ENGINE PERFORMANCE COMPARISON BETWEEN VARIOUS RON97 GASOLINE BRANDS AVAILABLE IN MALAYSIAN MARKET

A.F.M. Riduan[1], N. Tamaldin[1], A.K.M. Yamin[1] and A. Sudrajat[2]

[1]Faculty of Mechanical Engineering,
Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia.

[2]Faculty of Science and Technology, Universitas Nasional Jakarta,
JL. Sawo Manila, Kota Jakarta Selatan,
12520, Indonesia.

Corresponding Author's Email: [1]aifamori1001@gmail.com

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ABSTRACT: Disparities towards engine performance by various gasolines from different fuel producers have constantly been a discussion among road users and available information regarding it are still not conclusive. Thus, this paper centres upon examining several Research Octane Number (RON) 97 fuel products sold in Malaysia and determining the key variation among them towards engine outputs. Specific energy was firstly collected using an oxygen bomb calorimeter since it was identified as a main petrol component that could affect overall engine performance. In terms of engine outputs, power break specific fuel consumption (BSFC), and engine efficiency were gathered by experimenting RON97 gasolines with a test engine connected to an engine dynamometer. Outcomes had depicted engine performance from utilizing various petrol products to be dissimilar even though all fuels were evaluated in similar octane rating. It was also found that gasoline specific energy values played a major role towards improving overall engine performance output especially in terms of BSFC (up to 18.47% difference) and engine efficiency (up to 11.67% difference). Therefore, despite fuel calorific value only differs among one and another by a margin lesser than 1%, it had shown towards reducing petrol consumption with up to more than ten times the impact.

KEYWORDS: *Research Octane Number; Fuel Properties; Engine Power; Fuel Consumption; Engine Efficiency*

1.0 INTRODUCTION

Every petrol brand in Malaysia sells at least two different fuel RONs where each provides RON95 and RON97 as base options. Furthermore, all gasoline prices are regulated by a float system which was enforced on 1st December 2014 to remove fuel subsidies. Due to this, most road users query whether each petrol product sold are different or not when pumped in their cars, despite the gasolines priced similarly and possessed equal RON. It is usually believed that a higher RON would produce better engine performance outputs. This notion caused a lot of road users to pump in their vehicles gasoline with higher octane [6]. Therefore, this study aims to analyse various RON97 gasoline brands sold in Malaysia and examines the variation between each fuel tested.

Gasoline comprises a large number of hydrocarbons and are formed from crude oil found in buried fossilized organisms that had undergone natural processes for more than hundreds of millions years in the Earth's crust [3]. Furthermore, there is no specific point of reference that can be used to wholly portray petrol purity and quality since the chemical mixture differs based on each fuel refinery [1]. Due to this, details regarding exact mixtures used in commercial fuels, especially about utilized additives are undisclosed due to company confidentiality. However, an attribute which can be examined through standardized laboratory procedure is the gasoline heating value. A material specific energy or calorific value is express as energy per unit mass (MJ/kg). Fuel specific energy represents usable heat quantity released during full combustion and it varies around 40.1 till 41.9 MJ/kg for gasolines [4]. Higher RON gasoline which is considered premium fuel by most road users, would generally have greater calorific value. This was previously exemplified in [5] where commercial gasoline samples with higher RON were associated to larger specific energies. Since fuel calorific value can also be defined as a property which could influence engine combustion process, it is broadly recognized that higher RON gasolines would significantly increase overall engine performance [7].

With regards to this study, there were several previous studies which conducted near similar testing methods. One of which was a study on part-load performance and emission of a SI engine utilized with RON95 and RON97 fuels [7]. It was done because of the ongoing petrol price fluctuations between both RONs and finding out whether employing RON97 would benefit road users in the long run. Similar studies that can be found was examining effects of RON by testing RON91 and RON95 Saudi Arabian gasolines with direct injection and port injection systems [8]; as well as analysing effects of varying spark timing on SI engine performance and emission characteristics [9]. One study which experimented between two different octanes (RON90 & RON95) [10] found that utilizing gasoline with higher than intended engine recommended RON would lower engine performance outcomes but decreased carbon monoxide and nitrogen oxide outputs. The investigation also established that using a higher RON would cause greater noise. Moreover, in [11] tested five RONs (91, 93, 95, 97 and 98) to find varying spark timing effects at different octane numbers on engine performance and emission outcomes. For this paper, selected gasolines from various petrol brands with equal RON were analysed to ascertain whether all samples are similar or not without tempering other manipulated variables such as using other octane, fuel blending, or engine tuning.

2.0 METHODOLOGY

Three RON97 petrol products such as Brand A (A97), Brand B (B97), and Brand C (C97) were tested for this experiment. All fuel sample specific energies were firstly examined using an oxygen bomb calorimeter (Figure 1). An ASTM standard [15] was used for this procedure because it focuses on finding liquid hydrocarbon fuels specific energy using a bomb calorimeter with the precision method. Calculation to determine precise sample mass needed for the experiment were such as

$$V = (W \times 0.0032)/(Q \times D) \tag{1}$$

where

V = Fuel sample volume to be tested, cm^3.
W = Calorimeter energy equivalent, J/K.
Q = Fuel sample heat of combustion approximation, MJ/kg.
D = Fuel sample density, g/cm^3.

Formula of density was employed and substituted in Equation (1) to eliminate calculating V and focused on evaluating sample mass.

$$D = m/V \tag{2}$$

$$V = 0.0032W/(m \times Q/V) \tag{3}$$

Therefore, by removing V from overall formula and rearranging Equation (3), sample mass was given by

$$m = 0.0032W/Q \tag{4}$$

From Equation (4), it was established that each gasoline mass should reach at least 0.7229g ± 0.01g regardless of its density value in every specific energy tests. After that was done, decomposition vessel of which housed the weighted sample was pressurized with pure oxygen gas till 30 bar or 435 psi. Distilled water with a temperature range of 22°C ± 3°C was then filled in calorimeter. Calorimeter was set to automated isoperibol operation to begin fuel specific energy testing.

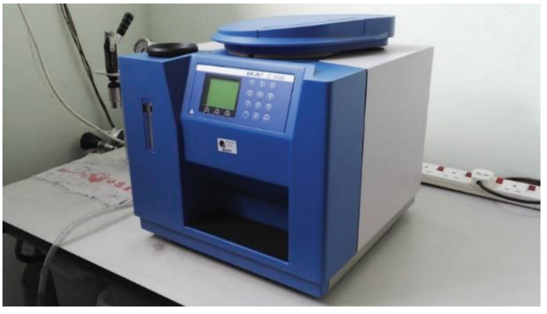

Figure 1: IKA C 200 oxygen bomb calorimeter

Petrol performance output data were gathered using Land & Sea's DYNO-mite Engine Dynamometer. Collected outcomes from each test run were power, BSFC and engine efficiency. Before experiment began, certain precautionary steps were carried out. Each petrol brand must at least run for 15 minutes to ensure engine only circulates tested fuel and prevent unwanted data errors. Engine temperature should at least reach 70°C before test run was initiated, and must not go over 100°C during experimentation to make sure optimal engine working temperature. Absorber temperature at the same time must not be more than 60°C to prevent overheating occurrences. Five trials of engine speed from 2000 RPM till 6000 RPM with 100 RPM increment every second at wide open throttle were recorded using automated sweep test procedure. Engine performance data were stored by the engine dynamometer data acquisition (DAQ) electronics.

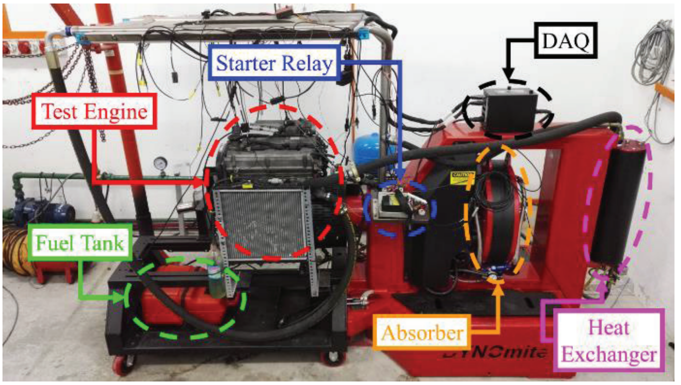

Figure 2: Engine dynamometer test setup

3.0 RESULTS AND DISCUSSION

3.1 Specific Energy (MJ/kg)

Average specific energy was found lowest from A97 with 39.960 MJ/kg, while the highest came through C97 with a value of 40.355 MJ/kg. Calorific value variations between one brand to another were estimated to increase not more than +0.307 MJ/kg and decrease at most by -0.088 MJ/kg when referenced with median 40.048 MJ/kg. Thus, making percentage increment and decrement as a total result be at merely +0.77% and -0.22%, respectively. This shows that when all petrol products were pitted against one and another in equal octane rating, differences in specific energy values and percentages were noticeably marginal. This can also be expressed as gasoline manufacturers following the strict guidelines in maintaining petrol quality so that it can be achieved the appropriate premium fuel standard for consumers. Table 1 summarizes the tested RON97 particularly to the energy results.

Table 1: RON97 fuel brands specific to the energy results

Brand	Average Specific Energy (MJ/kg)	Difference (MJ/kg)	Percentage Difference (%)
A97	39.960	-0.088	-0.22%
B97	40.048 (median)	0.0	0.0
C97	40.355	+0.307	+0.77%

3.2 Power (hp)

As seen in Figure 3, power outcomes depicted a linear increase in the 1st half range with slight deviations among RON97 fuels at 2600 – 3500 RPM. As engine testing went towards 2nd half range, two peaks of power outcomes and one downward curve at 5000 RPM were demonstrated before the power results started to decline from 5400 RPM till end of engine testing.

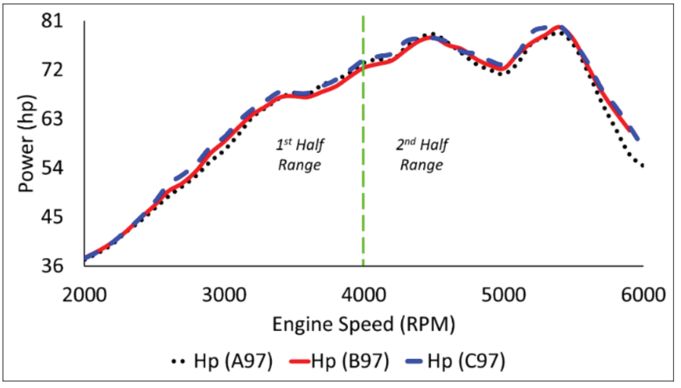

Figure 3: Power vs. engine speed

Max engine power was recorded highest and lowest from brand C97 with 80.11 hp and A97 by 78.82 hp, respectively. Variation in max power between RON97 petrol products were not that clearly distinct, where increased and decreased were only by +0.23 hp (+0.29%) and -1.06 hp (-1.33%) when compared to median. Table 2 summarizes the engine power outcomes when using the RON97 fuels.

Table 2: Max engine power results

Brand	Max Power (hp)	Difference (hp)	Percentage Difference (%)
A97	78.82	-1.06	-1.33
B97	79.88 (median)	0.0	0.0
C97	80.11	+0.23	+0.29

Since heat is converted to energy throughout combustion process to generate useable power, it is then implied that fuel specific energy relates directly towards engine performance. This statement is true where as shown in Figure 3, the graph illustrated the petrol calorific value directly correlated towards the engine power. Comparing among tested gasolines have determined that with a greater specific energy, performance figures inclined almost identical in terms of percentage increased.

This finding is also agreed by in [12, 16] where both studies concluded that increment of the specific energy value would improve the overall engine performance outcomes.

3.3 BSFC (kg/hp.h)

In the first half range of Figure 4, BSFC results were relatively stable with noticeable variations among RON97 gasoline. Afterwards, fuel usage from each tested samples rose exponentially from 4000 – 6000 RPM. All RON97 fuels generated max BSFC at 6000 RPM, where highest was received by A97 with 0.744 kg/hp.h and the lowest at 0.623 kg/hp.h through C97.

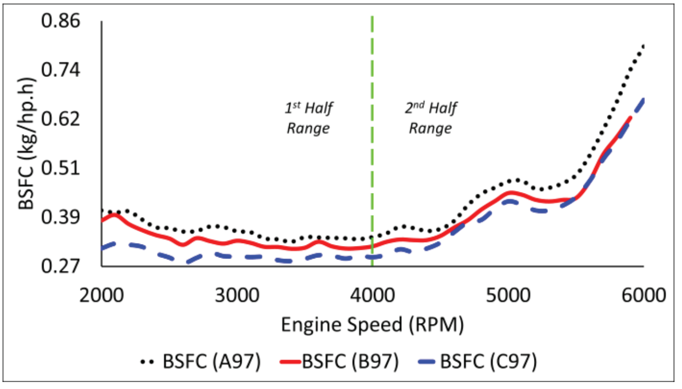

Figure 4: BSFC vs. engine speed

After max BSFC results were linked to median, it was computed that the changes in value among brands differed at most +0.116 kg/hp.h (+18.47%) and -0.005 kg/hp.h (-0.80%). Table 3 summarizes the max BSFC outputs when using the RON97 gasoline.

Table 3: Max BSFC results

Brand	Max BSFC (kg/hp.h)	Difference (kg/hp.h)	Percentage Difference (%)
A97	0.744	+0.116	+18.47
B97	0.628 (median)	0.0	0.0
C97	0.623	-0.005	-0.80

BSFC is a measurement of petrol consumed over a period of time with respective to engine power produced. By this definition, gasolines that produced high engine power would then lower BSFC output. Since fuel specific energy was shown to be linearly connected with engine power, the petrol attribute was used again as a correlation towards BSFC. By referring to Table 3, it can be seen that BSFC outcomes from each tested

RON97 gasolines were inversed compared to the fuel calorific value results (Table 1). Even though the differences in fuel specific energy were just between -0.22% and +0.77% compared to median output, it had significantly affected overall BSFC results with +18.47% increment and -0.80% decrement, respectively. Furthermore, the studies from [13, 17] also found that a greater gasoline calorific value would help in decreasing the BSFC overall outcome. Thus, high possibility of the petrol specific energy causing an effect to the BSFC final output.

3.4 Engine Efficiency (%)

By observing Figure 5, engine efficiency outputs were shown to be fluctuated at first and then experienced value decrement with greater engine speed. Even though engine testing at 1st half range seemed unstable when examined, it can be noted that results gathered at first glance were noticeably different between the RON97 gasoline. After dyno-experimentation passed 4000 RPM, engine efficiency outputs declined almost linearly till end of dyno-testing through each RON97 samples.

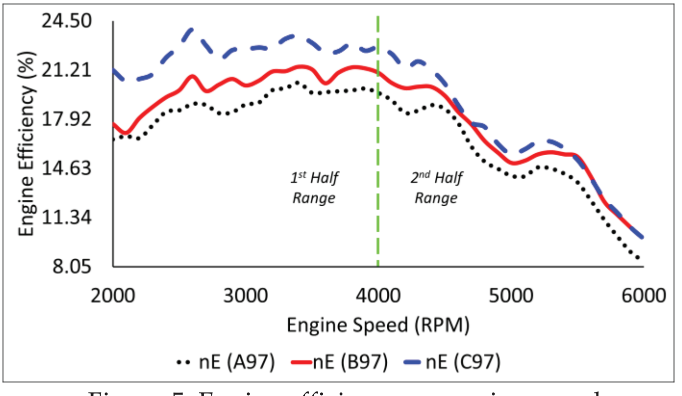

Figure 5: Engine efficiency vs. engine speed

Max engine efficiency was attained highest by C97 with 23.946% at 2600 RPM while A97 only able to achieve 20.370% at 3400 RPM which was considered worst performing among the three gasolines. Comparing those values towards result median, positive and negative variances of max engine efficiency between RON97 gasolines were established to not exceed +2.503% (pure % increased: +11.67%) or be more than -1.073% (pure % decreased: -5.00%). Table 4 summarizes the max engine efficiency results when using the RON97 gasoline.

Table 4: Max engine efficiency results

Brand	Max Engine Efficiency (%)	Difference (%)	Percentage Difference (%)
A97	20.370	-1.073	-5.00
B97	21.443 (median)	0.0	0.0
C97	23.946	+2.503	+11.67

Engine efficiency is regarded as how much effective power a vehicle motor would develop with available supplied energy. In mathematical terms, it is an inverse multiplication product between fuel specific energy and BSFC. Unlike before the gasoline specific energy was explicitly desired higher for tested petrol to perform better, a lower calorific value would much preferably suit better in this particular correlative investigation if studied upon just mathematically. While this might appear counterproductive since initially a high specific energy was stated can help reduced BSFC outcome, engine efficiency in contrast demands amount of input resources be utilized sufficiently and effectively. However, it cannot be determined whether gasoline calorific value or BSFC would play a major role when evaluating the engine efficiency.

By comparing Figures 4 and 5, it was depicted that engine efficiency results from all tested fuels were inverse against BSFC outputs. This meant a high BSFC as result of smaller gasoline specific energy value had altogether caused lower engine efficiency outcomes and vice versa. Hence, this would suggest that BSFC in some form or another was the bigger influencer in producing overall engine efficiency outcome. This result was parallel with [14, 18] where both disclosed higher engine efficiency outputs when engine tested at same instanced produced lower BSFC results. It needs to be pointed out that cited high engine efficiency outcomes were as a consequence of greater gasoline calorific values as well. However, it was not revealed on how high fuel specific energy should peak for achieving maximum engine efficiency before hitting over the threshold that could induced loss in engine efficiency. All in all, it can be safely established that engine efficiency results were mostly influenced from overall BSFC outcomes because it predetermined on how much the fuel used during the combustion process proportional to the total of the generated power output. At the same time, petrol calorific value showed the likewise demonstrated signs being a contributing component for overall engine efficiency output albeit very marginally. The clarification of what exact specific energy value should a gasoline possessed so maximum engine efficiency would be attained was not fully realized due to the small percentage differences among the tested fuel samples.

4.0 CONCLUSION

It can be concluded from gathered results that gasolines with similar RON but from different brands does cause engine performance to be varied especially in terms of BSFC and engine efficiency. Even though fuel calorific values among tested samples differed by a margin lesser than 1%, the consequences it could give towards petrol savings can be at times more than ten-fold. Aside from BSFC and engine efficiency, this research had also shown that debating which brand is better when comparing about engine power only is pretty much insignificant since the differences between gasolines of equal octane number had merely given out percentage difference smaller than 1.4%. Thus, road users should not solely focus on one particular gasoline brand as all petrol performs roughly the same, if just considering wanting to have more power from their engine. Apart from that, the prospect of finding each respective fuel formulation differences could give a clearer insight on how it would affect overall petrol consumption. Therefore, further study from here on would be about examining gasoline chemical substances such as additives used by fuel manufacturers, to see correlations it can have towards BSFC and engine efficiency under similar engine testing procedures.

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