Estimation of Bi-fuel Vehicular Emission with System Dynamics Approach

Abstract

This study is experimental study by using converted vehicle (bi-fuel) that can use gasoline or CNG. The experiment has done with chassis dynamometer testing to determine the power losses and fuel consumption also exhaust emission. Based on the chassis dynamometer testing result, some data will be use for simulation to determine the condition of some parameter such as CO, HC, and CO_2. Simulation conducted by using Powersim version 2.5d software.

The simulation result shows that in the year of 1997 the amount of CO is 614,887 in the year of 2002 are 1,436,002 ton and in the year of 2008 are 2,626,647 ton. The amount of HC in the year of 1997 is 25,167.80 ton, in the year of 2002 is 846,171.90 ton and in the year of 2008 are 2,036,683 ton. The amount of CO_2 in the year of 1997 is 9,702,000 ton, in the year of 2002 is 10,523,330 ton and in 2008 are 11,714,240 ton.

1. Introduction

1.1. Background

Development has done to increase prosperous, and cause industrial and transportation growing. The growth of industrial and transportation will cause increasing fuel oil utilization then will be increase air pollution.

In some big cities air pollution emit from vehicle has caused apprehension. The growth of vehicles in the big cities around 8-12% annually. The growth of vehicle in Indonesia during 1990 until 1998 dominated with motor cycles (72%), passenger cars (15%), cargo cars (9%), buses (4%) majority use fuel oil in the form of premix, gasoline or diesel oil (Abubakar, 2000).

Contribution vehicular emission as pollutant around 60-70%, industrial emission contribute around 10-15%. The rest percentage comes from household, disposal burning, forest burning. Carbonmonoxide are the major pollutant, and vehicle are the major source of that pollutant (Kusnoputranto, 2000).

Air pollution from transportation sector dominated from land transportation. Vehicles are source of some pollutant likes CO, NO_X, HC, SO_2 and tetraethyl lead (Soedomo, 2001).

Alternative fuel is the one of the effort for air pollution control. As Maxwell (1995) mentioned that the advantages of alternative fuel compare with gasoline or diesel fuel are: the alternatives fuel are more likely to be produced from domestic resources, alternatives fuel generally reduce vehicular emission, and some alternatives fuel offer the potential to lower operating cost. The type of alternatives fuel that can use for vehicle such as CNG (Compressed Natural Gas), LPG (Liquefied Petroleum Gas). The reserves of natural gas in Indonesia scattered on Aceh, North Sumatra, South Sumatra, West Java, East Java, East Kalimantan, Natuna and South Sulawesi. Besides of the availability, the advantages of natural gas is produce lower emission.

1.2. The Objectives of Study

Generally, the objectives of study are to anticipate the increasing of pollutant from exhaust emission from vehicle by using alternatives fuel especially compressed natural gas (CNG), and to support the conservation and diversification energy policy. In particular this study is to carry out a trial to know the change of CO, HC, and CO_2 pollutant from vehicle in the city by simulation.

This study is experimental study by using converted vehicle (bi-fuel) that can use gasoline or CNG. The experiment has done with chassis dynamometer testing to determine the power losses and fuel consumption also exhaust emission. Based on the chassis dynamometer testing result, some data will be use for simulation to determine the condition of some parameter such as CO, HC and CO_2. Simulation conducted by using Powersim version 2.5d software. Simulation has done with assumption as follows: the amount of vehicle always increase, vehicle trip 300 km per day, the amount of CNG refuelling station increase annually, service capacity of CNG refuelling station 2500 lpe (litre premium equivalent), refuelling capacity 80% from tank capacity, CNG vehicle increase 1000 units per year.

a. Concept

Simulation conducted with Fixes That Fail archetype. In fixes that fail situation, a problem symptom cries out for resolution. A solution is quickly implemented, which alleviates the symptom. However, the solution produces unintended consequences that, after a delay, cause the original problem symptom to return to its previous level or get worse.

b. Simulation model

In this case a problem symptom is the raising of CO, HC and CO_2 emission from vehicle based on fuel oil utilisation, the amount of vehicles, and vehicles trip. A solution implemented by using alternative fuel (CNG). Hopely, this solution will be dropped the emission, however because of limitation and distributing of CNG refuelling station, cause converting fuel from CNG to fuel again, so the problem symptom return to previous level (see Figure 1. Causal loop diagram).

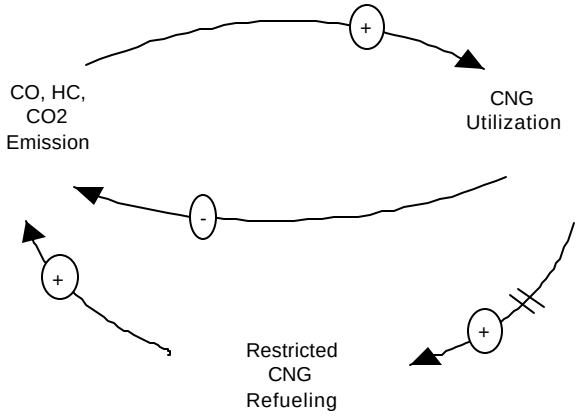

Figure 1. Causal Loop Diagram

Explanation of causal loop diagram

CO, HC, and CO_2 emission are the problem symptom because of combustion process in the engine by using fuel oil. The effort to dropped that emission implemented by using CNG. CNG utilisation expected to drop the emission, however because of restricted in CNG refuelling, the problem symptom return to previous level because fuel changing to fuel oil.

The simulation based on assumption as follows:

1. The growth of vehicle
2. Vehicle trip 300 km per day per vehicle
3. The CNG refuelling increase annually
4. Service capacity of CNG refuelling 2500 l per day
5. Refuelling capacity 80% from tank capacity
6. CNG vehicle increase 1000 units annually

c. Validity Model

Validity test conducted to look how far the output model suitable with empirical data. Validity test has done with Absolute Mean Error (AME). The

result of validity test shows that AME value for CO pollutant are 1.37%, HC pollutant are 10.61%, and CO_2 pollutant are 1.08%.

d. Sensitivity model

Functional intervention conducted to look the response of model to stimulus. Functional intervention conduct with 2 scenarios as follows:

Scenario 1: calculate the increasing of vehicle 2% from the amount of vehicles in 1997, CNG refuelling 90% from tank capacity, increasing of CNG vehicle 1000 units annually after 1997.

Scenario 2: calculate the increasing of vehicle 5% from the amount of vehicles in 1997, CNG refuelling 90% from tank capacity, increasing of CNG vehicle 2000 units annually after 1997.

Simulation Result and Discussion

The simulation result shows that in the year of 1997 the amount of CO is 614.887, in the year of 2002 are 1.436.002 ton and in the year of 2008 are 2.626.647 ton. The amount of HC in the year of 1997 is 25.167,80 ton, in the year of 2002 is 846.171,90 ton and in the year of 2008 are 2.036.683 ton. The amount of CO_2 in the year of 1997 is 9.702.000 ton, in the year of 2002 is 10.523.330 ton and in 2008 are 11.714.240 ton.(see Table 1 to 3).

Table 1. Simulation Result of CO Emission 1997-2008

YEAR	1.996	1.997	1.998	1.999	2.000	2.001	2.002	2.003
Rate_of_CO_emis	=?	191.636	151.945	153.115	161.657	169.602	177.965	186.767
CO_Emission	=?	614.887	786.677	939.206	1,097e6	1,262e6	1,436e6	1,618e6
CNG_Sales	=?	2,299e7	3,256e7	1,421e8	2,017e8	2,613e8	3,208e8	3,804e8
Rate_Of_CNG_Sa	=?	5,957e7	5,957e7	5,957e7	5,957e7	5,957e7	5,957e7	5,957e7
fuel_utilization	=?	3,79e10	3e10	3,02e10	3,19e10	3,35e10	3,52e10	3,69e10
CNG_Ref_Stat	=?	16,00	16,02	16,10	16,18	16,25	16,32	16,37

Table 1. cont'd

YEAR	1.996	1.997	1.998	1.999	2.000	
Rate_of_CO_emiss	=?	191.636,11	151.944,96	153.114,89	161.656,84	
CO_Emission	=?	614.887,00	786.677,36	939.206,31	1.096.591,20	1
CNG_Sales	=?	22.994.977,0	82.562.977,5	142.130.978	201.698.978	2
Rate_Of_CNG_Sal	=?	59.568.000,0	59.568.000,4	59.568.000,4	59.568.000,4	5
fuel_utilization	=?	7852027e10	0012218e10	0243303e10	1930512e10	3
CNG_Ref_Stat	=?	16,00	16,02	16,10	16,18	

The first scenario based on the calculation of vehicle growth 2% from total of vehicle in 1997, the growth of bi-fuel vehicle 1000 unit annually and 90% refill of CNG from tank capacity. The result shown that the amount of CO in the year of 2002 are 1.436.002 ton will reduced to 610.150,93 ton (57.51%), and 2.626.647 ton in the year of 2008 will reduced to 593.271,25 ton (77.41%). The amount of HC in the year of 2002 is 846.171,90 ton will reduce to 96.051,88 ton (88.65%). And 2.036.683 ton in the year 2008 will reduce to 169.916,67 ton (91.66%). The amount of CO_2 in the year of 2002 is 10.523.330 will reduced to 9.697.264 ton (17.85%). The amount of CO_2 in 2008 is 11.714.240 ton will reduced to 9.680.384 ton (17.36%).

Table 2. Simulation Result of HC Emission in 1997-2008

YEAR	1.996	1.997	1.998	1.999	2.000	2.001	2.002
Rate_of_HC_emis	=?	191.636	151.945	153.115	161.657	169.602	177.965
HC_Emission	=?	614.887	786.677	939.206	1,0966e6	1,2622e6	1,436e6
CNG_Sales	=?	2,2995e7	8,2563e7	1,4213e8	2,017e8	2,6127e8	3,2083e8
Rate_Of_CNG_Sa	=?	5,9568e7	5,9568e7	5,9568e7	5,9568e7	5,9568e7	5,9568e7
fuel_utilization	=?	3,785e10	3,001e10	3,024e10	3,193e10	3,35e10	3,515e10
CNG_Ref_Stat	=?	16,00	16,02	16,10	16,18	16,25	16,32

Table 2. cont'd

YEAR	1.996	1.997	1.998	1.999	2.000	2.001
Rate_of_HC_emis	=?	191.636,11	151.944,96	153.114,89	161.656,84	169.601,70
HC_Emission	=?	614.887,00	786.677,36	939.206,31	1.096.591	1.262.220
CNG_Sales	=?	22.994.977	82.562.977	1,42131e8	2,01699e8	2,61267e8
Rate_Of_CNG_Sa	=?	59.568.000	59.568.000	59.568.000	59.568.000	59.568.000
fuel_utilization	=?	3,7852e10	,00122e10	,02433e10	,19305e10	,34998e10
CNG_Ref_Stat	=?	16,00	16,02	16,10	16,18	16,25

The second scenario based on the calculation of vehicle growth 5% from total of vehicle in 1997, the growth of bi-fuel vehicle 2000 unit annually and 90% refill of CNG from tank capacity. The result shown that the amount of CO in the year of 2002 are 1436,002 ton will reduced to 808,039.03 ton (43.73%), and 2,626,647 ton in the year of 2008 will reduced to 1.039.825 ton (60.41%). The amount of HC in the year of 2002 is 846.171,90 ton will reduce to 97,217.56 ton (88.51%). And 2.036.683 ton in the year 2008 will reduce to 169,682.13 ton (91.67%). The amount of CO_2 in the year of 2002 is 10.523.330 will reduced to 9.702.090 ton (17.80%). The amount of CO_2 in 2008 is 11,714,240 ton will reduced to 9,702,197 ton (17.18%).

Table 3. Simulation Result of CO_2 Emission in 1997-2008

YEAR	1.996	1.997	1.998	1.999	2.000	2.001
Rate_of_CO2_emis	=?	.91.636,11	.51.944,96	.53.114,89	.61.656,84	.69.601,70
CO2_Emission	=?	614.887,00	786.677,36	939.206,31	1.096.591	1.262.220
CNG_Sales	=?	22.994.977	82.562.977	1,42131e8	2,01699e8	2,61267e8
Rate_Of_CNG_Sale	=?	59.568.000	59.568.000	59.568.000	59.568.000	59.568.000
fuel_utilization	=?	3,7852e10	,00122e10	02433e10	,19305e10	34998e10
CNG_Ref_Stat	=?	16,00	16,02	16,10	16,18	16,25

Table 3. cont'd

YEAR	1.996	1.997	1.998	1.999	2.000	2.001	2.002
Rate_of_CO2_emissic	=?	191.636	151.945	153.115	161.657	169.602	177.965
CO2_Emission	=?	614.887	786.677	939.206	1,0966e6	1,2622e6	1,436e6
CNG_Sales	=?	2,2995e7	3,2563e7	4,4213e8	2,017e8	2,6127e8	3,2083e8
Rate_Of_CNG_Sales	=?	5,9568e7	5,9568e7	5,9568e7	5,9568e7	5,9568e7	5,9568e7
fuel_utilization	=?	3,785e10	3,001e10	3,024e10	3,193e10	3,35e10	3,515e10
CNG_Ref_Stat	=?	16,00	16,02	16,10	16,18	16,25	16,32

Conclusion

The amount of CO in the year of 2008 will reduce to 593,271.25 ton (77.41%) if we perform scenario 1, and will reduce to 1,039,825.67 ton (60.41%) if we perform scenario 2. The amount of HC will be reduce to 169,916.67 ton (91.66%) if we perform scenario 1 and will be reduce to 169.682,13 ton (91.67%) if we perform scenario 2. The amount of CO_2 will reduce to 9,680,384 ton (17.36%) if perform scenario 1 and will reduce to 9,702,197 ton (17.18%) if perform scenario 2.

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