Contribution of Vehicle System and Accessories on Fuel Consumption of Perodua Viva

by

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CERTIFICATION OF APPROVAL

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December 2010

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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MOHD AKHIMULLAH BIN MOHD ROSDI

Abstract

'Contribution of Vehicle System and Accessories on Fuel Consumption of Perodua Viva' is a final year study regarding factors affecting fuel consumption of Perodua Viva. Several factors mentioned in this project are air-conditioning system, electronic devices, vehicle weight and the usage of Low Rolling Resistance Tire (LRR). The factors above contribute certain level of percentage of fuel consumption of the car. To clarify the percentage contribution of the factors, experimental based on real car, Perodua Viva had been done for every factor. Distance covered by the car using one liter of fuel was measured and analyzed to calculate the percentage of fuel consumption. From the experiment's result, a map of parameter has been developed to show the level of significance in term of fuel consumption for each factor. At the end of the project, map of parameter had classified three main factors that contribute significantly to fuel consumption, which are air-conditioning system usage, vehicle weight and the usage of Low Rolling Resistance Tire (LRR). While for electronic devices factor, the result is not too significant as the Perodua Viva car does not have any high technology equipment built in the car.

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Chapter 1

Introduction

1.1 Project Background

Efficient fuel consumption can be defined as the optimization of fuel usage in running an engine. In the author's research case, the car which travel the longest distance with 1 Liter of fuel are assume having good fuel consumption. The author will look into several factors that contribute to fuel consumption of a 3 inline cylinders car engine of 'Perodua Viva'. 'Perodua Viva' is a compact car produced by a Malaysian car manufacturer, Perusahaan Otomobil Kedua (Perodua) which is having 1000 cubic capacity (cc). Even though the car is already known as a car with efficient fuel consumption, the author will try to make it even better through the study of contribution of air-conditioning system, electronic devices, vehicle weight and usage of Low Rolling Resistance (LRR) tires to the fuel consumption of the car. Those mentioned factors are closely related with fuel consumption of car and the author will study and doing some experimental based research in order to enhance the fuel consumption. At the end of the study, a Map of Parameters will be develop as a reference in choosing which factors are feasible in contributing to fuel optimization.

1.2 Problem Statement

Perodua Viva is known as fuel-saving car among Malaysian. However, there are still few modifications can be done into that car model. In order to make a good modification to improve car fuel consumption, the manufacturer must have sufficient data and information regarding the system or part to be modified.

The study of 'Contribution of Vehicle System and Accessories on Fuel Consumption of Perodua Viva' can help to improve process of data gathering and analyzing in optimizing the car fuel consumption.

Fuel consumption of a Perodua Viva is contributed by several factors related to the engine performance and accessories of the car itself. The factors studied in this project are contributions of air-conditioning system, electronic devices, vehicle weight and the usage of Low Rolling Resistance (LRR) tires to fuel consumption of Perodua Viva.

All of the factors contribute at certain level of percentage in the car fuel consumption and at the end of this study, a Map of Parameter will be develop as a benchmark or reference in term of contribution of the factors above. This Map of Parameter will help the car manufacturer to decide which factor to be combine or to be eliminate in improving fuel consumption of the Perodua Viva model

1.3 Objectives

- To study the relationship of air conditioning system, electronic devices, the vehicle weight, and also the usage of Low Rolling Resistance tires (LRR) with fuel consumption of Perodua Viva

- To develop Map of Parameter based on factors contribute to fuel consumption of Perodua Viva

1.4 Scope of Study

The project is related to feasibility study of factors affecting fuel consumption of a car. Those related factors are air-conditioning system, electronic devices, vehicle weight and also the usage of Low Rolling Resistance (LRR) tires

This project is conducted through real model experiment and mathematical analysis.

For the outcome, a Map of Parameters is expected to been develop based on the factors affecting fuel consumption and percentage or degree of contribution. This Map of Parameter will be use as a selection medium or reference for automotive industry in enhancing the car for next production.

Chapter 2

Literature review / theory

2.1 Energy Conversion Chain

Electrical power for an engine can be obtain from fuel being consumed within the engine to feed an energy conversion chain. This chain starts with chemical energy stored in the fuel and ends with electrical energy from the alternator. In energy conversion process, not all energy will be converted into power with 100% efficiency including the process at alternator. These losses result in more fuel being consumed to produce a given amount of electrical power. Clearly, as the alternator becomes more efficient in the process of converting mechanical power into electrical power, less fuel is consumed. And even though the power demands of the alternator are generally small in comparison to the overall vehicle, the impact on fuel cost is not trivial. Furthermore, the unstable price of oil which can spikes very high may initiates the effort to look into the power losses and engine efficiency [1].

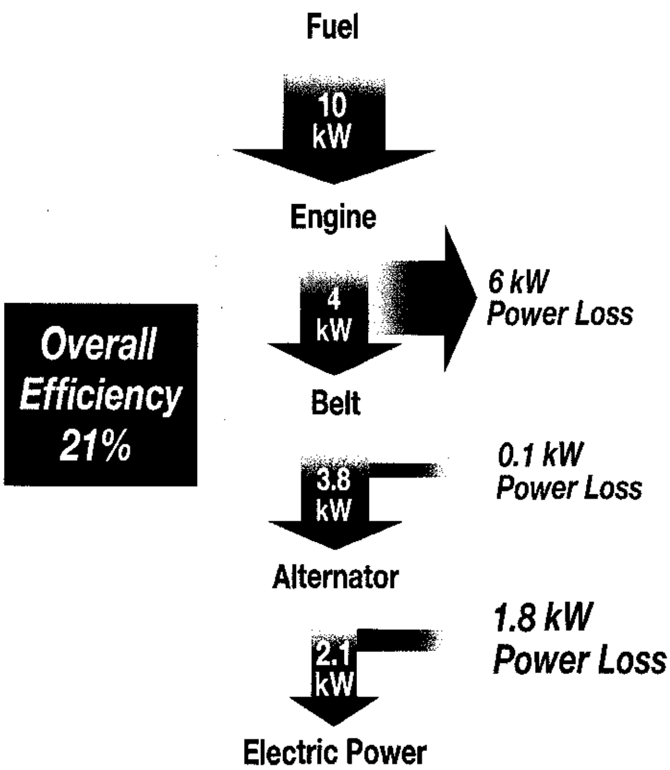

Figure 1

2.2 Relationship of Electrical System with Fuel Consumption

Electrical system such headlights, battery charging, active suspension, circulating fans, media systems, speakers, and other electronics can also significantly increase fuel consumption, as the energy to power these devices causes high load on the alternator. Since alternators are commonly only 40-60% efficient, the added load from electronics on the engine can be as high as 3 horsepower (2.2 kW) at any speed including idle. Headlights, for example, consume 110 watts on low and up to 240 watts on high. Fuel-efficiency decreases from electrical loads are most pronounced at lower speeds because most electrical loads are constant while engine load increases with speed. So at a lower speed a higher proportion of engine horsepower is used by electrical loads [2].

In addition, new vehicle today using high technology of entertainment system such GPS (Global Positioning System), interactive game medium such PlayStation (SONY), mini theater and even some of the vehicle are equipped with computer for the leisure of user. All of these devices not only using high electric consumption but it also consumes space in the vehicle especially the wiring system and the added wiring increased vehicle weight, weakened performance, and made adherence to reliability standards difficult. For an average well-tuned vehicle, every extra 50 kilograms of wiring or extra 100 watts of power will increase the fuel consumption approximately by 0.2 liters for each 100 kilometers traveled [2].

2.3 Relationship of air conditioning system with fuel consumption

The air conditioning system is the single largest auxiliary load on a vehicle by nearly an order of magnitude. Current air conditioning systems reduce the fuel economy of conventional vehicles, thus incremental improvements can have a significant near-term benefit because of the large number of new cars sold each year. For high fuel economy vehicles, current air conditioning systems have a completely unacceptable impact on fuel economy.

Conventional air conditioning systems of vehicle are powered by the fuel combustion in the engine or the car. This process claims substantial load on the engine especially during acceleration. The conventional air conditioning unit of motor reduces the available power of the engine, and this especially during critical period of time. Due to this, conventional air conditioning units are commonly installed in cars above certain engine volume. This system includes a compressor driven by the engine motor for compressing the refrigerant gas before the latter is condensed in the condenser. The power required for driving the compressor places a substantial power drain on the car engine, which reduces car performance and also increases fuel consumption. In addition, only relatively large car have sufficient spare power to drive the compressor [3].

2.4 Relationship of vehicle weight with fuel consumption

Another way to reduce your fuel consumption is by removing excessive weight from your vehicle because as the car is heavy, the more energy is required to make it move the same distance in the same amount of time. This additional energy is spent in the form of additional gas consumption. As a result, by decreasing the weight of vehicle the driver have less mass to move around the same distance. This requires less energy and will save gas. Reducing vehicle weight is a popular modification commonly performed on cars at the drag strip in order to make them accelerate faster for the same amount of horsepower. However, most people don't realize that if they drive at the same speed with the same acceleration they normally use but with reduced weight, it will raise their fuel economy. It has been noted that saving anywhere from 30 to 50 pounds of weight from your vehicle can net you a 1% savings in gas mileage. A good example of this is switching to a lightweight fiberglass aftermarket hood to replace the stock steel hood [6].

Reducing vehicle weight (mass) results in less tractive effort required to accelerate the vehicle and less rolling resistance from the tires. Drive cycles with more acceleration events (EPA city and European) show greater fuel economy benefits from weight reduction than highway or steady state conditions. Also, at higher vehicle speeds the engine is typically at higher throttle operating points and provides less opportunity for improvement. Since the tire losses are a greater percentage of total tractive effort at lower speeds (aerodynamic losses increase by velocity squared) the potential for fuel economy gain from weight reduction is greater at lower vehicle speeds [7].
Several ways to save vehicle weight and reduce fuel consumption include the following:

- Switch from steel rims to lightweight aluminum rims.
- Remove all excess baggage and weight from trunk
- Replace body panels with fiberglass components

2.5 Relationship of Low-rolling resistance tires with fuel consumption

Rolling resistance is usually can be assume as friction through rolling motion of tire. It is caused by term known as hysteresis, a characteristic for deformable material such that the energy of deformation is greater than the energy of recovery. The rubber compound in a tire exhibits hysteresis. As the tire rotates under the weight of the vehicle, it experiences repeated cycles of deformation and recovery, and it dissipates the hysteresis energy loss as heat. Hysteresis is the main cause of energy loss associated with rolling resistance and is attributed to the viscoelastic characteristics of the rubber [8].

Rolling resistance coefficient (RRC) is the value of the rolling resistance force divided by the wheel load. The Society of Automotive Engineers (SAE) has developed test practices to measure the RRC of tires. These tests (SAE J1269 and SAE J2452) are usually performed on new tires [8]. When measured by using these standard test practices, most new passenger tires have reported RRCs ranging from 0.007 to 0.014.

To encounter the rolling resistance of tires, Low Rolling Resistance tires have been design by tire's manufacturer. This type of tires consists of typically incorporate silica in place of carbon black in their tread compounds to reduce low-frequency hysteresis without compromising traction. Low-rolling resistance tires are tires which are designed to minimize the energy wasted as heat as the tire rolls down the road. This improves the fuel efficiency of a vehicle or reduces the effort required in the case of human-powered ones. Approximately 5–15% of the fuel consumed by a typical car may be used to overcome rolling resistance. A 2003 California Energy Commission (CEC) preliminary study estimated that adoption of low-rolling resistance tires could save 1.5–4.5% of all gasoline consumption, but that current data were also insufficient to compare safety and other characteristics [9].

Chapter 3

Methodology / project work

3.1 Project activities

The author's research project is an experimental based project where all studies related to fuel consumption will be conduct on real car model and mathematical simulation for analysis. The model of the car is Perodua Viva. The car will be drive by using 1 liter of fuel and the distance travel by the car will be measured.

3.2 Project variables and conditions

Stock car

For this variable, no modification is done on the car. This test is very important to create a benchmark of distance travel for the further testing. Perodua claims that Perodua Viva's fuel consumption is approximately 14 km/liter, the author cannot use the result as mentioned by Perodua because of testing parameters and conditions might be different.

Car without the air-conditioning system

Air-conditioning system is not turn on to study the fuel consumption of Perodua Viva without the system. As the system is unused, the compressor and condenser for air-conditioning is not working and no load is apply to engine from this system

Car without electrical devices

For this element, all electrical devices such as headlight, audio system are turned off to make sure no load is created from these elements onto the engine's alternator.

Car with weight reduction

For weight reduction, the author had removed some parts from vehicle such as

1. Passenger car seat
2. Car doors replacement with fiber glass material
3. Window replacement with lightweight plastic (Perspex)
4. Rim replacement
5. Fuel tank replacement
6. Styling / Spoiler

The calculation of items removed is summarized as follows;

- Initial weight of car
  ≈ 800 kg

- Final weight of car
  ≈ 670 kg

- Weight reduction percentage, ((800-670)/800)*100 = 16.25 %

Top 3 removed items (according to weight):

Items	Approximate Weight (kg)	Picture
Air Conditioning System	18	

Front Left Seat	16	
Original Fuel Tank	9	

FIGURE 2

Other items

Group	Example item (s)	Approximate Weight (kg)
Electronic device	Head unit, Air Conditioning system controller	87
Door	Rear doors	
Window	Front windows, Rear windows, Back windows	
Hood	Front & rear hood	
Tires	Front tires, Rear tires, Spare tire	
Seat	Back seat	

Car with Low Rolling Resistance Tires (LRR)

Stock tires with rims were replaced with Low Rolling Resistance (LRR) tires, MICHELIN MX1 ENERGY made by Michelin Tire Manufacturer. These tires are more expensive from the original tires but the manufacturer claims these tires are more efficient and consume low fuel to move a vehicle.

Constant condition applied for the experiment

- Average speed = 40 – 50 km/h
- Driver weight = 50 kg
- Windows are closed to reduce the drag friction
- Test track/road
- Driving skills (Same driver for each test)
- Tires Pressure (220 Kpa)
- Fuel type (RON 95)

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3.3 Experiment Methodology

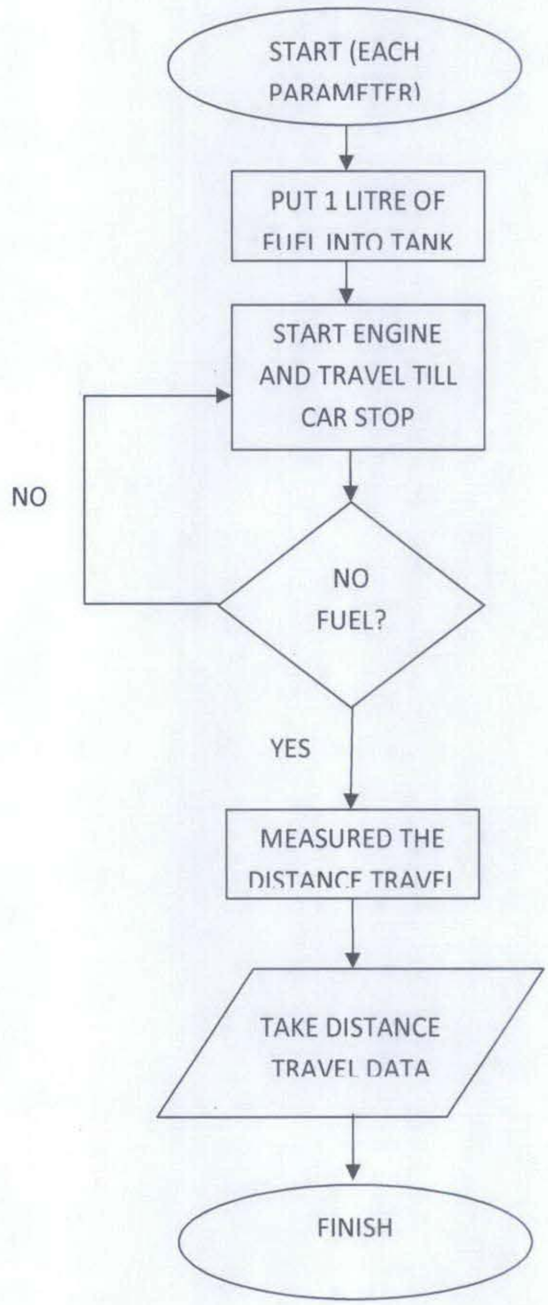

FIGURE 3

3.4 Perodua Viva car specification

Engine Total Displacement (cc)	989
No. of Cylinders	3
Valve Mechanism	Double Over Head Cam (DOHC) 12V
Max. output (kW/rpm)	45/6000
Max. torque (Nm/rpm)	90/3600
Fuel system	EFI
Fuel tank capacity	36.0

TABLE 1

3.5 Final Year Project Procedure

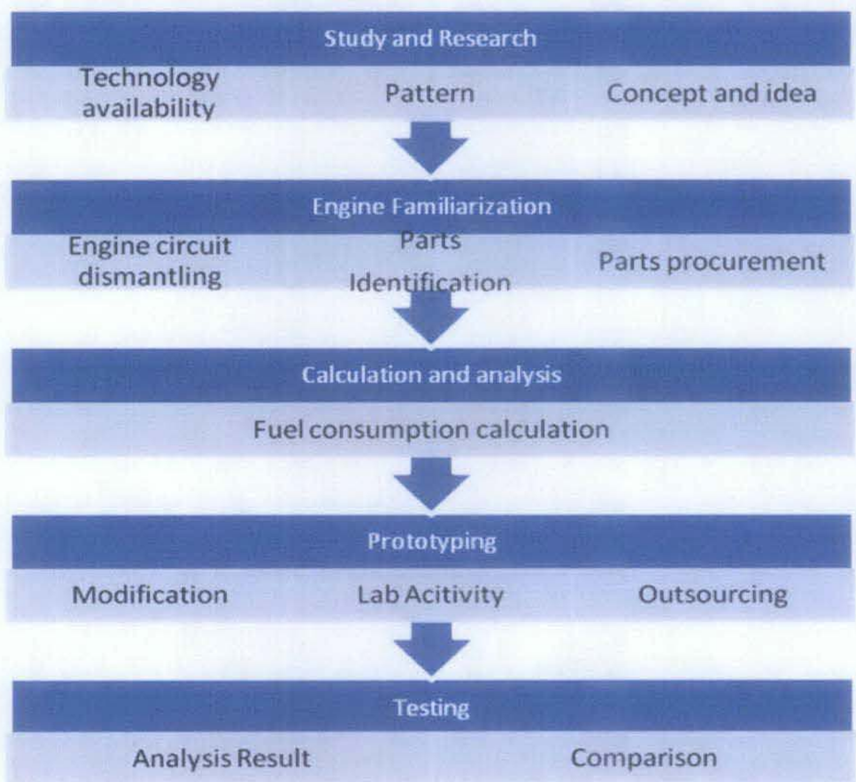

Figure 4

3.6 Final Year Project Planning

Suggested Milestone for Final Year Project II

No	Detail/Week	1	2	3	4	5	6	Mid-semester break	7	8	9	10	11	12	13	14
1	Project work continues	■	■	■												
2	Submission of Progress Report 1				●											
3	Project work continues				■	■	■									
4	Submission of Progress Report 2									●						
5	Seminar (compulsory)									●						
6	Project work continues								■	■	■	■	■	■	■	■
7	Poster Exhibition												●			
8	Submission of Dissertation Final Draft															●
9	Oral Presentation								During study week							
10	Submission of Dissertation (hard bound)								7 days after oral presentation							

● Suggested milestone

■ Process

Figure 5

Chapter 4

Result and Discussion

4.1 Experiment Result

No. of Experiment	Experiment Condition	Total Distance Travelled (km)
1	Stock car (no modification)	18.9
2	Car without the air-conditioning system	22.0
3	Car without electrical devices	19.0
4	Car with weight reduction (more than 10% of original weight)	21.2
5	Car with Low Rolling Resistance Tires (LRR)	22.1

Table 2

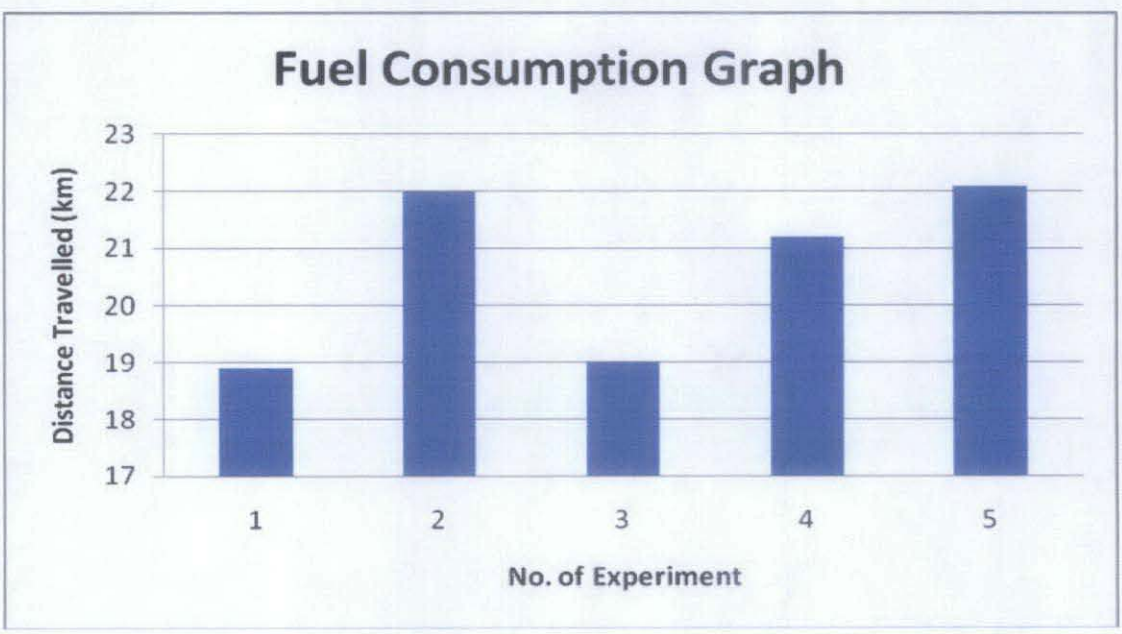

Figure 6

The author had conducted the first experiment for the car which is using the car without any modification done at the engine circuit. All systems including air conditioning system, electrical devices, original curb weight, tires are keep remain. The only modification done to the car is replacing the fuel tank with a modified version of fuel tank with capacity of 1 liter of fuel but the original fuel tank is not removed because it will affect the weight of the car. The idea of using this fuel tank is to maximize the amount of fuel used in this experiment. The fuel was pumped from the modified fuel tank into the fuel rail of injector. This experiment is important as a benchmark result for the next experiment which will be conduct afterwards. For each factor test, the component/system was removed from the car and the other remains. Regarding the weight of vehicle, the author removed approximately 130 kg from the 800 kg of original vehicle weight which is 16.25 % from original weight. For the Low Rolling Resistance tires (LRR), the author used set of Michelin Energy tires.

Feasibility Map of Parameters:

Element of study / Parameter	Percentage of mileage difference with stock car (minimum-10%)	Feasibility factor
Car without the air-conditioning system	((22-18.9)/18.9)*100 = 16.4 %	(green)
Car without electrical devices	((19-18.9)/18.9)*100 = 0.5 %	(orange)
Car with weight reduction	((21.2-18.9)/18.9)*100 = 12.1 %	(green)
Car with Low Rolling Resistance Tires (LRR)	((22.1-18.9)/18.9)*100 = 16.9 %	(green)

Table 3

Legend:

Color	Remarks
(green)	Recommended
(yellow)	Under consideration
(orange)	Not recommended

4.2 Discussion

From the experiment result above, the author has developed a Map of parameters to identify which factor is feasible to terminate in the vehicle system to reduce the fuel consumption. In order to make certain level of acceptance regarding contribution for the parameters studied, the author set 10% of difference between the stock car distance and the modified car distance.

The experiment conducted including the air-conditioning system, the electronic devices factor, usage of Low Rolling Resistance tires and also the vehicle weight factor.

For air-conditioning system, the difference in the mileage showed more than 10% difference. This significance result proves that without air-conditioning system, the fuel consumption is better than before. Engine load is reduced since the compressor and condenser were not operated. It has increased the engine efficiency as the power generated from the engine can be utilized more for mobilizing the vehicle. Based on Map of Parameter, this factor can be considered for the modification in enhancing the fuel consumption of Perodua Viva. However, it also depends on velocity of the car, at low velocity, usually less than 100km/h, using air-conditioning system is not feasible and the driver is advice to roll down the window to save the fuel because the effect of aerodynamic is too small at low velocity. At high velocity, driving with air-conditioning system running is more efficient compared with roll down the window because the drag force acts on the car will result in more fuel used. Therefore, contribution of air-conditioning factor on fuel consumption of Perodua Viva is high when the car is drive at low speed.

While for electronic devices parameter, the results is not too significant where the mileage percentage difference is less than 10%. The author found out that the main element in improving the electrical power of a vehicle is the alternator itself. These electronic devices rely on the alternator in feeding them with the electrical power. If the alternator is inefficient, the electronic devices will claim more power and create high load on the engine.

From the Map of Parameters, considering this factor is not feasible because it is not a major factor which contributes to vehicle high fuel consumption. This result is quite redundant or clashed with literature review fact that electrical devices may consume up to 3 horsepower, in the author view, this clashed data might caused by the technology built in the car itself. Perodua Viva does not have any high technology gadget operating inside it such as Global Positioning System (GPS), high technology audio system, halogen headlight which result in low load create onto the engine. Therefore, the effect of these electrical devices is too small for this car compared to any continental and high-end car such BMW offered for the owner.

For weight reduction factor, the author found out that a lighter in weight vehicle will results in good fuel consumption as power to weight ratio of the car is increase. However, the weight reduction must be greater than 10% of original weight in order to have a significance result. For Perodua Viva car, the author had removed 16.25% of total car weight, and based from the Map of Parameter, factor of reducing vehicle weight contributes more than 10% of mile age difference. Therefore, the manufacturer can modify the Perodua Viva in term of total weight of the car by using lighter material for the body; remove unnecessary parts and so on.

By using trap speed method, the horsepower of the car can be calculated.

Before weight reduction,

Horsepower = (Vehicle weight + Driver weight) x $(\text{Velocity}/234)^3$

= (800kg + 50kg) x $(50\text{km/h}/234)^3$

= (850kg x 2.204623lbs/1kg) x $((50000 \text{ m/h x } 0.000621\text{miles/1meter})/234)^3$

= (1873.9 lbs) x $(31.05 \text{ mph} / 234)^3$

= (1873.9 lbs) x (2.336×10^{-3})

= 4.378 hp

= 3.264 kW

After weight reduction,

Horsepower = (Vehicle weight + Driver weight) x $(\text{Velocity}/234)^3$

$= (670\text{kg} + 50\text{kg}) \times (50\text{km/h}/234)^3$

$= (720\text{kg} \times 2.204623\text{lbs}/1\text{kg}) \times ((50000 \text{ m/h} \times 0.000621\text{miles}/1\text{meter})/234)^3$

$= (1587.3 \text{ lbs}) \times (31.05 \text{ mph} / 234)^3$

$= (1587.3 \text{ lbs}) \times (2.336 \times 10^{-3})$

$= 3.708 \text{ hp}$

$= 2.765 \text{ kW}$

The above calculations proved that vehicle with less weight consume less power to move compared to vehicle with high weight. However, too light vehicle might reduce vehicle safety factor also. Therefore, the car manufacturer must find the suitable vehicle weight to optimize the engine power

The last parameter studied in this project is the usage of Low Rolling Resistance (LRR) tires. Based from the result obtain, the mileage difference between the stock car and the car with LRR tires is more than 10%. The result proved that LRR tires can save more fuel since it has low rolling resistance coefficient compared to original tires from car manufacturer. As shown in the Map of Parameter, LRR tires usage can decrease fuel used by Perodua Viva and the contribution of this factor can be consider as high.

Rolling Resistance Force,

F_R = (mass) x (gravitational acceleration) x (rolling resistance coefficient)

$= mgf_R$

Since the value of rolling resistance coefficient of tires decreased, the rolling resistance force experience onto the tires also decreased.

Chapter 5

Conclusion

As for conclusion, the author had studied the relationship of air conditioning system, electronic devices, the vehicle weight, and also the usage of Low Rolling Resistance tires (LRR) with fuel consumption of Perodua Viva. Based on the Map of Parameters developed from the experiment result, the air-conditioning system, vehicle weight reduction and usage of Low Rolling Resistance tires contribute more than 10% of mileage difference. It gives a conclusion that the factors mentioned before are highly contributed to fuel consumption of Perodua Viva. The other factor which is the usage of electronic devices can be neglected as it only contribute less than 10 % of mileage difference for fuel consumption of Perodua Viva.

For air-conditioning system, no load is applied onto car engine as the system is not running and it result in higher efficiency of engine performance. Fuel consumption of the car is low as the car travel longer without the system. The second factor contributes highly to fuel consumption is the vehicle weight. Vehicle weight determines power-to-weight ratio of Perodua Viva. As the weight is decreased, the power-to-weight ratio is increased which means less power needed to move the car and more fuel is saved. Then, for contribution of tire factor, the usage of Low Rolling Resistance (LRR) tires results in low fuel consumption for the Perodua Viva. The car can travel longer with 1 Liter of fuel by using the tires compared to stock tires. Low Rolling Resistance tires are designed with different material from stock tires to reduce the rolling resistance of the tire. The power used to counter rolling resistance is reduced and can be utilized to move the car.

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APPENDICES

- Car testing map