Design of the MCCIS on the Gas-Fueled Motorcycle to Overcome Detonation in Engine Idling

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ABSTRACT

Gasoline consumption is greater than fuel oil production in Indonesia. The situation has come to that of a fuel oil crisis. Prior research indicates that the exhaust gas emission of motorized vehicles using gasoline contains lead still as heavy metal. The problem with vehicles using fuel gas is that with the engine ignited and left idling detonation occurs because the gas supply is great while the air supply is small. In addition, the gas tank posible to explodes when sparks come from the combustion chamber. The objective of the research concerned here was to design the Mechanics Converter Considering Idle System (MCCIS) to overcome the problem of detonation at the time of engine idling, to design a flame arrester to prevent an exploding gas tank, and to testing the exhaust gas emission. The MCCIS may be used on low or high speed motorcycles using fuel gas. No detonation occurred in idle speed throughout. The flame arrester was able to avoid the sparks so the fire wasn't moving into the gas tank. Results of the exhaust gas emission tests indicate that exhaust gas emissions at idling, moderate and high speeds are included in the CO and HC content of the specified magnitude.

Keywords: *converter, gas, detonation, idling, flame arrester*

Introduction

The production of gasoline in Indonesia was decrease year by year, while the consumption of gasoline was increase. Figure 1 shows the production and consumption of gasoline [1]. The situation has come to that of a fuel oil crisis start in 2003 [2]. The difference in the use and production of gasoline increases from year to year. It is caused by the increasing number of motorized vehicle owners, which causes gasoline demand to increase as well. On the other hand,

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the use of fuel gas for transportation is still quite little compared to its production so that there is still sufficient room for fuel gas marketing, particularly for transportation [3]. Figure 2 shows a production and consumption of natural gas in Indonesia. A great deal of the natural gas produced is exported abroad.

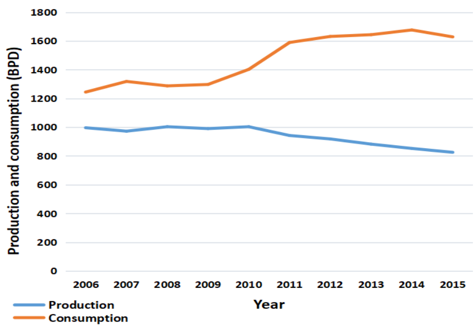

Figure 1: Production and consumption gasoline [1]

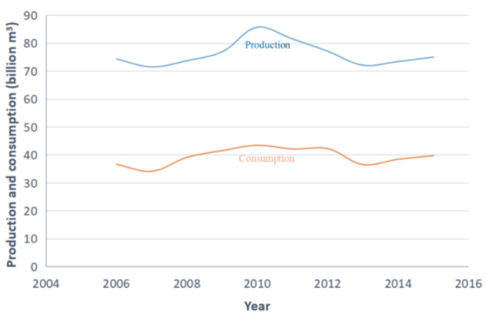

Figure 2: Production and consumption of natural gas in Indonesia [3]

It is hoped that in the future many motorcycles use fuel gas.Indonesia is rich with natural resources. Fuel gas in Indonesia is quite great in potential because of the quantity of gas resources. Therefore, the demand for alternative fuels to decrease dependence on conventional fuel becomes very important. Vehicles using fuel gas need to be developed; among them are those using fuel gas. In cost as fuel, gas is cheaper compared to gasoline.

The exhaust gas emission of motorized vehicles using fuel oil contains lead and it causes air pollution. The air pollution due to lead still as heavy metal (Pb) happens because of imperfect combustion in the combustion chamber [4]. The metal Pb in natural state could not degrade or be destroyed.

This metal is also called a non-essential trace element whose content is the highest so that it is very dangerous if accumulated in the human body [5, 6]. Suthisripok et al. mentioned that at an average speed of 60 km/h, the average LPG consumption rate from the city road test was 40 km/L, around 17.7 % higher. This corresponded to a decrease in the energy density of LPG of about 16.2%. The concentration of CO and HC were 44.4 % lower and 26.5% lower in emissions [7].

As for fuel gas as motorcycle fuel, researchers have made research on its use. The use of fuel gas in a motorcycle originally using gasoline could be done with a conversion kit. Erkus et al. seek the influence of the front, middle, and rear positions of fuel spraying into the intake manifold. In the case of gasoline use, the lowering of fuel consumption index achieved in relation with the rear fuel spraying position is optimum compared to those achieved in relation with the front and middle fuel spraying positions at 6000 rpm [8]. There has been researched by Romadoni et al. on gas-fuelled motorcycle performance. The performance of a motorcycle using fuel gas shows improvement in torque and power and lowering in CO, CO_2, and HC emission contents [9]. Another testing method is applied by adjusting the ignition timing or ignition angle to lower the CO and HC emission contents [10, 11]. Results of the testing show that by setting the ignition angles at 11°, 14°, and 17° prior to TMA (thermomechanical analysis) lowering of CO emission amounting to 0.24% - 97.68% and HC emission amounting to 97.5% in volume is known to take place [12].

The type of fuel gas often used is natural gas. Fuel gas compounds are propane (C_3H_8), propylene (C_3H_6), iso-butane (C_4H_{10}), and butylene (C_4H_8). Fuel gases are mixtures of such hydrocarbons which are gaseous under atmospheric pressure but for storage and transportation purposes they could be condensed into liquids at normal temperature under sufficiently great pressure. Liquefied fuel gas, when evaporating, could form into gas around 250 times greater in volume [13].

Fuel gas has the advantage of, among others, having a high octane rating ranging from 120 to 130. It is higher than that for gasoline, which is 80 for the premium type and 90 for the premix type. The result of gas combustion is cleaner because the carbon chain of fuel gas is quite short compared to that of gasoline [14, 15].

A constraint in the use of fuel gas in motorcycles is the overly high engine speed in idling condition. It is caused by overly great amount of fuel gas coming into the intake manifold and the low specific weight of fuel gas (0.562 kg/m^3), which is even lower than that of gasoline. It causes detonation when the engine is in ignited and idling condition. In addition, it is easy for the gas tank to explode when sparks come from the combustion chamber. The gas tank explosion highly endangers the motorcycle rider. Therefore, the researcher has made a converter engineering to overcome the problem in engine ignition and idling and designed a device to prevent gas tank explosion when sparks occur.

The problem occurring in the converter is especially at the time when the engine is on and kept idling. When the engine is idling, detonation occurs because of excessive gas supply while the air supply is still lacking. Gas has the character of being very light and inflammable so that even with a small hole for the gas to go through, its flow would remain great. This does not matter when the engine is run at high speed because then the need for gas is also great. To overcome the problem of a gas tank that is prone to easily explode, it is necessary to design a tank that does not leak easily and is not easily prone to explode. In addition, the creeping of sparks from the combustion chamber needs to be prevented by applying a flame arrester. The flame arrester is useful as safeguard when sparks occur in the area around the engine by means of halting the fire in order that it does not creep to the gas tank.

The research operation concerned here centered on the design of the converter designed, which was called MCCIS from here, to overcome detonation at the time when the engine is on and idling andthe design of the flame arrester. The research activity went through the stages of designing the MCCIS, manufacturing it, assembling it, testing it, and obtaining research data.

Research Plan

A design of scheme diagram of the fuel gas flow is seen in Figure 3. First, gas is caused to flow out of the gas tank by using a pressure regulator in 0.05 MPa. After that the gas is allowed to flow to the safety valve or diaphragm valve. The valve functions to direct the gas to idling or high speed engine running. After the safety valve, the gas directed to the idling regulator for flow advance to idling speed engine running and then the process of combustion. When the combustion chamber occurs, the suction process will vacuum at the intake manifold. This process causes the opening of the diaphragm valve and gas to flow toward the idle regulator or faucet to the converter. The idling regulator needed to regulate the consumption of fuel charts idling. Idling speed engine running occurs at the engine speed range of 1000-1200 rpm. When the engine is operating at idle conditions the gas supply is regulate by a pressure regulator and the air supply is very small. Pressure is regulated so that gas and air requirements are very small and in accordance with needs. Gas regulation uses a small gap so that the gas needs when idle are met.

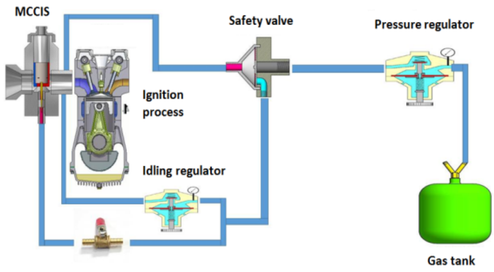

Figure 3: A scheme of the fuel gas flow

Any speed above that range is already upper speed. When the engine at high speed running, the gas is directed toward the regulator for flow advance to upper speed engine running and then the process of combustion. The function of the faucet is to reduce the gas pressure going to the converter. The gas that comes out the cylinder must stay high then it is lowered using a faucet. The principle of decline uses the Bernoulli principle, namely by shrinking the cross section of the flow. Using a smaller cross section the flow will increase but the gas pressure will decrease.

MCCIS functions to regulate the supply of gas and air to combustion chamber so perfect combustion is obtained. This mixing is divided into two types of combustion, namely combustion idle conditions and high speed combustion. Perfect combustion will produce maximum output power. MCCIS parts include body converter, cover converter, jet needle, needle, piston valve, main jet, idle screw, pilot jet, pressure idle control and intake manifold. Comparison between fuel and air is usually called AFR. The AFR to get perfect combustion is 1:11.5.

Figure 4 shows a cross-section image of the MCCIS. The complete version of the MCCIS system could be seen in Figure 5. The materials the MCCIS is made of are aluminum and brass. The reason for these choices is that these materials possess the character of being resistant to heat, releasing heat easily, being resistant to fuel gas pressure, and being resistant to corrosion.

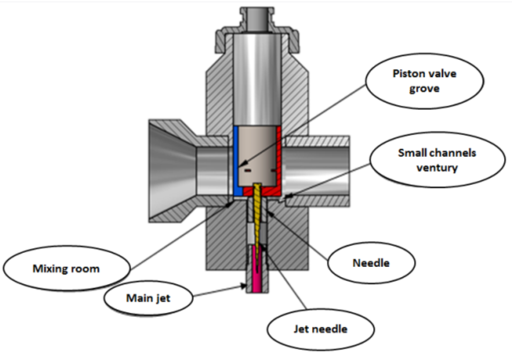

Figure 4: Converter

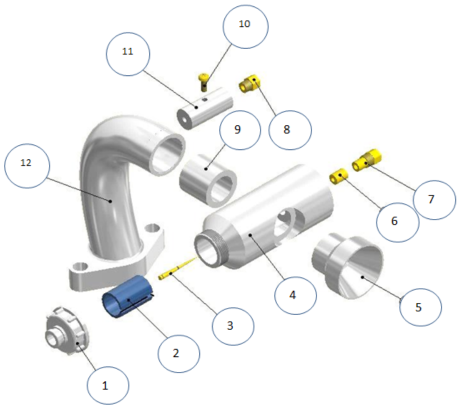

Figure 5: MCCIS System

Remark:

No	Name of part	Material
1	Cover converter	Aluminum
2	Piston valve	Brass
3	Jet needle	Brass
4	Body converter	Aluminum
5	Venturi converter	Aluminum
6	Needle jet	Brass
7	Main jet	Brass
8	Idle jet	Brass
9	Converter joint	Aluminum
10	JIS B 11 – A M3 x 8	Brass
11	Idle part system	Aluminum
12	Intake manifold	Aluminum

Figure 6 shows the gas discharge control. The gas discharge control at higher engine speed is regulated by using, among other components, the piston valve, the jet needle, and the needle.

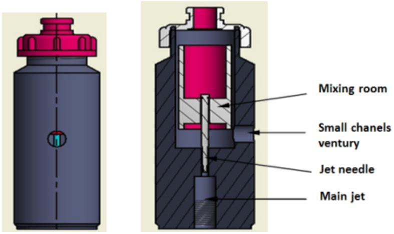

Figure 6 : The gas discharge control

Figure 7 shows the safety valve. This valve functions to release and stop the gas flow. Such regulation works automatically. When the intake manifold contains only a vacuum because of the suction process happening in the combustion chamber, the membrane opens and gas flow occurs and after that the membrane would close again and so on.

Safety kits are components of the MCCIS system guarding the vehicle user's security against and safety from the dangers of a flame or a fire when gas leak occurs and gets ignited because of sparks from a short circuit in the electricity or the surrounding environment. This system consists of the safety valve, diaphragm, and flame arrester. The flame arrester functions to halt fire creeping when a fire occurs so that it reduces the risk of facing greater danger. Figure 8 shows a flame arrester. This device would let fuel gas flow into water and proceed until it comes out of the water and then it would flow to the converter kits .The water functions to halt and extinguish the fire in order that it does not creep to the gas tank. In the flame arrester, there is a valve in order that the water does not get inside the converter kits.

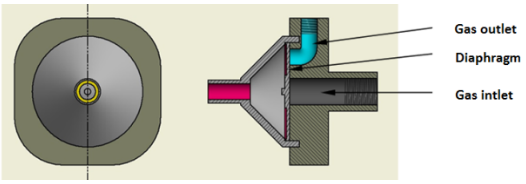

Figure 7: Safety valve

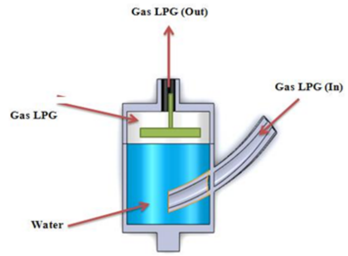

Figure 8: Flame arrester

Method of Experiment

The research used a Honda Supra Fit 100 cc motorcycle produced in 2006. Prior to the research, the motorcycle used conventional petrol fuel as its fuel. In the research, the petrol was replaced with natural gas. Petrol is clearly different in character from natural gas. In order to make it ignite easily, conventional fuel should be sprayed so that it becomes a mist. The mixing and misting process uses a carburetor. Because conventional fuel is liquid in form, it should be made to flow in accordance with the laws of liquid fluids. As for fuel gas, for the combustion, it needs only to be directly ignited with no need to be made misty first. This fluid is quite light; it would fill up empty space. A motorcycle using fuel gas needs a converter that would regulate the fuel gas needed. The gas tank used was a gas container 3 kg in weight produced by the Indonesian state-owned oil and natural gas mining company, Pertamina. It was done in order to make the gas provision easy and such a gas container already proved to be safe.

The research was to design the MCCIS as converter to regulate the fuel gas needed. The MCCIS regulates the gas flow for running the engine at idling speed and athigher speed. To know whether the device functions well or not, the engine needs to be tested. The testing is on the engine running at idling speed and at higher speed. In addition, exhaust gas emission testing and torque testing also need to be done. The fuel mixing system operates by using converter kits with several components, namely, a piston valve, a jet needle, a needle, a mixing chamber, a pilot jet, and a pressure idling control as regulator of the idling condition. The regulator of the amount of air entering the combustion chamber used the piston valve with a groove with a cross-section area of 0.3 cm^2 as place for air entrance when the engine was at idling speed. The testing on the engine running at idling speed was done at Faculty of Engineering at Universitas Negeri Yogyakarta, by turning on the engine and running it at the speed of around 1200 rpm for twenty minutes with the vehicle in an immobile condition. At this stage, attention was paid to the engine to check whether there was any detonation or not. In addition, the engine was also checked to see whether it remained running or stalled. The detonation was checked using the sound of the motor engine. If detonation occurs, small explosions will occur in the exhaust.

Running the engine at higher speed was done at moderate and high speeds. The engine was started and run at the speed of around 4000 rpm for twenty minutes. Then it was run at the speed of around 8000 rpm for five minutes. At both speeds, the vehicle was not ridden anywhere (the gears were kept in neutral position). A check was made to decide whether detonation occurred or not. The detonation also checked using the sound of the motor engine. If detonation occurs, small explosions will occur in the exhaust. In addition, the engine also checked to decide whether it stalled or remained running.

Testing Machine and Research Support Equipment

The motorcycle performance testing was done in an open place and the road. The testing in the open place was done on the motorcycle with the engine running at idling speed and at higher speed without the vehicle leaving its place. The testing with the engine idling was at the speed of around 1200 rpm. The testing with the engine running at higher speed was at the moderate speed of around 4000 rpm and at the high speed of around 8000 rpm. As for the testing on the road, it was to test the maximum speed and maximum fuel gas consumption. The equipment used in the testing consisted of a motorcycle using fuel gas, a safety helmet, a camera, a digital scale, and a video maker.

Besides the tests above, the exhaust gas emission and the torque produced would also be tested. The torque produced was tested by using a dynamometer while the exhaust gas emission was tested by using an exhaust gas analyzer. The exhaust gas emission testing was done on the vehicle with the engine on at low, moderate, and high speed. The exhaust gas emission threshold levels according to the Indonesian Ministry of Life Environment [16] could be seen in Table 1 while that according to Euro standards [17] could be seen in Table 2.

Table 1: The maximum constrain of exhaust gas emission based on Living Environment Ministry

Category	Made year	Parameters	
		CO%	HC (ppm)
Motorcycle 2 stroke	< 2010	4,5	12.000
Motorcycle 4 stroke	< 2010	5,5	2.400
Motorcycle 2 and 4 stroke	≥ 2010	4,5	2.000

Remark: ppm (part per million)

Table 2: The maximum constrain of exhaus gas emission based on Euro Standard

Reference	CO	HC	NOx	PM
Euro0	12,3	15,8	2,6	-
Euro1	4,9	9,0	1,23	0,4
Euro2	4,0	7,0	1,1	0,15
Euro3	2,1	5,0	0,65	0,1
Euro4	1,5	3,5	0,46	0,02
Euro5	1,5	2,0	0,46	0,02

Result and Discussion

Idling Engine Testing

The motorcycle using fuel gas with the MCCIS successfully passed the testing with the engine idling. During idling speed there was no detonation occurred and the combustion went smoothly. The mixing of the fuel with the air was done well; however, no comparison related to the use the two different fuels was measured. The exhaust gas emissionat idling speed remained below threshold levels. The torque produced was not different, either, from that produced when fuel oil was used.

When the engine was running at idling speed, the gas supply was regulated by a pressure regulator at 0.05 MPa. The air coming in was also controlled in order that there was very little flow. The ratio between air and gas was 1:12. The pressure was adjusted so that a suitable ratio was attained for igniting and running the engine in an idling condition. The engine speed around 1200 rpm. In that condition, the MCCIS let very little supply of fuel gas flow because the gap gone through was quite narrow with the cross-section of the hole quite small in area. That was purposely done because the fuel gas and the air needed for engine idling were very little. When the fuel gas flow is great, then detonation would occur. The setting of the fuel gas and air flow was done by trial and error until the most perfect engine running at idling speed was obtained.

The function of the faucet located before the MCCIS system was to maintain the same pressure when supplying fuel gas to the MCCIS. When the pressure exerted was greater compared to the engine need, it was then reduced with the faucet so that the pressure exerted fitted the engine need. It could maintain the same fuel gas pressure in the MCCIS every time in spite of changing engine conditions. It applied the Bernoulli principle as theoretical basis in designing the MCCIS.

Testing of Engine Running at Higher Speed

As previously implied, the system of fuel mixing by using the MCCIS went through several components, namely, the piston valve, jet needle, needle, mixing chamber, and pilot jet. The regulator of the air amount entering the combustion chamber used the piston valve having a groove as the place for the air entrance. The needle and jet needle tapering in form regulated the amount of LPG flow while the magnitude of the air flow entering the combustion chamber was regulated by the piston valve. When acceleration was done, the cross-section area would increasingly enlarge until it became 1.53 cm^2 to supply more air.

The testing results showed that the motorcycle successfully passed the testing on the engine running at higher speed. No detonation occurred while the engine was on. No problem occurred, either, in starting and running the engine. The mixing of the fuel with the air was also well done; however, no comparison related to the use of the two different fuels was measured, either. The exhaust gas emission at higher speed remained below threshold levels. The torque produced was not different, either, from the one produced by the motorcycle using fuel oil.

Fuel Gas Consumption Testing

The testing on fuel gas consumption was done on the road to attain the condition of actually using the motorcycle on the road. Data collection was done each time a distance of 10 km was covered at the same speed. The data related to the same speed were collected two to three times according to need. The speed used was from three ranges, namely, the 0-40 km, 40-60 km, and 60-90 km speed ranges. It was for the purpose of knowing the fuel gas needed at each speed. The final result was the average of the data obtained at each speed. The data about fuel gas consumption at each speed rangecould be seen in Table 3.

Table 3: Gas consumption

Experiment	Speed range	Gas consumption
1	0-40	73.03
2	40-60	97.77
3	60-90	45.51
Average		72.1

The general average fuel gas consumption obtained from the three data items above was 72.1 km/kg. Meanwhile, the general average fuel oil consumption was around 50 km/kg. Compared to the use of fuel oil, the use of fuel gas showed an efficiency of 44%.

Exhaust Gas Emission Testing

The data resulting from the emission testing could be seen in Table 4 and trend content of CO, CO_2, HC and O_2 shows in Figure 9 and Figure 10. With the results displayed on the printout from the testing device and the table of threshold levels, it could be concluded that the idling speed of around 1200 rpm produced a CO content of 0.354%. It was already included among the predetermined magnitudes. The HC content of 356 ppm with the lambda (λ) value of 1.385 was also already included among the predetermined magnitudes. The speed of around 8000 rpm produced a CO content of 0.119%, which was already included among the predetermined magnitudes. The HC content of 274 ppm with the lambda (λ) value of 1.342 was also already included among the predetermined magnitudes. The speed of around 10.000 rpm produced a CO content of 0.162%, which was already included among the predetermined magnitudes. The HC content of 630 ppm with the lambda (λ) value of 1.305 was also already included among the predetermined magnitudes.

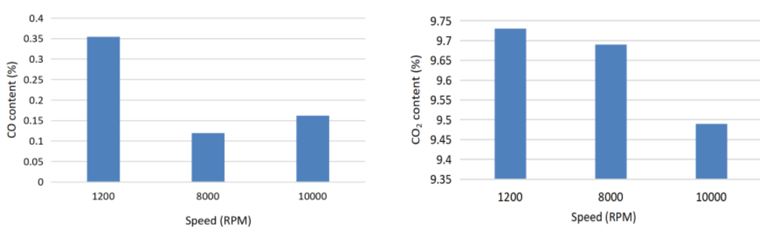

Figure 9: CO and CO_2 content

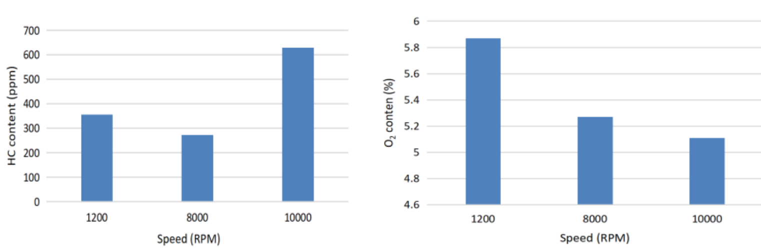

Figure 10: HC and O_2 content

Table 4: Exhaus gas analysis

Gas	Speed	Speed	Speed
Outside temperature (°C)	35	34	34
Pressure (kPa)	988	988	989
Real Humidity (ZHR)	50	50	51
Relative air/fuel ratio (λ)	1,305	1.342	1.385
CO (%)	0.162	0.119	0.354
CO_2 (%)	9.49	9.69	9.73
HC (ppm)	630	274	356
O_2 (%)	5.11	5.27	5.87

Torque Testing

The data about the torque of the motorcycle using natural gas could be seen in Figure 11. The same motorcycle was used to make the comparison. The dynamometer was used to measure the torque related to the motorcycle. The testing was done several times with various speed. The testing was done at the speed which would produce the maximum attainable torque and power; that speed should be greater than 5000 rpm. The testing result showed that the maximum attainable power was 5.6 hp at the speed of 7801 rpm and the maximum attainable torque was 6.02 Nm at the speed of 6153 rpm. For comparison, the maximum attainable torque of the motorcycle using petrol at the same speed was 6.21 Nm. The result of the comparison showed that the torque produced was relatively similar.

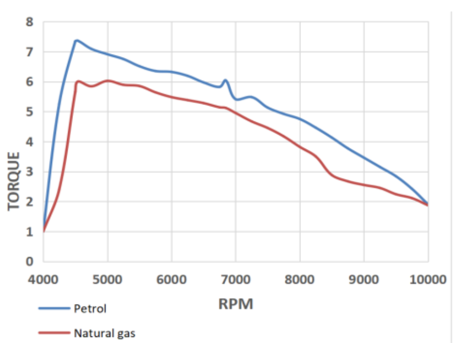

Figure 11: Torque test result for motorcycle using conventional and gas fuel

The natural gas produces 17% lower torque than petrol as shown in the Figure 10. According Suthisripok et al. [7], the performance of the converted natural gas will generally drop 15-20% from the petrol. In general, modified vehicles suffer from power loss and experience drive problems as a result of retro fit conversion packages design and/or installation.

Conclusion

The conclusion of the research is as follows. The MCCIS could be used on motorcycles using fuel gas with the engine for both idling and higher speed. During idling speed there was no detonation occurred and the combustion went smoothly. The flame arrester could stop the sparks so that the fire did not creep to the fuel gas tank. The results of emission testing indicate that the engine running at idling, moderate, and high speeds produce CO and HC contents that are already included among the predetermined magnitudes. The motorcycle using fuel gas and gasoline produce relatively similar torque.

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