DEVELOPMENT OF FUEL CONSUMPTION ENGINE MAP FOR MYVI ENGINE VOLUMETRICALLY

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DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

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Abstrak

Kajian ini menghasilkan peta penggunaan bahan api enjin Myvi (Daihatsu K3-VE). Objektif kajian ini adalah untuk menghasilkan peta penggunaan bahan api peta yang andal. Sebelum ini, peta enjin penggunaan bahan api dicapai dengan kaedah gravimetrik. Manakala, kajian eksperimen ini telah disiapkan dengan kaedah isipadu, menentukan kadar penggunaan bahan api dalam mililiter sesaat (ml / s). Buret dan jam randik digital telah digunakan sepanjang eksperimen untuk mengira kadar penggunaan bahan api. Pekali korelasi untuk penggunaan bahan api, kuasa brek dan brek kecekapan haba antara eksperimen gravimetrik dan isipadu adalah kurang daripada 0.7, ini telah menunjukkan keputusan antara dua eksperimen mempunyai sepadan yang sederhana.

Abstract

This study generates fuel consumption engine maps of a Myvi engine (Daihatsu K3-VE). The objective of this study is to produce reliable fuel consumption engine maps. Previously, fuel consumption engine maps were achieved by gravimetric method. In this experimental study, the maps were completed in volumetric method whereby the rate of fuel consumption was measured in milliliter per second (ml/s). Burettes and a digital stopwatch were used throughout the experiment to calculate the fuel consumption rate. The results from this experiment are compared to the previous results by using the correlation coefficient in Matlab. The correlation coefficient for fuel consumption, brake power and brake thermal efficiency between gravimetric and volumetric experiments are less than 0.7, that indicates a moderate matching between both experiment results.

1. INTRODUCTION

The prices for petrol and diesel are updated every Wednesday starting 29 March 2017. Minister of Domestic Trade, Cooperatives and Consumerism announced that the petrol and diesel prices are set based on the automatic pricing mechanism (APM) according to the monthly average of global crude oil prices. The fluctuations in fuel prices created concern among consumers and petrol station operators. [1]

During the uncertainty of fuel price, drivers are advised to drive in eco-driving, which is a way of driving with the purpose to reduce fuel consumption and carbon dioxide emissions. In one study found that drivers with the eco-driving training lead to a significant reduction in fuel use of 4.6%. The training curriculum focused on braking and accelerating gently, using the right gear for the conditions, and maintaining a steady cruise speed on highways. This training has certain effects on the engine operating conditions, which are the engine speed (rpm) and engine load (Ian Jeffreys, Genevieve Graves, Michael Roth, 2016) [2]. The method that can be used to improve fuel economy is to minimize vigorous acceleration and deceleration (Avid Chaim Mersky, Constantine Samaras, 2016) [3]. Drivers can reduce fuel consumption by knowing the operating conditions that have good fuel efficiency.

Every vehicle has its own optimum performance zone in the particular range of engine speeds and engine torques. One of the methods to achieve the fuel economy is by driving under the high brake thermal efficiency zone (BTE) and the low brake specific fuel consumption zone (BSFC). Brake thermal efficiency is the ratio of the brake power output of a heat engine to the thermal input from the fuel. It is used to evaluate the efficiency of an engine to convert heat energy from a fuel to mechanical energy [4]. High brake thermal efficiency indicates that the engine has good conversion of heat from fuel to mechanical energy. Brake specific fuel consumption is a measure of how efficiently a specific amount of fuel is converted into a given amount of power [4]. A low BSFC indicates that an engine requires less amount of fuel to produce the same amount of power, and thus is a good fuel efficiency. The benefits of vehicles operated in this zone are decent performance and good fuel economy.

Fuel consumption engine maps provide information on BSFC and BTE to the drivers. With the engine map, drivers can have a better understanding about the vehicle fuel efficiency at different engine speeds and engine loads. However, car manufacturers do not provide the fuel consumption engine maps to customers. Therefore, the reliability of fuel consumption engine maps (gravimetric method) are uncertain as we did not have the default fuel maps from car's manufacturer to validate the reliability. This study was conducted with the objective to determine the consistency and repeatability of engine maps of both studies.

Previously, the fuel consumption engine map was done using the gravimetric method. The rate of fuel consumed by the engine was determined by a weighing machine. The fuel was placed on top of the digital weighing scale, the initial weight and final weight was recorded. The changes of fuel mass over a period of time represents the fuel consumption rate. In this experimental study, the fuel consumption engine maps were developed using the volumetric method. This experiment setup had a similar setup with the "Performance of Internal Combustion Engine" experiment [5]. The rate of fuel consumption was determined by burettes and a digital stopwatch. The time required for a certain volume of fuel decrement was measured. The rate of change of volume represents the rate of fuel consumption.

The fuel consumption engine map was developed in the steady-state condition. Time measurements were started when the values of engine speed and torque were stable. In this experiment, a range of engine speeds and torques were set [6].

The 3D and 2D fuel consumption, BTE and BSFC engine maps were plotted by using MATLAB.

2. DESCRIPTION OF EXPERIMENT SETUP

In this study, a 1298cc, four-cylinder Myvi engine (Daihatsu K3-VE) was used. The details of the engine's specifications are shown in Table 1.

Engine type	Four – stroke
Fuel type	Gasoline RON 95
Number of cylinder	4
Displacement (cc)	1298
Cylinder bore x stroke (mm)	72 x 79.7
Compression ratio	10
Cooling type	Water cooling tower, fan
Aspiration	Natural Aspirated
Maximum torque	116 Nm at 3200 rpm
Maximum power	64kW at 6000 rpm

Table 1: Myvi engine specifications [7]

2.1. EXPERIMENT SETUP

The decrement of fuel volume was determined by using burettes. The time required for a specific volume of fuel consumed by the engine is taken using a digital stopwatch.

The previous fuel consumption engine map was studied. Based on the results of the maximum fuel consumption rate in grams per second (g/s), the calculation and prediction of the maximum fuel consumption rate in milliliter per second (ml/s) was obtained. From the prediction, two burettes of 100 ml volumetric capacity were installed.

In this study, two burettes were connected to the fuel line along with the fuel filter, fuel pump, fuel pressure regulator and finally to fuel injectors. This fuel delivery system has a return fuel line. The fuel was regulated by a fuel pressure regulator. The excessive amount of fuel will return to the point in the fuel line before fuel filter and fuel pump. The fuel delivery setup is shown in figure 1.

The connection of burettes was in parallel. Both ends of the burettes experienced the same pressure. One end of the burette was exerted with atmospheric pressure, while the other end was exerted with fuel pressure in fuel line. Fuel level on both burettes remained the same as both burettes had the equal pressure difference. The rate of fuel consumed by the engine on both burettes are the same.

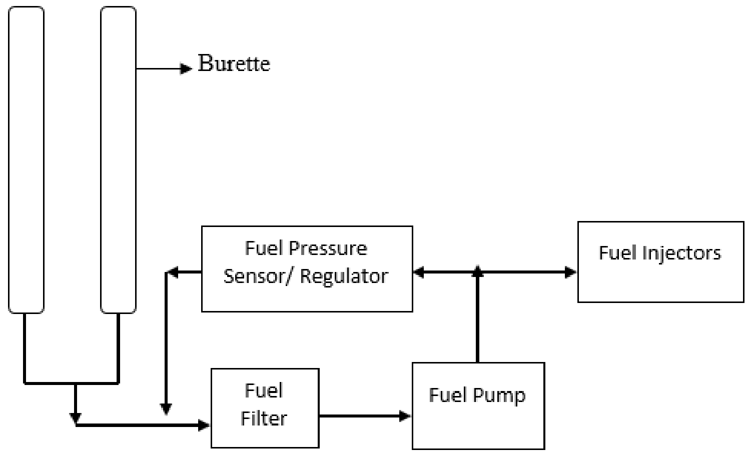

Figure 1: Experiment setup of the fuel delivery system

Figure 2: Experiment setup of the burettes

2.2. EXPERIMENT SETTING

Before the experiment was carried out, a few modifications and settings were made to facilitate the progress of the experiment. First and foremost, the throttle pedal was relocated to the control room, and the throttle cable was extended along with the pedal. This effort was for the convenience of the operator. Since the control panel of the dynamometer was located in the control room, by relocating the throttle pedal, it allowed the operator to monitor the engine speed and engine load while adjusting the pedal.

In order to measure the fuel consumption rate, the fuel tank was replaced by the two burettes. The nozzles of the burettes that have smaller diameter were cut off to meet the high fuel consumption rate by the 1.3L engine. The remaining cylinders of the burettes that have larger diameter were polished. Both burettes were then connected to the rubber hose and then was jointed together by a Y- connector. The connection is shown in Figure 2.

2.3. EXPERIMENT PROCEDURES

The experiment was performed at various engine speeds and engine loads. Before conducting the experiment, the engine lubricant oil level and water level were checked to ensure they were sufficient. The water cooling tower and cooling fan were switched on. Then, the control panel of dynamometer was turned on. All the wires were connected to the battery and the engine was turned on.

The experiment was carried out with engine speeds ranging from 1000 rpm to 4500 rpm with an interval of 500 rpm. The engine load was set from 10 Nm to the steady state maximum torque of each engine speed. For 1000 to 2000 rpm, the experiment was conducted with an interval of 5 Nm engine load. While for the range between 2500 and 4500 rpm, the experiment was conducted with an interval of 10 Nm. This was due to the difficulties in controlling the throttle pedal for a specific setting of the engine speeds and loads. Taking longer time to adjust the settings caused the engine to overheat, especially at high speeds.

The constant volume of fuel decrement for engine speeds within the range from 1000 to 2000 rpm, was set at 20 ml. While for higher engine speeds, the constant volume was set at 40 ml. The constant volume of fuel for higher engine speeds was raised as the engine consumed fuel at a faster rate at higher engine speeds. The time required for constant volume of fuel consumption was measured by a digital stopwatch. Each experiment was repeated twice to obtain the average time taken for fuel consumption.

Throughout the experiment, the temperature of the engine was checked frequently to avoid overheating of the engine. The engine was cooled by turning it off when the temperature rose to temperatures higher than the normal working range.

Figure 3: Throttle cable extension

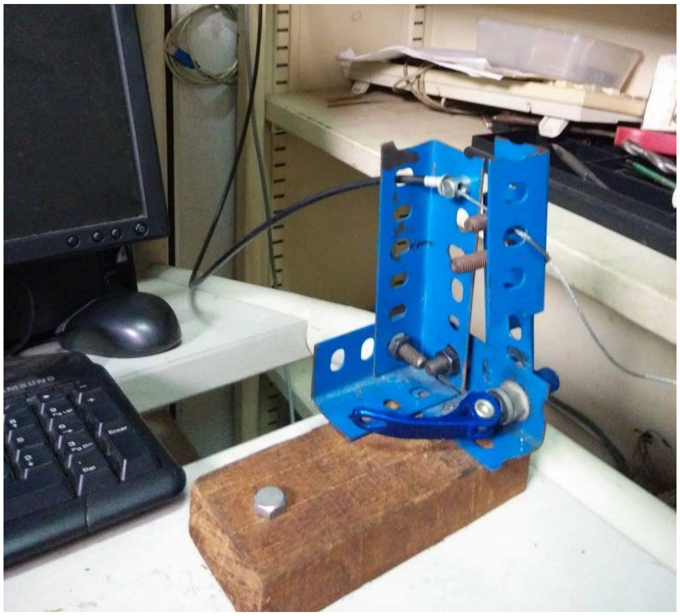

Figure 4: Throttle pedal relocated to the control room

2.4. EXPERIMENT PARAMETERS

The fuel consumption rate that was measured in millilitre per second was converted into gram per second by multiplying the parameter with the fuel density.

For fuel consumption rate, F_f

$$F_f = V/T \qquad (1)$$

where V is volume of the fuel(ml), and T is time required for that volume of fuel to be consumed by engine(s).

For fuel mass flow rate, M_f

$$M_f = F_f \; X \; \rho \qquad (2)$$

where ρ is fuel density, 0.716 g/ml.

For Brake power, B.P

$$\mathrm{B.P} = 2\,\pi\,\mathrm{T}\,\mathrm{N}/60 \qquad (3)$$

where T is the real engine torque(Nm) and N is the real engine speed(rpm) from dynamometer. The unit of brake power is in W. Brake power is the usable power delivered by the engine to the load.

For brake specific fuel consumption, BSFC

$$\mathrm{BSFC} = M_f \;\mathrm{X}\; 3600/\,\mathrm{B.P} \qquad (4)$$

where M_f, is mass fuel consumption rate(g/s) and B.P is brake power in kW. The unit for BSFC is in g/kWhr. Brake specific fuel consumption is a measure of how efficiently a specific amount of fuel is converted into a given amount of power [4].

For brake thermal efficiency, BTE

$$\mathrm{BTE} = \mathrm{B.P}\,/(\,Q_{LHV}\; X\; M_f\,)\; X\; 100\,\% \qquad (5)$$

where B.P, is brake power(kW), Q_{LHV} is calorific value, 39782 kJ/kg and M_f is in kg/s. Brake thermal efficiency is used to evaluate the efficiency of an engine to convert heat energy from a fuel to mechanical energy [4]. The calorific value was given by Wan Dun Ye, he determined the heating value from a bomb calorimeter experiment.

2.5. EXPERIMENT RESULT INTERPOLATION AND COMPARISON

The data was interpolated by Leong Yong Sheng using MATLAB. The experimental results and interpolated results were used in producing the fuel consumption maps.

The current results were compared with previous results (gravimetric method) by using the correlation coefficient function in Matlab. The correlation coefficient (R) is a measure of the strength of the linear relationship between two variables. The values range between +1 and -1. +1 indicates a perfect positive linear relationship, one variable increases as the other variable increases. -1 indicates a negative linear relationship, one variable decreases as the other variable increases or vice versa. While 0 indicates no linear relationship [8] [9].

The use of correlation coefficient (R) in evaluating the simulation results and experimental results was studied [10] [11]. In both of the researches, the correlation coefficient represented the degree of how well the experimental data matched that of the simulated. The data used to make comparisons were under the same operating conditions.

3. RESULT AND DISCUSSION

From the experiment, different engine speeds had different steady state maximum torques. The maximum engine torque for 1000 rpm was 75 Nm. For 1500 and 2000 rpm, both had a maximum torque of 80 Nm. From 2500 to 3500 rpm, the maximum torque was 90 Nm. For 4000 and 4500 rpm, the maximum torque was 95 Nm and 100 Nm respectively.

For both gravimetric and volumetric experiments, the fuel consumption maps and brake power maps show a similar trend. Figure 5 and 6 show the fuel consumption maps using the volumetric method, while Figure 7 and 8 show the fuel consumption maps using the gravimetric method. Figure 9 and 10 show the brake power maps using the volumetric method, while Figure 11 and 12 display the brake power maps using the gravimetric method. From these figures, a close relationship between fuel consumption rate and brake power was revealed. Fuel consumption rate increases as the engine load and engine speed were increased. The engine consumed fuel faster at high engine loads and high engine speeds. The higher the engine load and speed, the higher the brake power as brake power has a directly proportional relationship with the engine load and speed.

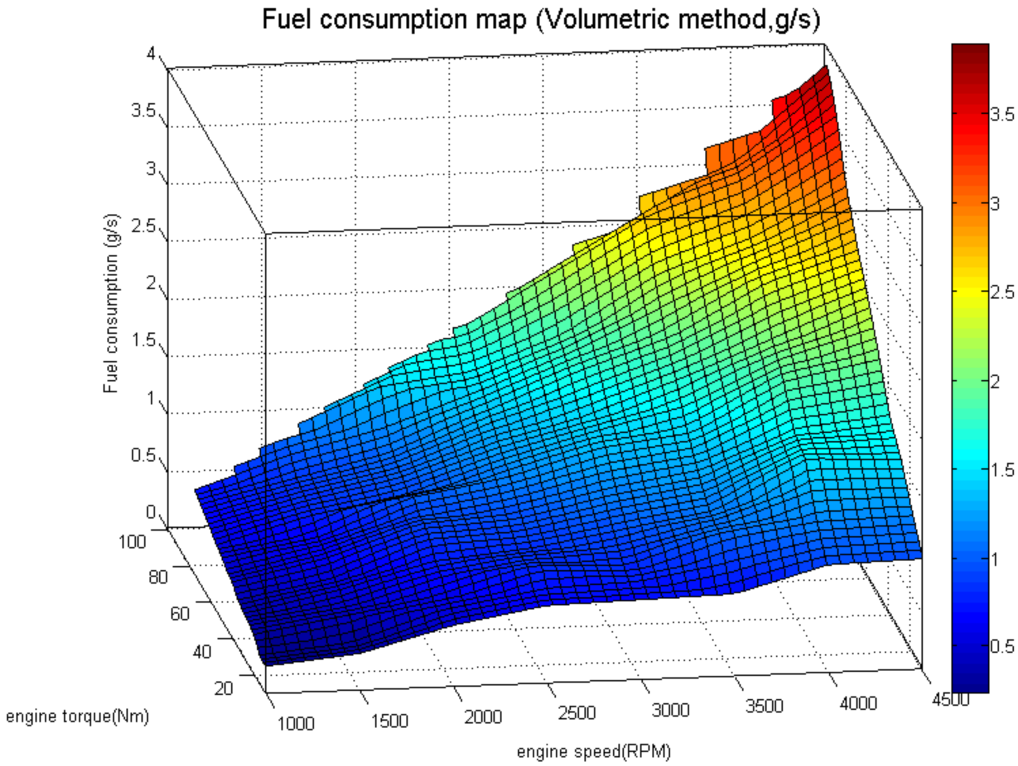

Figure 5: 3D Fuel consumption engine map by volumetric method

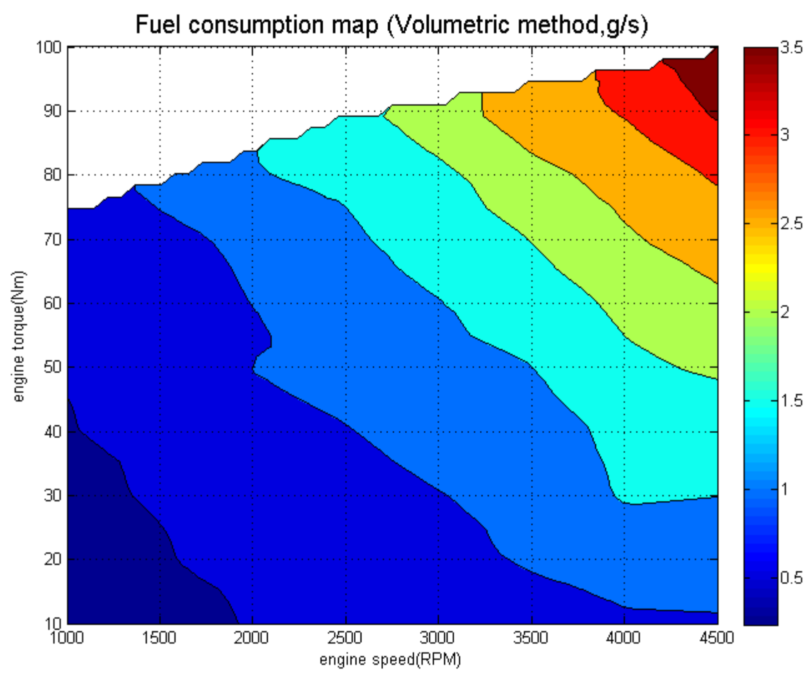

Figure 6: Fuel consumption engine map by volumetric method

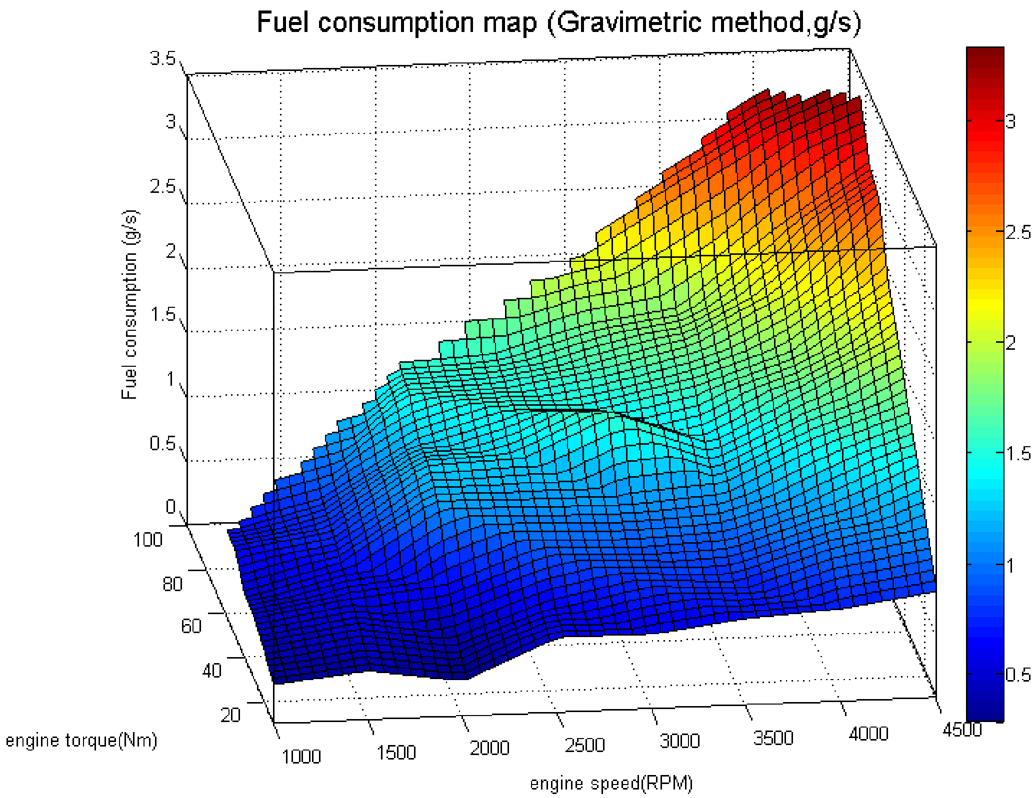

Figure 7: 3D Fuel consumption engine map by gravimetric method

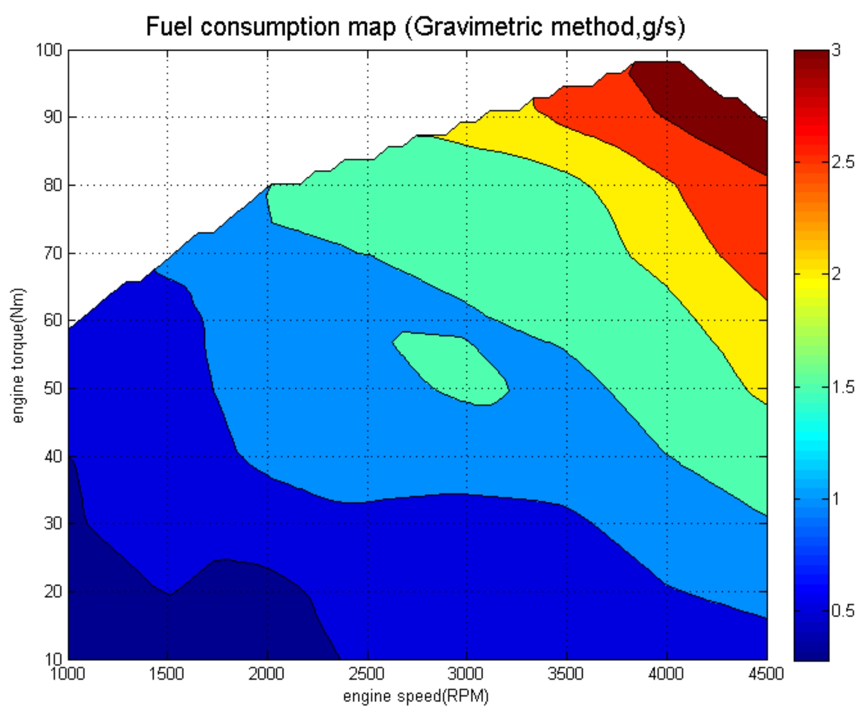

Figure 8: 3D Fuel consumption engine map by gravimetric method

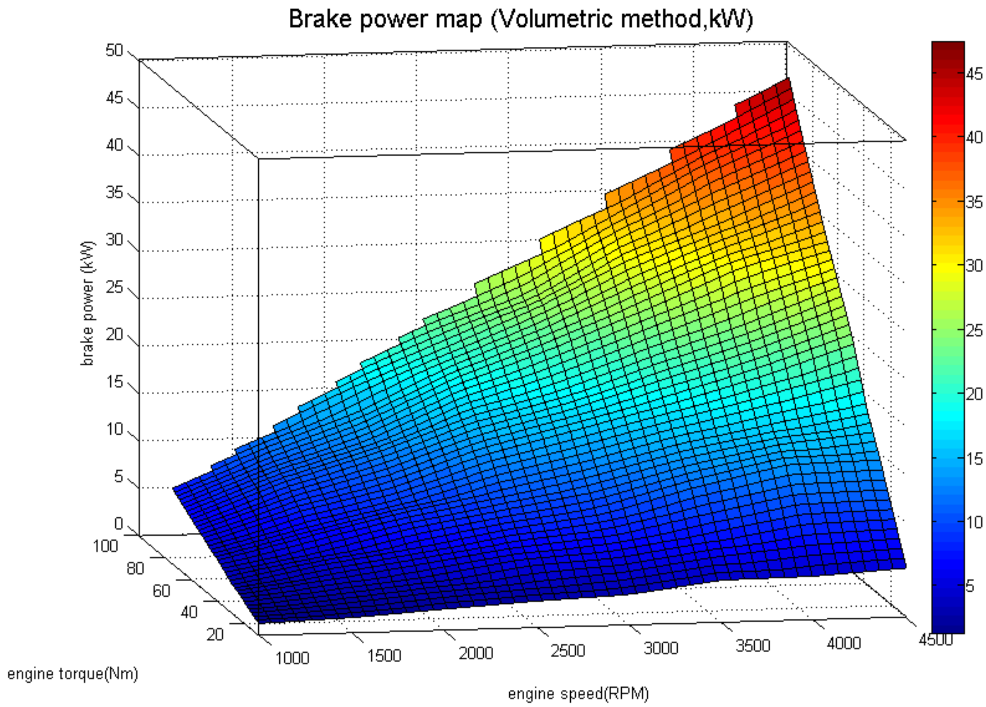

Figure 9: 3D Brake Power engine map by volumetric method

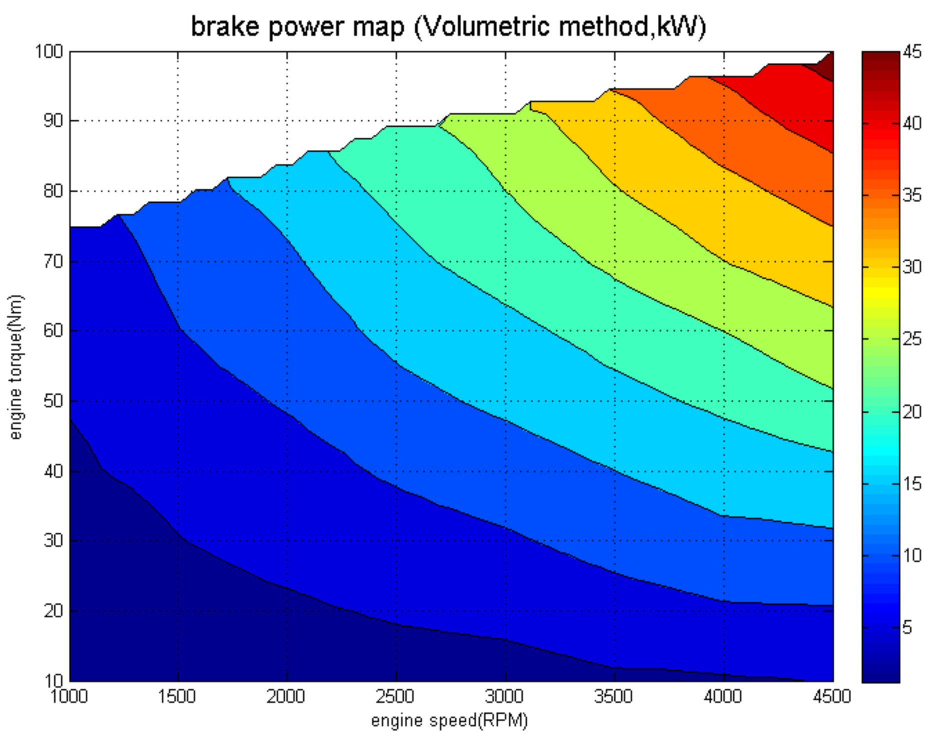

Figure 10: Brake power engine map by volumetric method

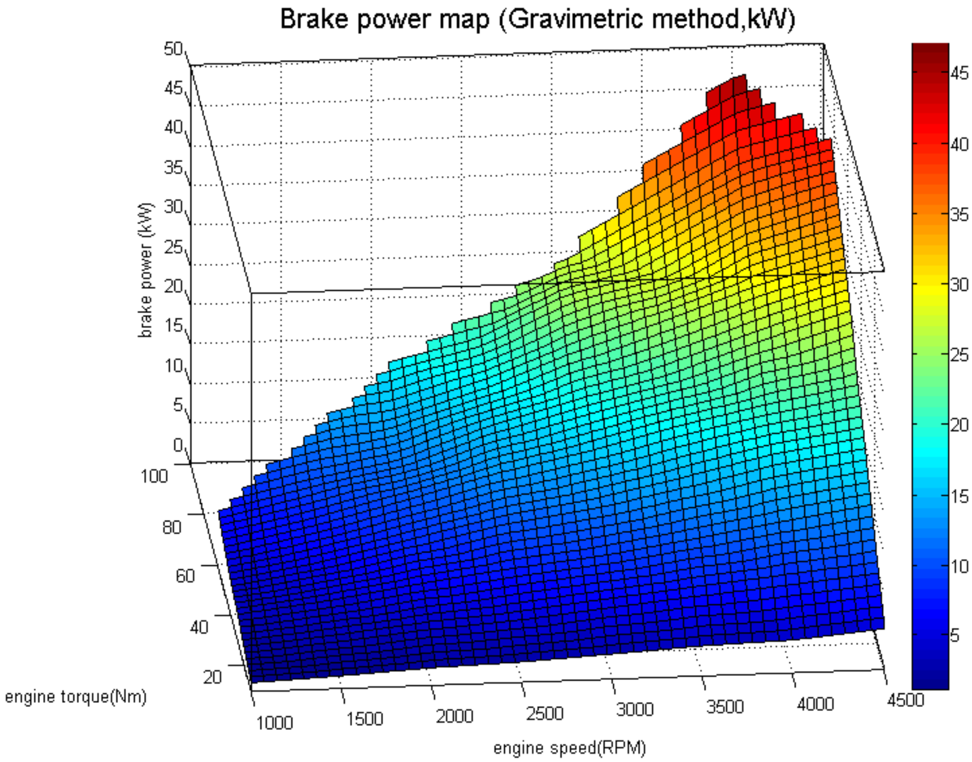

Figure 11: 3D Brake power engine map by gravimetric method

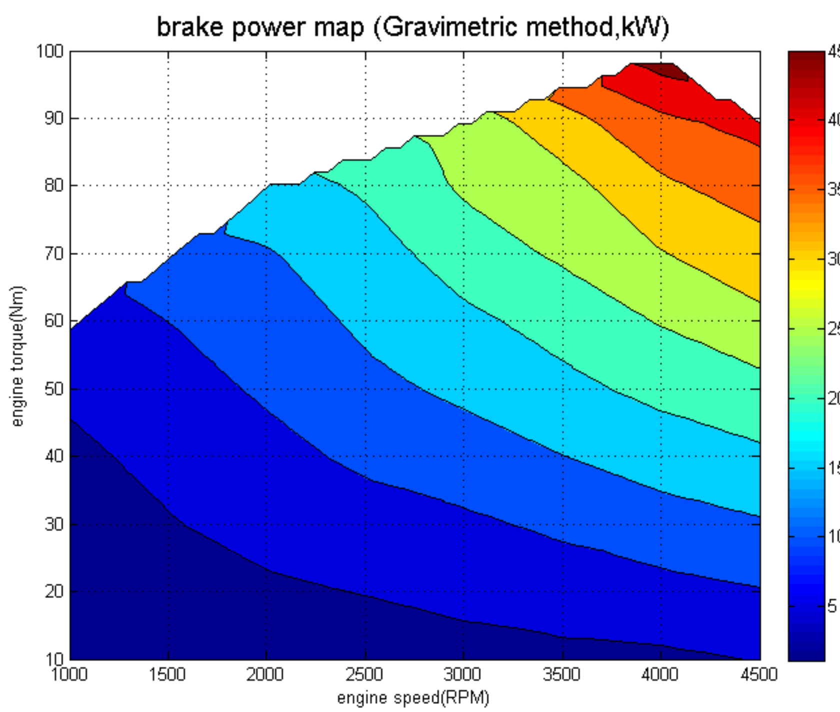

Figure 12: Brake power engine map by gravimetric method