Influence of gear ratio pattern on vehicle acceleration performance

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ABSTRACT – This paper presents the influence of gear ratio on vehicle acceleration performance particularly on small MPV B-segment vehicle. It is due the customer requirement of having acceleration performance of this type of vehicle to be comparable with the passenger cars. Gear ratio pattern is investigated by using mathematical modeling simulation approach. 5 sets of gear ratio are used including 3 sets of customized configurations. The customization is carried out by using geometric progression approach. The results of the simulation reveals that customized gear ratio that using increment geometric progression of 10 %, 20 %, 30 % and 40 % between the ratios has the best acceleration performance. It clocks only 8.8 s for the vehicle to accelerate from 0 to 110 km/h. It proves that gear ratio pattern has a great influence in vehicle acceleration performance.

1. INTRODUCTION

The demand of small MPV B-segment vehicle is increasing especially in Malaysian market due to its capabilities of having bigger interior space and ability to carry more passengers. But, customers are demanding this vehicle to have better or comparable acceleration performance as passenger cars [1]. Because of that, multiples approaches have been carried out to improve the acceleration performance. Aside from improving the engine performance, powertrain system can assist in reducing the acceleration time [2].

Powertrain system especially the vehicle transmission can be modified to meet the purpose of increasing its efficiency. Most of the common approach is by replacing the conventional automatic transmission with Continuous Variable Transmission (CVT) [3]. It reduces the losses especially during the gear change process. Other method is by manipulating the gear shift pattern to comply with driver's demand [4]. But, one of the aspect that is rarely utilized is by changing the gear ratio pattern. Because of that, it becomes the focus of this study.

Mathematical modelling simulation approach is utilized due to its capability of eliminating the needs of experimental apparatus [5]. It also provides the opportunities to simulate the real vehicle of facing various environments by simply changing the simulation parameters. This method is highly suitable for this study by eliminating the needs of physical vehicle transmission system.

2. RESEARCH METHODOLOGY

2.1 Simulation Model

Simulation model was constructed by using Matlab-Simulink software. It was based on 5-speed automatic transmission system. The gear ratio selection model can be represented as Figure 2.1 below.

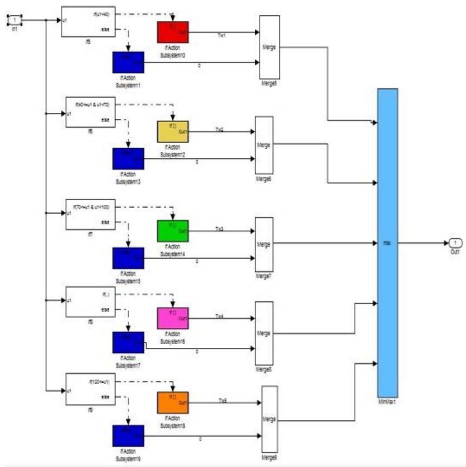

Figure 2.1 Gear ratio selection model

A simplified full vehicle system model as in Figure 2.2 was integrated with the gear ratio selection model. The vehicle was assumed to operate at wide open throttle (WOT) condition. Road loads considered in this study were the vehicle aerodynamics and rolling resistance. The vehicle was also assumed to travel on the flat road.

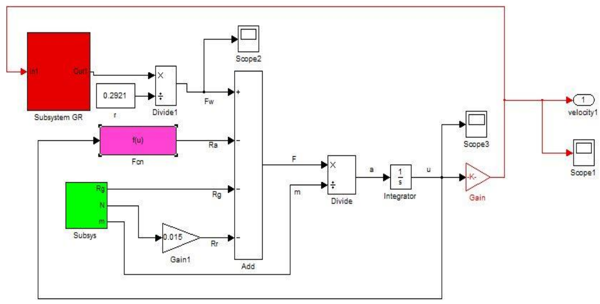

Figure 2.2 Full vehicle system model

2.2 Vehicle Specifications

Table 2.1 shows the vehicle specifications that had been used for this study. These specifications were based on one of Malaysian car manufacturer B-segment model.

Table 2.1 Vehicle Specifications

Components	Parameters	Value
Vehicle	Mass	1200 kg
	Frontal are	2.75 m^2
	Drag coefficient	1.23
	Tire radius	0.292 m
	Wheelbase	2.75 m
Engine	Type	3sz-ve ,DOHC
	Max torque	136Nm/100ftlb/13.9kg m@ 4400rpm
	Max power	76kW(104hp)@6000rp m
	Cylinder	4 inline,16valve with DVVT

2.3 Gear ratio determination

5 sets of gear ratio were used for this study. One set was based on the original gear ratio of the vehicle and set as the referenced values. The other was based on competitor specifications of the same car segment. 3 sets of gear ratio were customized based on the original gear ratios by using geometric progression. Custom 1 was based on constant geometric progression and Custom 2 was based on increased geometric progression of 10 %, 20 %, 30 % and 40 % between the gear ratios. Custom 3 was obtained based on decreased geometric progression of 40 %, 30 %, 20 % and 10 % between gear ratios. The specifications of gear ratio are shown in Table 2.2 below.

Table 2.2 Specifications of gear ratio

Gear Ratio	1.5 3s-ve	Custom 1	Custom 2	Custom 3	1.3 k3-ve
1^{st}	3.091	3.091	3.091	3.091	3.182
2^{nd}	1.892	2.5058	2.8569	2.1546	1.842
3^{rd}	1.25	1.921	1.9205	1.4523	1.25
4^{th}	0.865	1.335	1.6864	0.9841	0.865
5^{th}	0.75	0.75	0.75	0.75	0.75
FD	4.643	4.643	4.643	4.643	4.267

3. RESULTS AND DISCUSSION

3.1 Acceleration performance (0-110km/h)

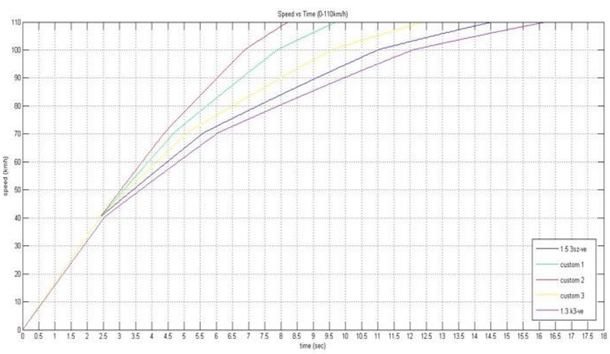

Figure 3.1 Acceleration performance (0-110 km/h)

Figure 3.1 shows the same performance of 4 sets of gear ratio specifications when the vehicle is accelerating from 0 to 40 km/h. This is because, it still uses the same setting of gear ratio with only 1.3 k3-ve produces slightly slower acceleration. Original (1.5 3sz-ve), Custom 1, Custom 2 and Custom 3 only need 2.382 seconds to achieve 40km/h but 1.3 k3-ve needs 2.523 seconds to reach the same amount of speed. The results show more significant difference when the vehicle exceeding the speed of 40 km/h.

Custom 2 has the best acceleration performance by achieving 110 km/h in only 8.8 s. It follows by Custom 1, Custom 3 and the original specification. 1.3 k3-ve reveals the worst performance by clocking 16 s. Table 3.1 below shows the acceleration time for all gear ratio specifications.

Table 3.1 Acceleration time

Specifications	0-110km/h (s)
1.5 3sz-ve	14.4
Custom 1	9.7
Custom 2	8.8
Custom 3	12.2
1.3 k3-ve	16.0

The results show the possibility of having better acceleration performance by manipulating the gear ratios pattern. Worst performance by 1.3 k3-ve indicates the requirement of having engine transmission matching before it can be utilized in any particular vehicle. Slower performance of original gear ratios as compared to the customized ones demonstrates that other factors are taking into consideration in determining the gear ratios. Most notable factor is the fuel economy of the vehicle.

4. SUMMARY

This study showed that gear ratio pattern contributed to the acceleration performance of a vehicle. It is accomplished by using mathematical simulation method. Sets of gear ratio was customized based on geometric progression method. Custom 2 specifications produced the best performance by clocking 8.8 s to accelerate from 0 to 110 km/h.

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