Level of gas emissions of passenger car on climb road segment

N Sari[1*], S W Praja[1], and B Hidayat[1]

[1]Land Transport Academy, Ministry of Transportation, Jl. Raya Setu No.89 Cibitung Bekasi 1700, Indonesia.

[*]Email: miss_vita20@yahoo.com

Abstract. Each island in Indonesia has its own topographical characteristics, which generally consists of plains, plateaus, hills and mountains. This topography influences vertical alignment of the roads. Gradient of vertical alignment on road construction planning is maximum 10%, but in facts it is shown that in some areas they are reached more than 10%. While the vehicle gas emission test in Indonesia currently only apply for public transport and freight cars, where the test is only performed on a flat road and in idle conditions without considering geometric aspects. Passenger cars are not subject to this test contrary to the increase of their population of about 10-15% annually which is much higher than the public transport. This research aims to determine the level of gas emissions of passenger cars on climb road segment (vertical alignment). The methods of analysis are by using distribution frequency of the vehicle gas emissions data test of passenger cars in dynamic condition on climb road segment. This research conduct with Gas Analyzer Equipment which is measured CO, CO_2, HC, and Lambda (The composition of gasoline and Air). Sample of passenger cars used by two cars with the same specification and different age. The data used in this research are passenger cars speed with three variations are 30, 40 and 50 kph. The gas emissions test of passenger cars is performed on the road which have the gradient of vertical alignment is maximum 10%, and this test is regardless to the value of skid resistant, roughness and driver characteristics. The result shown that climb and slope road segment influence the level of gas emissions of passenger cars for CO and CO_2 has almost the same value. The condition climb and slope road segment for Lambda 0.99 % volume, the value of CO volume is 0.35% volume and CO_2 is 12.3% volume. While the content of HC has different characteristics that is when the vehicle climb, HC content lower than when the vehicle slope. When the mixed composition of fuel and air (Lambda 0.99% volume), the vehicle climbed about 11.5 ppm and when the vehicle sloped about 30.5 ppm. The ratio of HC between vehicles climbed and sloped is 1: 2.

Keywords: climb road segment, gas emissions, vertical alignment

1. Introduction

1.1. Background

Geographically Indonesia is an archipelago with have more than 17 thousand islands. Each island has its own topographical characteristics, which generally consists of plains, plateaus, hills and mountains. This topography influences the vertical alignment of the roads in Indonesia. On road construction planning in cities of Indonesia, the gradient of vertical alignment is maximum 10%, but in facts it is shown that in some areas they are reached more than 10%, for example crest and sag at Nagrek area.

The vertical alignment more than 10% impact to engine performance of the vehicle, this condition is increase the level of vehicle gas emissions.

Traffic represents one of the largest sources of primary air pollutants in urban areas. Large amount of vehicle exhaust emissions will have seriously adverse effects on human health. Assessing the effects of air quality management strategies in urban areas is a major concern worldwide. In addition, worldwide epidemiological studies show a consistent increase in cardiac and respiratory morbidity and mortality from exposure to vehicle exhaust pollution. Both in urban and residential regions, this has become the main areas of toxic compound emissions from the unrestrained use of vehicles burning fossil fuels. In these areas, the population is very sensitive to vehicular pollution [3].

In Indonesia vehicles increased from year to year, the exhaust gas produced from the vehicles causes air pollution about 70 to 80 percent, while industrial air pollution only 20-30 percent. Air pollution caused by many things, among others: vehicle fumes, factory smoke, garbage burning and etc. Vehicle exhaust is the biggest cause of air pollution because the development of technology in various fields, especially in the transportation field, resulting in the number of vehicles with a wide range type and brand increased quietly high [4].

1.2. Research problem

The vehicle gas emission test in Indonesia currently only apply for public transport and freight cars, where the test is only performed on a flat road and in idle conditions without considering geometric aspects. Passenger cars are not subject to this test contrary to the increase of their population of about 10-15% annually which is much higher than the public transport.

1.3. Research limitation

The limitation of this research is the specification vehicle that become sample test for this research are passenger cars with gasoline, capacity 1300 cc, two variant ages: vehicle with age 6 years and 8 years. The location test of this research is underpass at Tambun market, Bekasi. Equipment that used to calculated the CO_2, CO and HC value by using Gas Analyzer CAP 320.

2. Literature Review

2.1. Gas emission

Air pollution that cause by vehicle exhaust gas produced from incomplete fuel combustion. The gas emission cause by incomplete burning of fuel in engine vehicle. Elements contained in gas emission among others CO, NO_2, HC, C, H_2, CO_2, H2O and N_2, where it's become pollutant on air and can disturb human health to cause the dead at a specific level [5].

2.1.1. Carbon Monoxide (CO)

CO content from the vehicle exhaust depends on the comparison of fuel and air. But on perfect fuel combustion, the CO value can be zero. Carbon monoxide which content 0.03% can be dangerous toxin on air that is inhaled by human. This gas in human body will attack the erythrocyte, which bring the oxygen to whole human body. In the indoor room, percentage of CO volume 0.1% or more can be deadly [1].

On high level the concentration of CO inhaled humans could make fatal risks on human body, even can cause the death. The character of CO is a gas odorless and colorless and very toxic, then CO is often referred to as a silent killer. The effect of CO gas is a harmful gas for human body due to the binding capacity of CO gas to Hb is 240 times the bonding power of CO to O2. When the blood CO gas (HbCO) is enough high, it would start to occur symptoms include headache (HbCO 10 percent), nausea and shortness of breath (HbCO 20 percent), impaired vision and concentration decreased (HbCO 30 percent)

unconscious, coma (HbCO 40-50 percent) and if would continue to cause death. On long term would showing symptoms of neurological disorders, cerebral infarction, cardiac infarction and infant death in the womb. High level of CO gas in the blood can come from cigarettes and smoke from motor vehicles. Air quality on indoor room, CO gas can also be a gas that causes building associated illnesses, with complaints of headache, nausea, and vomiting [4].

2.1.2. Carbon Dioxide (CO_2)

Carbon Dioxide (CO_2) in Indonesia increased, its share in total global CO_2 emissions from 0.6% in 1990 to 1.2% in 2005 and 1.4% in 2015. Since 1990, the only decline in CO_2 emissions has been recorded for 2008 (0.6%); in 2015, the increase was 4%, which was above the average over the last 10 years (3.4%). Coal consumption in Indonesia increased continuously, at an average rate of 15.5% per year, between 1990 and 2007, then decreased by 13% in 2008 and increased again by 14.4%, on average, between 2009 and 2015 [6].

2.1.3. Hydrocarbons (HC)

Hydrocarbons are gasoline compound element. Hydrocarbons (HC) are produced from incomplete fuel combustion. Hydrocarbons (HC) measured on ppm (part per million). It formed from incomplete fuel combustion on cylinders. Hydrocarbons (HC) may cause cancer, and some Hydrocarbons (HC) also can cause harmful effects on tissues and the human immune system [5].

2.2. Vertical alignment

Vertical alignment is elevation plan on road geometry which design on every axis. The vertical alignment of a road consists of gradients (straight lines in a vertical plane) and vertical curves. The vertical alignment is usually drawn as a profile, which is a graph with elevation as vertical axis and the horizontal distance along the center line of the road as the horizontal axis. Almost the passenger cars could past the vertical alignment with gradient 7-8% without changing speed comparison on flat area [2].

3. Research Methodology

The research method used is as follows:

3.1. Collecting data

This research collects data from primary data. The data are collected by testing passenger car's gas emissions in the field. The vehicle gas emissions testing which categories: the location has gradient more than 10%, emission gas test on three variation of car speed are 30 kph, 40 kph and 50 kph. The data analyzed are CO, CO_2, and HC value.

3.2. Method of analysis

The methods of analysis are by using distribution frequency of the vehicle gas emissions data test of passenger cars in dynamic condition on climb road segment (Figure 1). This research conduct with Gas Analyzer Equipment which is measured CO, CO_2, HC, and Lambda (The composition of gasoline and Air) (Figure 2). Sample of passenger cars used by two cars with the same specification and different age. The data used in this research are passenger cars speed with three variations are 30, 40 and 50 kph. The gas emissions test of passenger cars is performed on the road which have the gradient of vertical alignment is maximum 10%, and this test is regardless to the value of skid resistant, roughness and driver characteristics.

Figure 1. Location test at underpass Tambun market, Bekasi.

Figure 2. Setting up the gas analyzer CAP 320 on passenger cars with capacity 1300 cc.

4. Research Analysis

4.1. Result and discussion

Data from the measurement result in the field are presented in the table below:

Table 1. Level of gas emission car aged 6 in slope segment.

Speed	Level of Gas Emission						Rotation Per Minutes
	CO	CO_2	O_2	HC	Lambda	CO correction	
30	0.115	12.6	-0,09	20	0.99	0.14	2500
40	0.35	12.3	-0,08	30.5	0.98	0.37	3300
50	0.57	12.4	-0,09	43	0.97	0.66	3000

Table 1 shows from the results of the exhaust emission test experiment with car aged 6 on the slope segment, the CO and HC levels rise in proportion to the increase in vehicle speed while the CO_2 and O_2 levels do not increase and decrease significantly with increasing speed.

Table 2. Level of gas emission car aged 6 in climb segment.

Speed	Level of Gas Emission						Rotation Per Minutes
	CO	CO_2	O_2	HC	Lambda	CO correction	
30	0.325	12.4	-0,045	29	0.98	0.38	2500
40	0.15	12.6	0.095	11.5	0.99	0.18	3300
50	0.67	12.3	-0,02	23	0.97	0.77	3000

Table 2 shows the results of the exhaust emission test experiment with car aged 6 on climb segment, CO and HC levels increased and decreased with the lowest decrease at a speed of 40 km/h with CO and HC levels of 0.15% and 11.5 ppm and the highest increase at a speed of 60 km/h with CO and HC levels of 0.67% and 23 ppm.

Table 3. Level of gas emission car aged 8 in slope segment.

Speed	Level of Gas Emission						Rotation Per Minutes
	CO	CO_2	O_2	HC	Lambda	CO correction	
30	0.375	13.1	0.33	76	1	0.445	2500
40	0.56	13.3	0.06	57.5	0.985	0.61	3300
50	35.785	13.2	0.08	57	0.98	0.695	3000

Table 3 shows the results of the exhaust emission test experiment with car aged 8 on the slope segment of CO and HC levels increased and decreased with the highest decrease at a speed of 40 km/h with CO and HC levels of 0.56% and 57.5 ppm and the lowest increase at a speed of 60 km/h with CO and HC levels of 0.67% and 23 ppm.

Table 4. Level of gas emission car aged 8 in climb segment.

Speed	Level of Gas Emission						Rotation Per Minutes
	CO	CO2	O_2	HC	Lambda	CO correction	
30	0.48	13.2	0.195	75.5	0.99	0.52	2500
40	0.6	13.1	0.305	63.5	0.99	0.655	3300
50	0.99	10.75	3.68	66.5	1.22	1.365	3000

Table 4 shows from the results of the exhaust emission test experiment with car aged 8 on the climb segment, the CO level rises in proportion to the increase in vehicle speed while the level of HC levels decreases inversely with the vehicle speed. For CO_2 and O_2 levels there is no significant increase and decrease on increasing speed.

4.2. Correlation of emission gas with vehicle speed

Correlation of emission gas with vehicle speed with climb and slope segment conditions where the speed of the vehicle running at speeds of 30, 40 and 50 kph are shown in figures below.

4.2.1. Correlation between CO and vehicle speed in slope segment

The increase of vehicle speed will increase the CO level contents that produced from gasoline and air exhausted (Figure 3). Whereas the percentage of car aged 6 years increased average 62% and car aged 8 years increased 49%. The condition shown vehicle moved in slope segment.

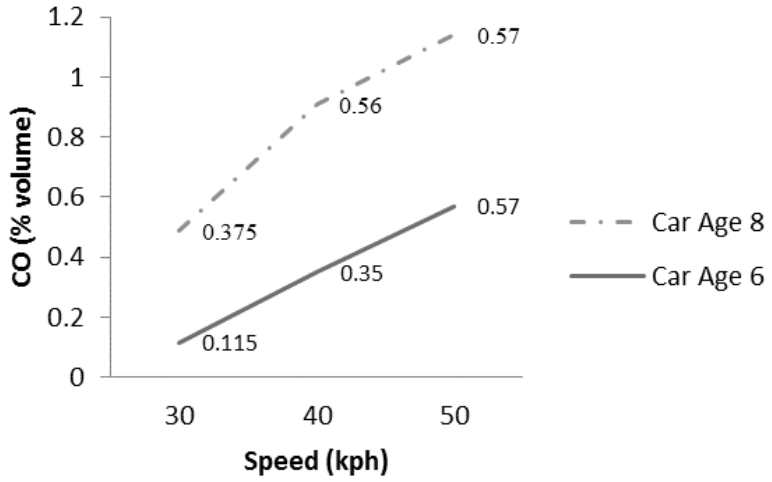

Figure 3. Correlation between CO and vehicle speed in slope segment.

As shown in the Figure 3, can be interpreted that the increase of vehicle speed will increase the CO level contents that produced from gasoline and air exhausted. Whereas the percentage of car aged 6 years increased average 62% and car aged 8 years increased 49%. The condition shown vehicle moved in slope segment.

4.2.2. Correlation between CO_2 and vehicle speed in slope segment

The increase of vehicle speed wouldn't effected on the CO_2 level contents that produced from gasoline and air exhausted (Figure 4). Regardless vehicle speed CO_2 level contents produced fluctuated at average 12-13% volume. The condition shown vehicle moved in slope segment.

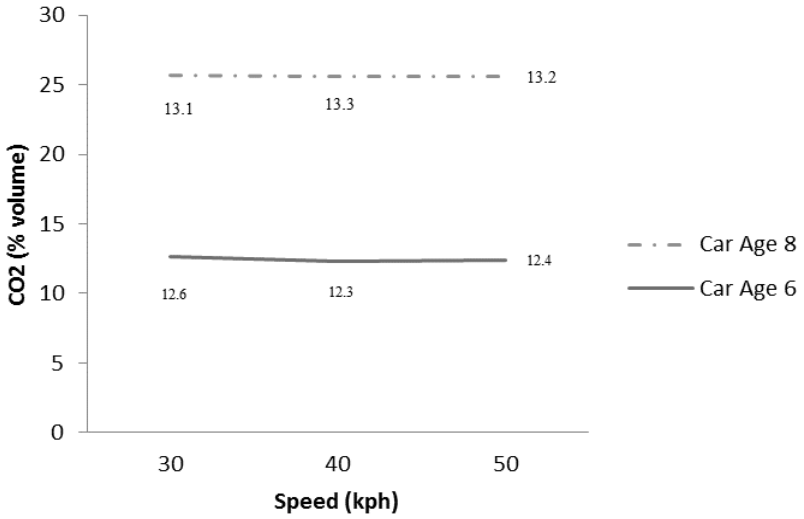

Figure 4. Correlation between CO_2 and vehicle speed in slope segment.

As shown in the Figure 4, can be interpreted that the increase of vehicle speed wouldn't affected on the CO2 level contents that produced from gasoline and air exhausted. Regardless vehicle speed CO2 level contents produced fluctuated at average 12-13% volume. The condition shown vehicle moved in slope segment.

4.2.3. Correlation between HC and vehicle speed in slope segment

The increase of vehicle speed will affect the HC level contents that produced from gasoline and air exhausted (Figure 5). The percentage of car aged 6 years increased average 41% and car aged 8 years decreased 15%. The condition shown vehicle moved in slope segment.

As shown in the Figure 5, can be interpreted that the increase of vehicle speed will affect the HC level contents that produced from gasoline and air exhausted. The percentage of car aged 6 years increased average 41% and car aged 8 years decreased 15%. The condition shown vehicle moved in slope segment.

4.2.4. Correlation between CO and vehicle speed in climb segment

The increase of vehicle speed will increase the CO level contents that produced from gasoline and air exhausted (Figure 6). Where is the percentage of car aged 6 years increased from 5% (30-40 kph) to 97% (40-50 kph) and car aged 8 years increased from 25% (30-40 kph) to 65% (40-50 kph). The condition shown vehicle moved in climb segment.

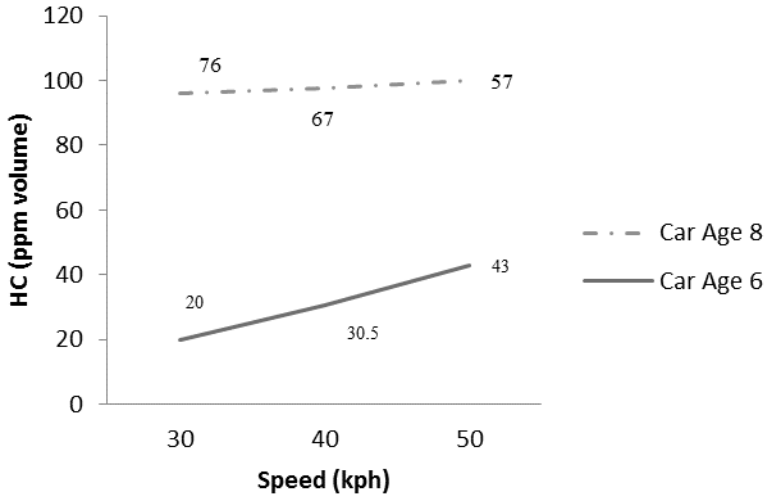

Figure 5. Correlation between HC and vehicle speed in slope segment.

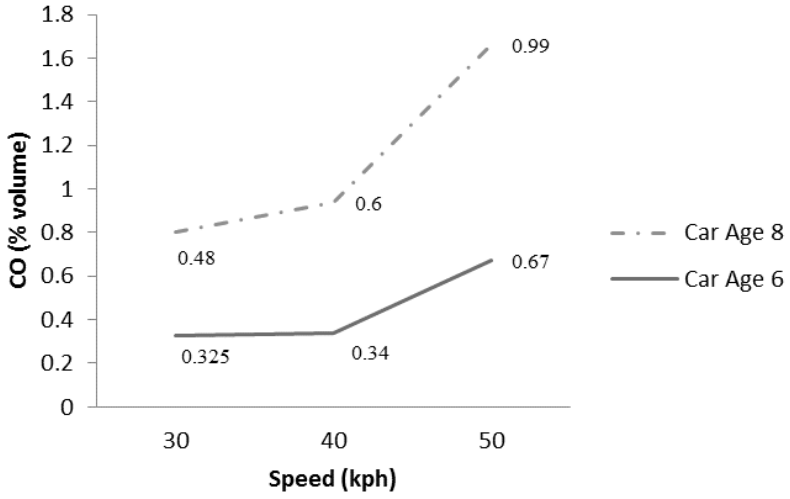

Figure 6. Correlation between CO and vehicle speed in climb segment.

As shown in the Figure 6, can be interpreted that the increase of vehicle speed will increase the CO level contents that produced from gasoline and air exhausted. Whereas the percentage of car aged 6 years increased from 5% (30-40 kph) to 97% (40-50 kph) and car aged 8 years increased from 25% (30-40 kph) to 65% (40-50 kph). The condition shown vehicle moved in climb segment.

4.2.5. Correlation between CO_2 and vehicle speed in climb segment

As shown in the Figure 7, can be interpreted that the increase of vehicle speed wouldn't effected on the CO_2 level contents that produced from gasoline and air exhausted. Regardless vehicle speed CO_2 level contents produced fluctuated at average 12-13% volume. The condition shown vehicle moved in climb segment.

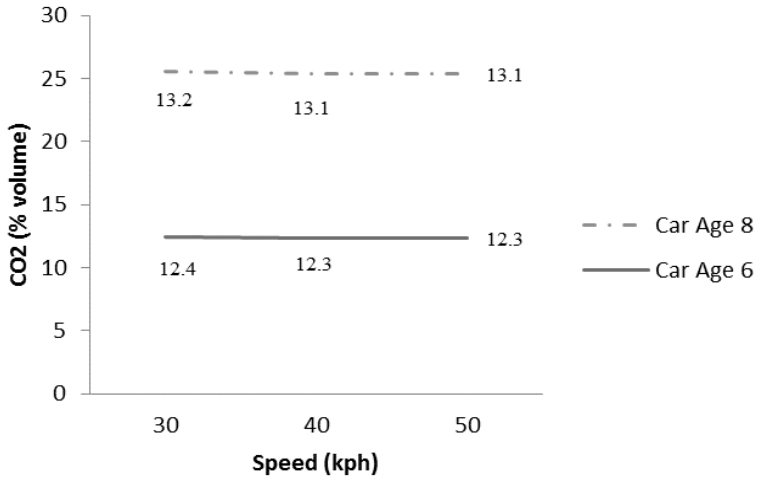

Figure 7. Correlation between CO2 and vehicle speed in climb segment.

4.2.6. Correlation between HC and vehicle speed in climb segment

The increase of vehicle speed will effected on the HC level contents that produced from gasoline and air exhausted (Figure 8). Where is the percentage of car aged 6 years changed with slope curve shape average from decrease 60% (30-40 kph) to increase 100% (40-50 kph) and car aged 8 years increased from decrease 16% (30-40 kph) to increase 5% (40-50 kph). The condition shown vehicle moved in climb segment.

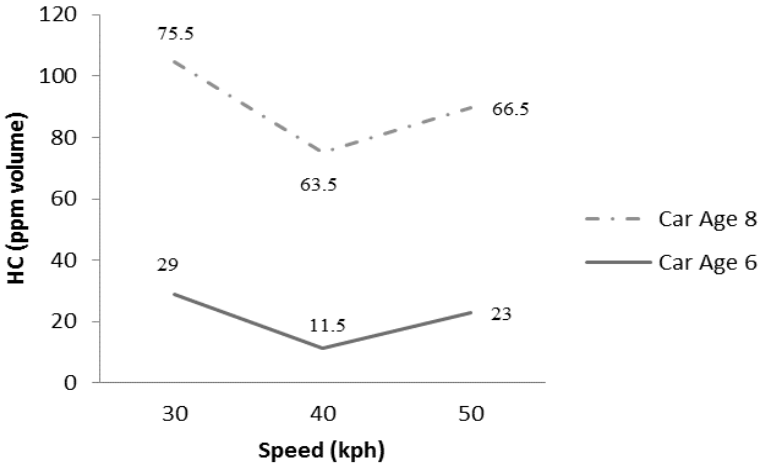

Figure 8. Correlation between HC and vehicle speed in climb segment.

As shown in the Figure 8, can be interpreted that the increase of vehicle speed will affected on the HC level contents that produced from gasoline and air exhausted. Whereas the percentage of car aged 6 years changed with slope curve shape average from decrease 60% (30-40 kph) to increase 100% (40-50 kph) and car aged 8 years increased from decrease 16% (30-40 kph) to increase 5% (40-50 kph). The condition shown vehicle moved in climb segment.

4.2.7. The influent of gasoline and air mixture in engine combution

The amount of exhaust emissions is determined from the combustion process in the Vehicle combustion chamber. Advance technology and vehicle maintenance affect the exhaust emissions produced. Another factor that also affects the level of exhaust emissions is the quality of fuel used (octane levels).

The results of the exhaust emission test apparatus for the composition of the fuel and air mixture are expressed in lambda. The lambda unit is % volume. If the lambda value close to 1 indicates that the composition of the fuel and air mixture better.

An emission test for vehicles aged 6 years and 8 years with the composition of fuel and air mixture of 0.99% volume, evidently 8 years old vehicle has CO content in the exhaust gas higher 0.26 to 0.30% volume than the vehicle age 6 years.

For the composition of the fuel mixture and the air of 0.99%, the CO_2 content in the emission gas for both test vehicles has approximately the same value in the range of 12-13% volume. This condition is different from the HC content of the combustion engine results indicate that the average age of 8 years vehicle has 60 ppm HC and for the age of 6 years vehicle on average has 30 ppm HC. HC levels are also affected by engine rotation speed (RPM) which has a relationship inversely proportional, if high RPM then low HC content and instead low RPM then high HC content.

4.2.8. The influent of climb or slope segment in level of gas emission

The influence of climb and slope on exhaust emissions (CO and CO_2) has almost the same value. Road condition climb and slope for Lambda 0.99% CO content volume is 0.35% volume and CO_2 is 12.3% volume. While the content of HC has different characteristics that is when the vehicle climbed HC content lower than when the vehicle sloped. When the mixed composition of fuel and air (Lambda 0.99% volume) the vehicle climbed about 11.5 ppm and when the vehicle sloped about 30.5 ppm. The ratio of HC between vehicles climbed and sloped is 1: 2.

5. Conclusion

The result shown that climb and slope road segment influence the level of gas emissions of passenger cars for CO and CO_2 has almost the same value. The condition climb and slope road segment for Lambda 0.99 % volume, the value of CO volume is 0.35% volume and CO_2 is 12.3% volume. While the content of HC has different characteristics that is when the vehicle climb, HC content lower than when the vehicle slope. When the mixed composition of fuel and air (Lambda 0.99% volume), the vehicle climbed about 11.5 ppm and when the vehicle sloped about 30.5 ppm. The ratio of HC between vehicles climbed and sloped is 1:2. The government regulation on the vehicle gas emissions test should not be on static condition, but it's should be considering real conditions, which is the vertical alignment impact to the level vehicle gas emissions.

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