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The Environmental Effect Of Added Brown Gas On The Automotive Diesel Engine

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Abstract – Brown Gas Generator (BGG) is a device that produces Hydrogen (H2) and oxygen (O2) gas, known as Brown Gas or HHO gas based on electrolysis. BGG uses aqua dest electrolyte and stainless-steel spiral electrodes. Installation of internal combustion engines, in this case, gasoline and diesel engines, is one of the BGG applications which empirically claim to be able to save fuel. In this study, BGG will be applied to a diesel-type automotive engine, namely the Isuzu Panther TBR 52, 2300 cc engine. Brown Gas will be introduced into the combustion chamber through the engine intake air. Baking soda (NaHCO3) will be mixed in each liter of distilled water to facilitate the occurrence of HHO gas. As a variation, baking soda is mixed with a composition of 3 grams, 6 grams, 9 grams, and 15 grams of electrolytes per 1.5 liters of distilled water. While testing, it was deemed necessary to add the composition of 7 grams and 8 grams as variables. Automotive testing was carried out on the "Chassis Dynamometer" at the Fuel and Motor Combustion Laboratory in the Department of Mechanical Engineering FTI, Sepuluh Nopember Institute of Technology Surabaya, taking the ASTM test standard as a guide. The test results show that the composition of 7 grams provides a better performance improvement than other compositions. On average, the engine power increased by 9.6%, torque increased by 8.6% and SFC decreased by 9.7%

Keywords – Brown Gas Generator, HHO gas, Automotive diesel engine

I. INTRODUCTION

The automotive sector, as one of the areas where gasoline and diesel engines are used, has carried out various research and developments on engine efficiency technology. Several efficiency-enhancing technologies have been applied to cars and motorcycles. These include electrical improvements for ignition of spark plugs, use of electric motors to adjust valve timing and fuel injection, filtration and fuel purification systems using magnets, and much more. The most notable problem is that the power efficiency technology of today's automotive engines is neither cheap nor simple (Arat et al, 2016).

The alternative to increasing the efficiency of the automotive engine studied by the author is the addition of hydrogen gas in the combustion process of the combustion engine. Hydrogen gas is added through the engine air suction channel, where the flammable nature of hydrogen gas will complete the combustion process while increasing the power of the combustion engine (Bahreini et al, 2012).

Brown Gas Generator (BGG) itself requires a low cost to get it. To get the BGG created by ITS Surabaya, it only takes approximately 1 million rupiahs for a vehicle. Aquades as electrolyte fluid in BGG are also relatively cheap and easy to obtain. Meanwhile, to facilitate the formation of HHO gas, a catalyst in the form of baking soda was added to the BGG electrolyte (Chraplewska et al, 2011).

II. Literature Review

2.1. Brown Gas

Brown gas or HHO gas is a flammable gas produced by the electrolysis reaction of H2O with DC. It is also called HHO because the electrolysis of water with a DC produces two moles of H2 gas and one mole of O2 gas (Karthikeyan et al, 2020).

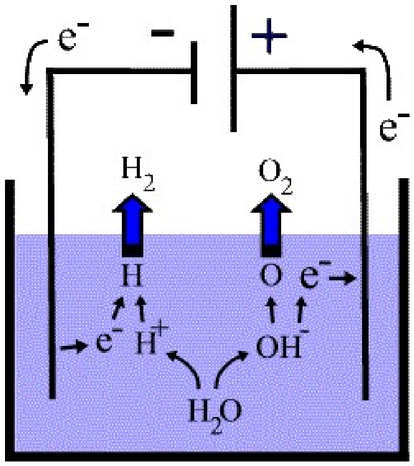

Figure 1. Material Characteristic

To analyze the test results using a chassis dynamometer, several theoretical foundations of internal combustion engine calculations are used. The amount of thrust an engine generates is important. But the amount of fuel used to generate that thrust is sometimes more important because the airplane has to lift and carry the fuel throughout the flight. Engineers use an efficiency factor, called thrust-specific fuel consumption, to characterize an engine's fuel efficiency. The fuel consumption of TSFC is "how much fuel the engine burns each hour (Bannister et al, 2010).

2.2. Torque (T)

The amount of torque is the product of the length of the torsion arm with the load indicated by the dynamometer (Lee et al, 2013):

$$T = \frac{716,2\,Ne}{n}(kgm)$$

T = Torque moment (Kgm)

Ne = Effective power (hp)

nd = dynamometer rotation (rpm)

2.3. Break Mean Effective Pressure (BMEP)

The average effective pressure observed (break mean effective pressure, BMEP) according to Arismunandar is the average effective pressure is the theoretical effective pressure acting along the volume of the piston stroke to produce power equal to the observed effective power (Lloyd & Cackette, 2001):

$$bmep = \frac{60 \cdot Ne \cdot z}{A \cdot L \cdot n \cdot i.1{,}34}(KPa)$$

Where :

A = Cross-section of piston (m2)

L = piston stroke (m)

I = Number of cylinders

N = Engine speed (rpm)

z = 1 (2-stroke motor) or 2 (4-stroke motor)

Ne = Effective power (hp)

1 KW = 1.34 hp

2.4. Thermal Efficiency (HTH)

Thermal efficiency is a measure of the use of heat energy stored in the fuel to be converted into effective power by an internal combustion engine (Reşitoğlu et al, 2015). Theoretically written in the equation:

$$\eta_{th} = \frac{632}{Sfc \cdot Q_c} \cdot 100\%$$

Where :

η_{th} = Thermal efficiency

2.5. BGG Testing

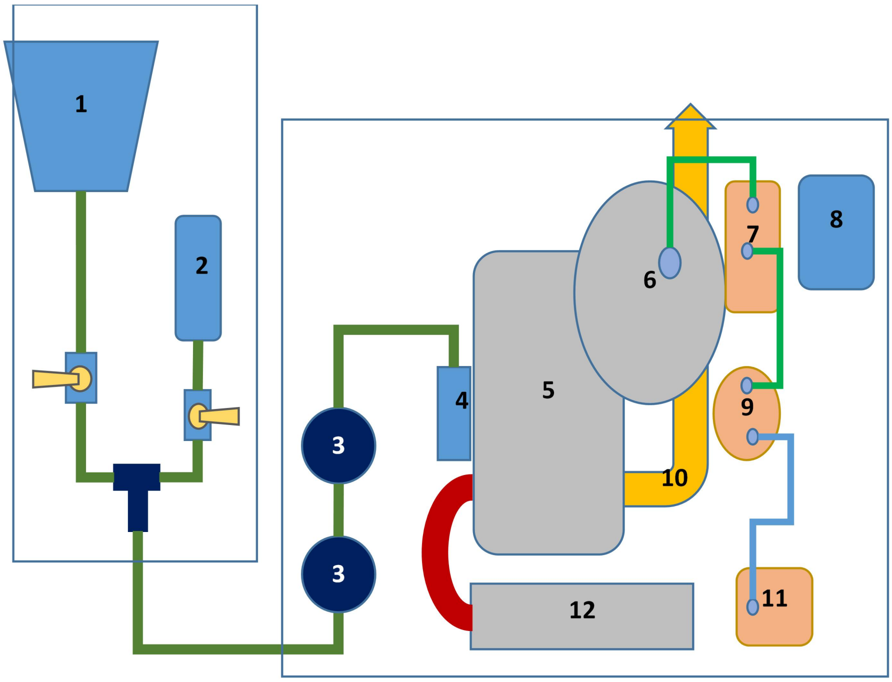

Figure 2. Test equipment layout diagram

Where:

1. Solar storage tank
2. Guess cup 80 ml
3. a. Pre-filter solar

   b. Solar main filter

4. Fuel pumps
5. Machine
6. Air Filter
7. Water trapper BGG
8. Accu
9. BGG
10. Exhaust manifold
11. BGG reservoir
12. Radiator
13. Radiator intake pipe

The test preparation of this final project includes

a. Test planning

The test is carried out based on the testing standard that has been set in chapter 1, namely ASTM D6201-99.

b. Checking

Check the condition and presence of test equipment. At this stage, it is ensured that all the required test equipment is available and in good condition.

c. Equipment assembly

After obtaining certainty about the condition of the test equipment, the assembly of test equipment is carried out which includes (Rimkus et al, 2013):

1) Assemble the BGG so that it can function properly in all engine operating conditions
2) Assembly of equipment for calculating fuel consumption time.
3) Catalyst-electrolyte mixing according to research needs.
4) Additional equipment placement

2.6. Testing Steps

Testing in this final project can be explained through the following testing steps:

a. Place the car on the dynamometer.

b. Install a portable blower in front of the engine radiator and turn it on when the car engine is running.

c. After the car is positioned on the dynamometer chassis safely and steadily, the car is heated to an operational condition characterized by the achievement of a temperature of 46-48 ° C in the engine oil crankcase. At the time of heating, the portable blower starts to turn on. In testing the engine with BGG when heating is also used to ensure that BGG operates and produces brown gas. This is indicated by the appearance of air bubbles in the BGG water trapper. If it turns out that BGG is not working, repeat step 3 by first fixing the BGG working function (Saravanan et al, 2008).

d. After the crankcase temperature of 46-48°C is reached, the test begins. At first, the car was operated normally in stages from 1st gear to 4th gear. In 4th gear, data collection began. With the initial engine speed of 1000 rpm, the engine speed is increased gradually by 500 rpm to 4000 rpm. For every 500 rpm increase, data will be taken after first achieving engine rotation stability (Sulatisky, 2006).

e. Data retrieval is carried out in parallel at each measuring point.

1) For power and speed data, the dynamometer is taken directly by reading the display screen. Power is expressed in HP and speed is in km/h.

2) Rpm, The dynamometer is obtained by measuring the rotation of the dynamometer "drum" using a digital tachometer.

3) The amount of fuel consumption per unit time is obtained by calculating the duration of the decline in the diesel surface in the guessing glass, from the top line to the bottom line. Time was measured using a digital stopwatch. The beaker can be refilled by connecting the beaker to a temporary holding tank which is installed higher than the beaker.

4) Changes in the temperature of certain points are obtained by measuring these points using an infrared digital thermometer. These points include (Yang et al, 2016):

- Radiator inlet pipe. The temperature here shows the engine temperature
- Exhaust manifold pipe. The temperature here shows the engine exhaust gas temperature
- Crankcase oil. The temperature here shows the engine oil temperature.

5) To determine the effect of catalyst changes on BGG, the current flowing in BGG was measured. Measurements were made using digital ampere pliers with BGG positive pole wire as a measuring point.

6) The test is considered complete after all data at each level of the round has been taken. The end of the test begins by slowly lowering the engine speed until it reaches idle speed. Then the engine is turned off, the fuel flow control valve on the gauge is turned off.

f. Steps a to e are carried out sequentially in testing each variation. Meanwhile, each variation was carried out 3 times for data collection. Data starts to be taken when the oil temperature is 46° – 48° C (Shajahan et al, 2020).

g. After the standard test is carried out, samples of used engine lubricant are taken to be examined in the laboratory. But first, the car is run up to + 1000 km. The same thing was also carried out when testing machines with BGG.

With the reason that it does not interfere with the teaching and learning process in the campus environment and reduce the influence of ambient temperature, the test is carried out at night until the early morning (Verma et al, 2018).

III. RESULTS AND DISCUSSIONS

3.1. Data Analysis

From the test data obtained some processed data. The results of the processed data are graphed to see the changes that occur.

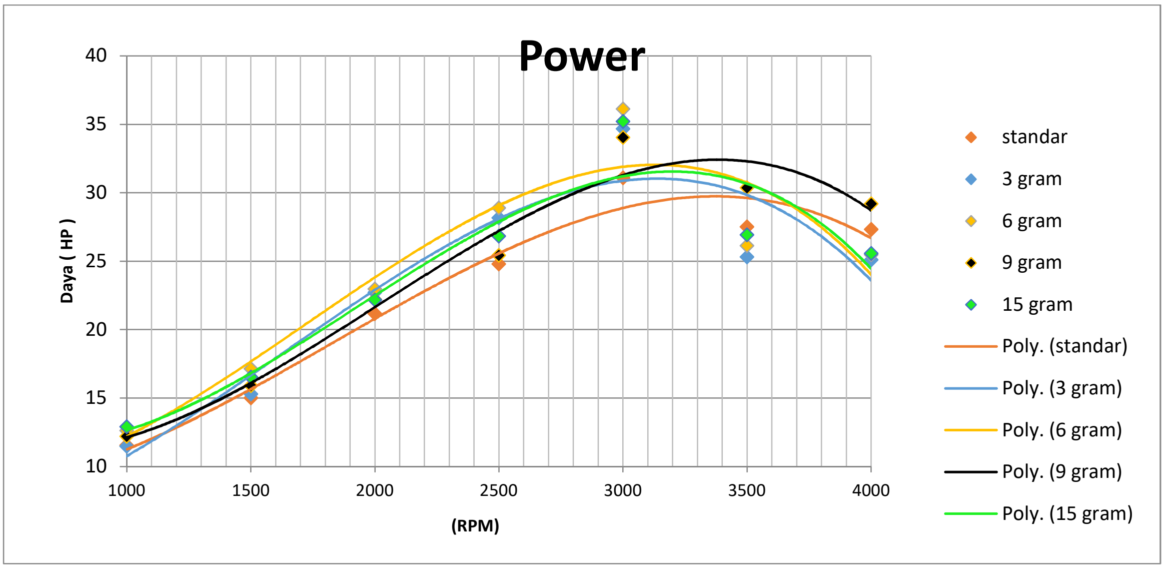

Figure 3. Power and RPM (3, 6, 9, 15 gram)

The 6-gram catalyst has the best effect on the panther engine. While the 9-gram catalyst has an increase that is not too high at low rotations but reaches peak power at 3500 revolutions and the power does not decrease sharply at above 3500 revolutions. This difference raises the question "Is the composition between 6 grams and 9 grams able to give a better effect".

The author decided to take additional data by changing the composition of the catalyst to 7 grams and 8 grams.

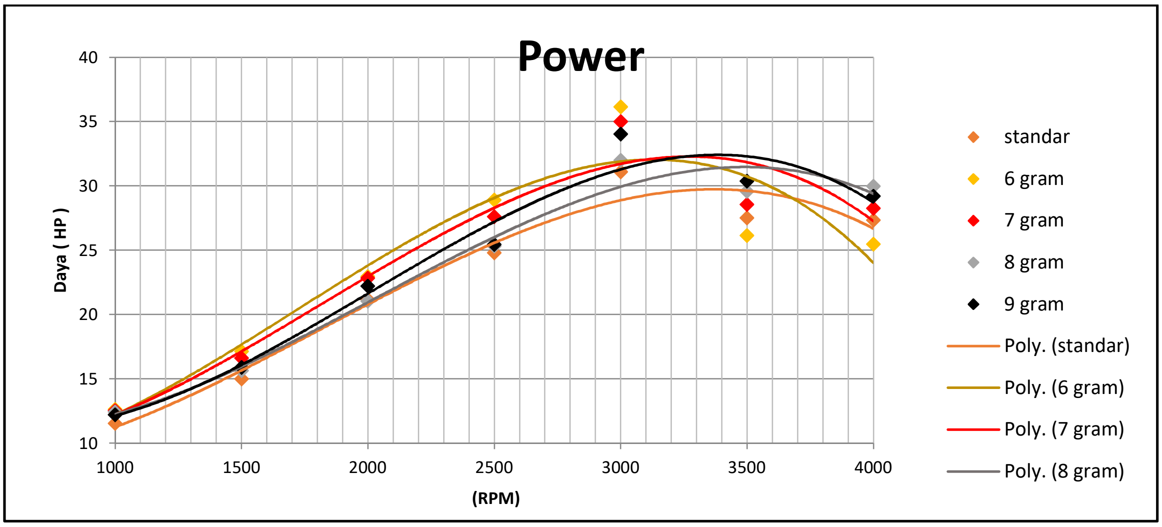

Figure 4. Power and RPM (6, 7, 8, 9 gram)

The weakness of the 6-gram catalyst which decreased sharply after the peak power was not seen in the 7-gram catalyst. The 7-gram catalyst gave a greater power addition than the 6-gram catalyst although not as big as the 9-gram catalyst. While the 8-gram catalyst did not give better results than the 7-gram catalyst. In automotive engines, the main cause of power loss at high rpm is the reduced combustion time.

In this test, the engine power graph with the addition of brown gas makes the above things clearer. Brown gas, even though it is introduced through the intake air duct, can be considered as a form of fuel addition. This makes the combustion of the engine with brown gas more complete at speeds below 3000 rpm and imperfect at 3500 rpm and more imperfect than standard conditions at speeds above 3500 rpm. This phenomenon causes the engine power with brown gas to be lower than the standard at high rpm.

3.2. SFC Analysis

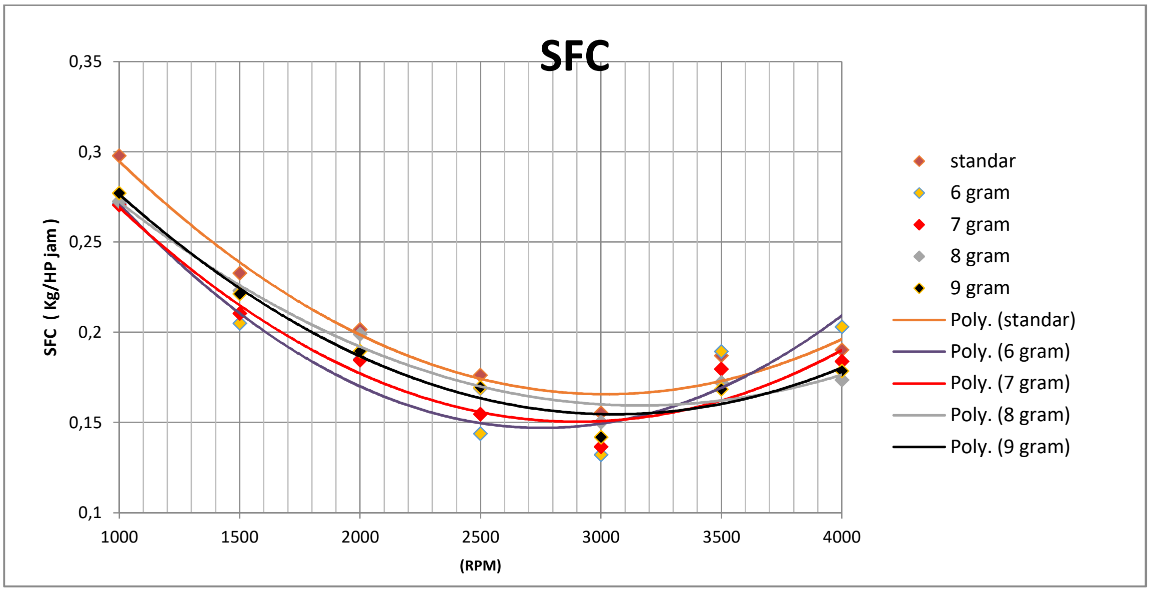

Figure 5. SFC and RPM (6, 7, 8, 9 gram)

At 2500 rounds, 6 grams of catalyst is still the lowest, but at above 3000 cycles, 6 grams of catalyst is more wasteful than 7.8 or 9 grams of catalyst, even under standard conditions. While the 7-gram catalyst, although did not give a decrease of 6-gram catalyst, it was able to give a lower SFC reduction than the others. So in general the 7-gram catalyst reduced SFC better than the other test compositions.

3.3. Torque Analysis

From the graphs and percentages, it can be concluded that the 6-gram catalyst provides the largest additional torque at 2500 to 3000 revolutions but becomes weaker than the standard at the above rotations. The 9-gram catalyst provides a better torque addition only at revolutions above 3500, while the 7-gram catalyst provides an additional torque greater than 9 grams at 2500-3000 rpm and provides additional torque better than 6 grams at above 3000 rpm.

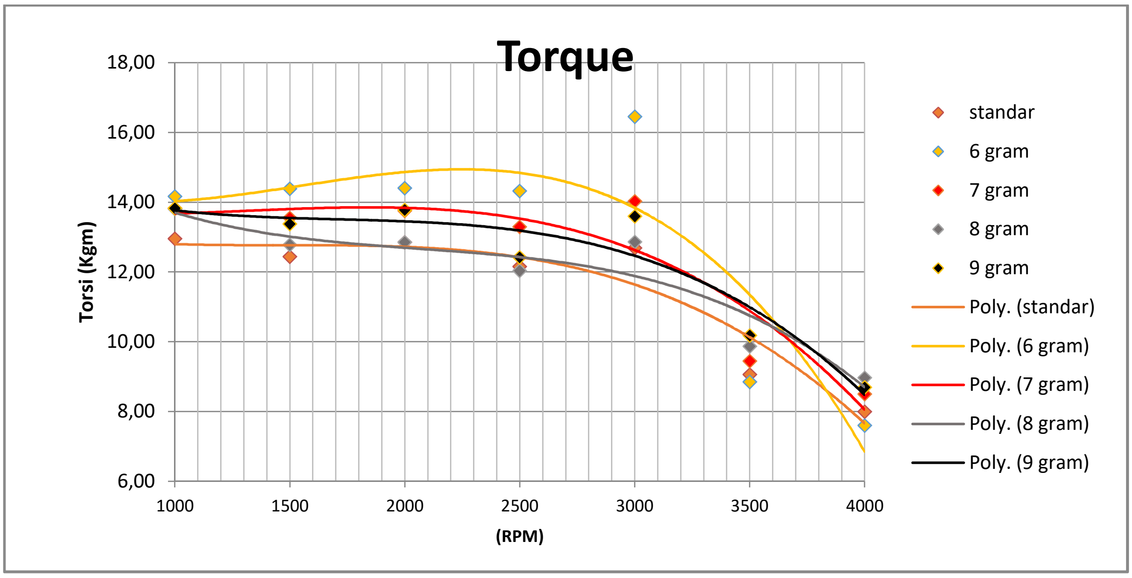

Figure 6. Torque and RPM (6, 7, 8, 9 gram)

3.4. Operational RPM Regional Analysis

It was found that the use of BGG with a catalyst of 6 grams gave an average increase of 10% power, 17.6% torque and 9.2% decrease in SFC. 7 gram catalyst gives an average power increase of 9%, the torque of 8.5%, and a decrease in SFC of 8.6%. And an average 9-gram catalyst provides a 7.6% increase in power, 7% torque, and a 6.4% decrease in SFC.

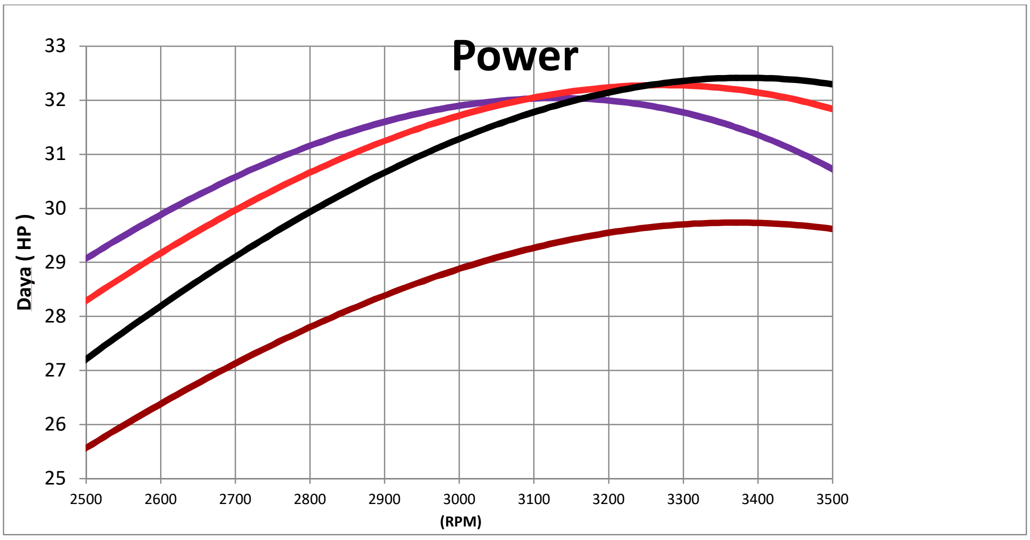

Figure 7. Power and RPM Summary of Environmental Effect Gas Brown

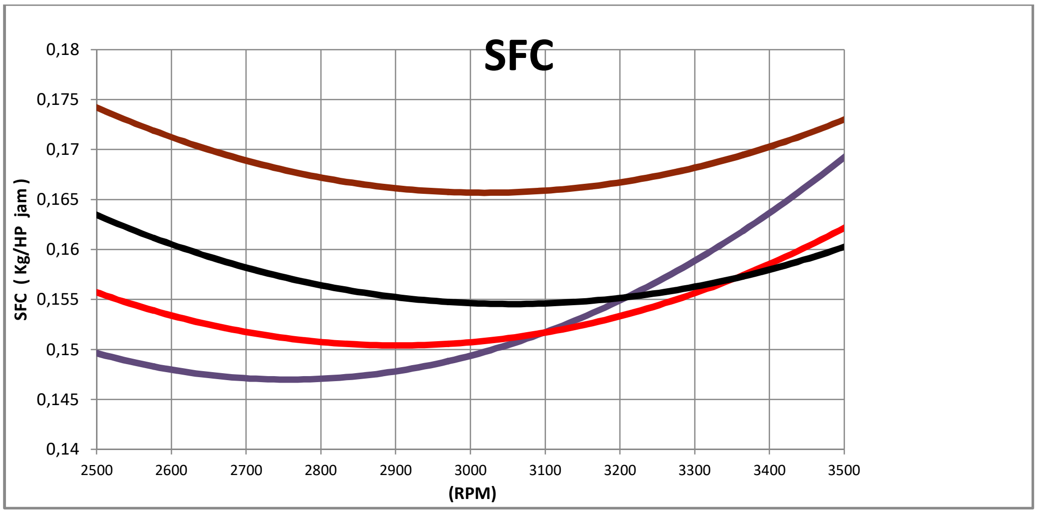

Figure 8. SFC and RPM Summary Summary of Environmental Effect Gas Brown

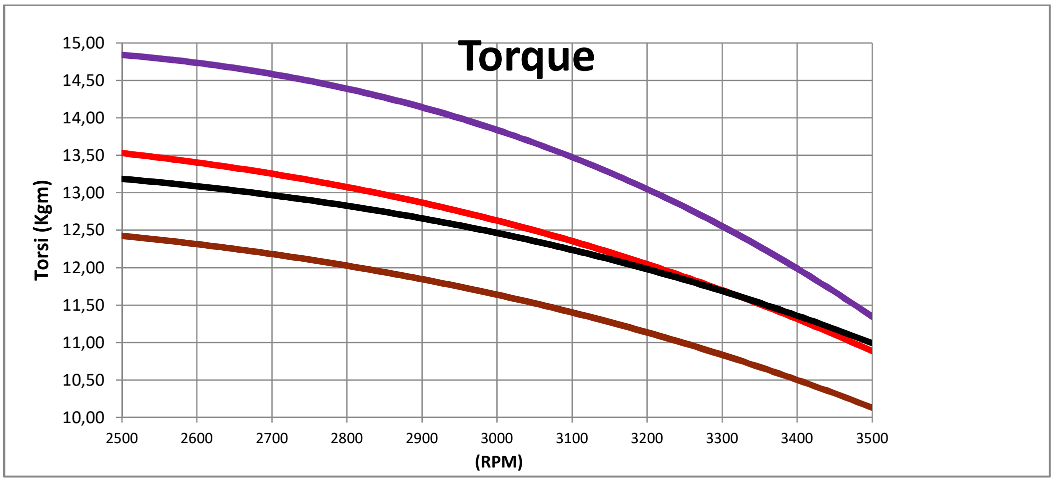

Figure 9. Torque and RPM Summary Summary of Environmental Effect Gas Brown

3.5. Used Lubricant Analysis

Globally, the use of BGG has a positive effect on the condition of used panther car engine lubricants. However, one thing that needs attention is the premature decrease in TBN of lubricants under BGG test conditions. This still needs to be studied further to find the cause.

As for the action to overcome problems or side effects, the use of BGG, especially in terms of TBN lubricants, is recommended to add TBN additives at every engine lubricant replacement. The size of the addition depends on the type of lubricant used, the volume of the lubricant tank, and the type of additive used. It must be admitted that in this writing, this matter has not been explained in more detail. So, for more precise advice and analysis regarding lubricants in machines with the BGG application, deeper research needs to be carried out.

IV. Conclusion

After going through a series of tests and analyses, the author has the following conclusions:

a. The addition of Brown Gas to the combustion process of the Panther TBR 52 2300 cc diesel engine provides an increase in engine performance in the form of increasing power, increasing wheel torque, and decreasing engine SFC.

b. The composition of the baking soda catalyst 7 grams per 1.5 liters of distilled water gave the best performance improvement compared to other test compositions. The 7-gram catalyst provides (on average) an increase in power of 9.6 %, an increase in torque of 8.6 %, and a decrease in SFC of 9.7 %.

c. In the operational speed area of the Panther TBR 52 engine, the 6-gram catalyst provides an increase in engine performance that is better than the other test compositions with an increase in power of 9.9%, a torque of 17.6%, and a decrease in SFC of 9.1%.

d. The addition of Brown Gas to the Panther TBR 52 diesel engine has a side effect of accelerating the decrease in TBN of engine lubricant, up to twice the standard condition (without Brown Gas.

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