional stainless steel stack with diameter of 5 cm. Total pressure and velocity pressure are measured with S-type pitot using digital manometer. Formula (2) and (3) is used to calculate the exhaust gas velocity.

$$V_s = K_p \times C_p \times \left(\frac{T_{gas}}{P_{stat} \times M_{gas}} \times \Delta P_p\right)^{\frac{1}{2}} \qquad (2)$$

$$K_p = \left(2 \times g_c \times R_u\right)^{\frac{1}{2}}$$

In which:
V_s = gas velocity in tunnel, m/second
C_p = pitot type S coefficient, dimensionless,
K_p = constant
M_{gas} = gas molecular weight
P_s = tunnel static pressure, mm Hg
T_s = tunnel temperature, Kelvin
Δp = tunnel velocity pressure, mm H2O

Formula (4) was used to calculate emission on idle condition.

$$E = C \times V_s \times A_s \qquad (4)$$

In which:
E = Emission rate (g/second)
C = Emission concentration (g/m3)
Vs = Gas velocity in tunnel (m/second)
As = Area of tunnel section (m^2)

To calculate exhaust emission on various speed, formula (5) was utilized.

$$E = C \times V_s \times A_s \times \left(\frac{1}{V_k} \times 3600\right) \qquad (5)$$

In which:
E = Emission rate (g/km)
C = Emission concentration (g/m3)
Vs = Gas velocity in tunnel (m/second)
As = area of tunnel section (m^2)
Vk = vehicle speed (km/hour)

III. RESULTS AND DISCUSSION

On this study, idle emission rate is on gram/second unit and mobile emission rate is on gram/km unit. Measurement results from 20 motorcycle samples are presented on Table 2 for idle emission rate, and on Table 3 for mobile emission rate. High standard deviation value and mean-median difference show that there are broad data distribution. To perform more detail data analysis, sample number should be increased on further study.

The result on Table 2 shows that, the longer the vehicle on idling condition, the highest the emission emitted. This study found that dominant pollutant that emitted during idle condition is CO_2 compared to CO and HC.

Those number can be used to estimate motorcycle emission on intersection and stand still traffic congestion.

Previous studies have also found that idling condition increase the emission level and makes inefficient fuel used [17, 18]. Idling stop policy is one of idling-emission reducing effort example that was implemented by Taiwan government. Study on motorcycle found that motorcycle user willing be to turn off their vehicle at intersection for 82s to 150s and this affects to lowering fuel of 1021 L/hour and CO_2 emission of 0.56 metric tons/hour [19, 20].

Typically in Indonesia, idling condition not only happened on intersection, but also when traffic congestion occurs. Besides idling condition, low speed vehicle movement also increase the emission.

This study found that emission tend to be lower on higher speed (Figure 1 and 3). For CO_2, and HC the higher the speed, the lower the emission. However, CO emission profile is different with other parameters which emission on 20 km/hour is higher than the 10 km/hour and on 60 km/hour is higher than the 50 km/hour (figure 2). This might be caused by variability of the data which mean is about 2 to 3 times of median and standard deviation value mostly higher than mean value (See Table 3).

To get more reliable profile for CO, additional motorcycle should be tested. Generally, emission profiles indicate that the speed between 30-50 km/h could be recommended as the most suitable traffic speed in urban area to ensure mobility, safety, and specifically, the lowest emissions.

Table 2. Emission rate on Idling Condition

Parameter	Mean	Median	Standard Deviation
CO_2 (g/s)	0.157	0.092	0.150
CO (g/s)	0.025	0.006	0.078
HC (g/s)	0.002	0.001	0.004

Table 3. Emission rate on mobile condition

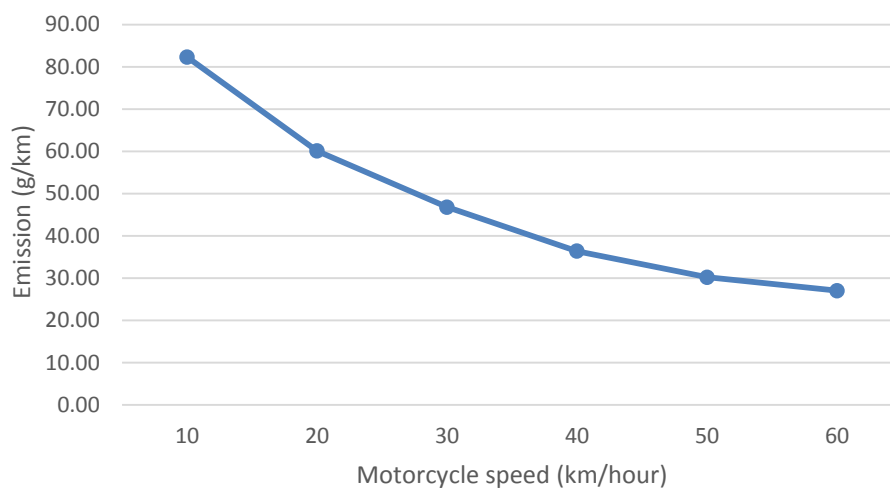| Parameter	Speed	Mean	Median	Standard Deviation
CO_2 (g/km)	10	82.30	69.11	55.01
	20	60.07	46.40	54.49
	30	46.79	33.27	54.47
	40	36.38	24.33	43.53
	50	30.21	23.13	23.43
	60	27.03	21.54	18.37
CO (g/km)	10	11.47	4.54	21.72
	20	12.85	2.69	26.73
	30	7.28	2.34	11.58
	40	4.54	2.63	5.06
	50	4.18	2.27	4.96
	60	4.90	2.33	7.36
HC (g/km)	10	0.55	0.32	0.59
	20	0.28	0.22	0.24
	30	0.21	0.15	0.22
	40	0.14	0.11	0.13
	50	0.13	0.13	0.08
	60	0.10	0.09	0.05

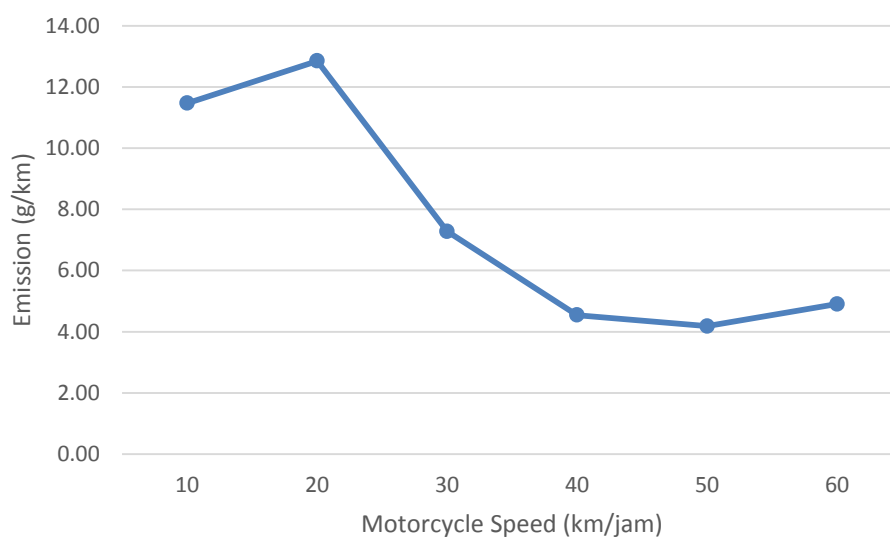Figure 1. Speed-related CO_2 emission profile

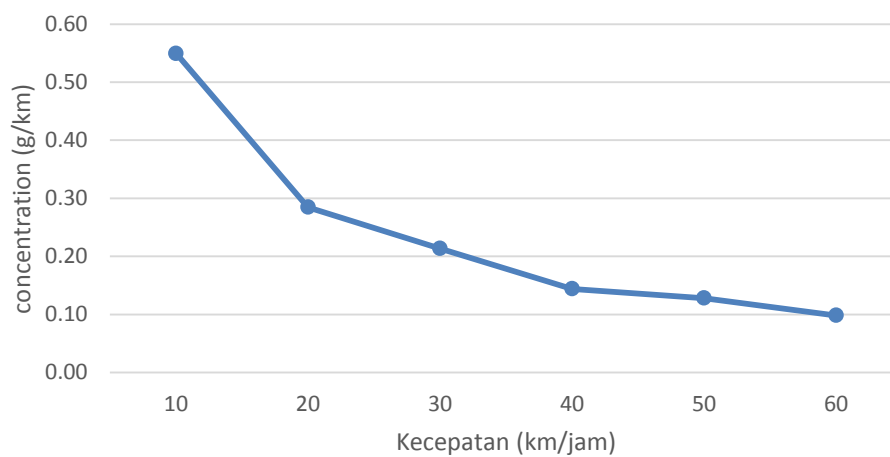Figure 2. Speed-related CO emission profile

Figure 3. Speed-related HC emission profile

Even with relatively small number of data, non-linear relationships similar to the multinomial to emission pattern used for developing European emission factors

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[21] were found. However, for European pattern the emission is slightly increase when the speed is higher than 50 km/hour. One factor that could affect this pattern difference is fuel usage. Ideally, gasoline category II on World Wide Charter [22] should be used for Euro II and Euro III but the quality of fuel commonly sold in Indonesia still not meet category II standard. However, very limited data available in Indonesia to get the picture of transportation sector impact, especially to urban air quality. So, this finding might become a valuable input for transportation management as a part of environmentally sustainable transportation.

IV. CONCLUSION

This study suggested measurement method to get real world emission from motor cycle using simple instrumentation. On this study it is found that the highest the motorcycle speed, the lowest the CO_2, CO and HC emission. According to this result, traffic congestion which motorcycle mostly on idle and lower speed condition might worsen urban air quality. To meet environmentally sustainable transportation, this study suggests to reduce unnecessary idling condition and recommend average speed on urban area of 30 – 50 km/hour. Besides the driving safety reason, that speed also could reduce fuel cost and emission. More motorcycle samples are needed to get better data resolution and accuracy.

V. ACKNOWLEDGEMENT

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