UNIVERSITI TEKNIKAL MALAYSIA MELAKA

OPTIMIZATION OF A RACE CAR TOP SPEED DURING AN EVENT IN VIRTUAL FORMULA

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Engineering Technology (Technology Automotive) (Hons.)

By

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfilment of the requirement for the degree of Bachelor of Engineering Technology (Technology Automotive) (Hons.). The member of the supervisory is as follow:

.....

(Mr. Saiful Naim Bin Sulaiman)

ABSTRACT

VI-GRADE is a global leader production automotive market and it providing the simulation tool in racing car. VI-Grade launched the VI-Grade Virtual Formula competition to allow the student increase their knowledge of vehicle dynamics, to develop their design and compare the concept and test the design and develop the idea. The purpose of this project is to study and to optimize the powertrain of the virtual formula race car to achieve the maximum top speed in the acceleration event and to optimize the powertrain characteristic to get minimum lap time during a race event in VI-Grade. To optimize the powertrain it use the VI-Grade software, and it software optimize the several parameter in powertrain. The setup system to optimize the powertrain is must follow the rules and regulation in VI-Grade. The best result of powertrain parameter after optimize must sent to VI-Grade to get the final result after compete with other race car around the world. The end of this project, the best result of the optimizing in powertrain can be used for future development.

DEDICATION

This thesis is dedicated to my family, lecturer and my friend for their keen and endless guidance, encouragement, critics and inspiration till the success and completion of this project.

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I am so thankful to Allah S.W.T for giving me a chance to complete this project to success. While completing this project, there several individuals that keeps giving me their support and advises to complete this project successfully. I would like to express my deepest gratefulness and appreciation to my Project Supervisor, Mr Saiful Naim Bin Sulaiman in all his guidance, teaching, advises and time for me. Without his constant supervision, I may be not able to complete this project. Thank you for the advices, guides, tips and generous support that you have gave me. To my friends, my special gratitude and thanks you for all the support and guidance. Also not forgotten to all lecturers and people who help me in completing this project whether it directly or not. Without all the support and help, this project may be cannot complete. Thank you.

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LIST OF SYMBOLS AND ABBREVIATIONS

LSD	=	Limited Slip Differential
DOE	=	Design of Experiment
FIT	=	Approximation
RSM	=	Response Surface Method
LSR	=	Least Squares Regression
MLSM	=	Moving Least Squares Method
HK	=	HyperKriging
RBF	=	Radial Basic Function
ARSM	=	Response Surface Method

CHAPTER 1

INTRODUCTION

1.0 Introduction

VI-Grade Virtual Formula is competition to allow student develop their idea, compare the concept and develop design and increase the knowledge of vehicle dynamic. VI-Grade is a software company and provides the simulation tool to the race car. This competition more than 200 team joined around the world and the challenge is to get the faster lap time to finish the track. This competition is in 'virtual' and this project it to optimizing the powertrain characteristic in race car using the Virtual Formula software to get the maximum top speed in acceleration event. The characteristic in powertrain is gear ratio, gear shifting and differential. In Virtual Formula, the rules and regulation is given and the parameter can be changed based on the rules and regulation. Powertrain is the system generates the power and delivers to the road surface from gear ratio, gear shifting and differential. The differential in powertrain use Limited Slip Differential (LSD) and its fixed in virtual formula competition. The differential has the limitation and need follow the limitation. The function differential is to transmit the power to the wheel follow the power produce by gear ratio. The gear ratio need to optimize to get the correct value to achieve the maximum top speed and also need to use the correct gear in straight line and cornering at track. The timing to shift the gear at cornering and straight line must fast and correct. The powertrain system is very important parameter to study in race car to increase the performance.

1.1 Problem Statement

The powertrain system is main component in race car to transfer the power in to the road. The parameter powertrain is gear ratio and differential (LSD) also the gear shifting must use the method correctly to get the maximum top performance. The method to use for the setting gear ratio, differential and gear shifting is very difficult and the information about gear ratio, differential and gear shifting is limited. VI-Grade competition give the default model and its must optimize the default model to get the better result from default model. To optimize the default model it must follow the rules and regulation in VI-Grade virtual formula and have a limit time. The powertrain system is important system in race car and it different for other race car. For the differential (LSD), the preload and lockup percentage have a limitation, and its must follow the limitation in optimization in powertrain. It's difficult to optimize the best gear ratio for race car; it must refer the other journal to know the method need to use to get the best gear ratio. In Vi-Grade virtual formula its give the Vi-Grade software, the software can tune the parameter and test directly in virtual formula race track. The software can help to understand the problem and can give the correct value or setting to parameter.

1.2 Objective

The objective of this study is:

I. To optimize the powertrain characteristic to get minimum lap time during a race event in VI-Grade
II. To achieve the best top speed during acceleration event in VI–Grade

1.3 Scope

The scope is:

I. Optimize only powertrain characteristic to achieve minimum lap time
II. Only involve simulation using the software VI-Grade
III. Other specification are according to default
IV. The result for VI-Grade not validated until real test.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction of Powertrain

The powertrain system is a system that provides a driving force for the vehicle. The power source for this system is by internal combustion engine, controlled by the transmission system to deliver the tractive effort to the wheel. The powertrain consists of the engine, transmission, drive shafts, differentials, and the final drive.

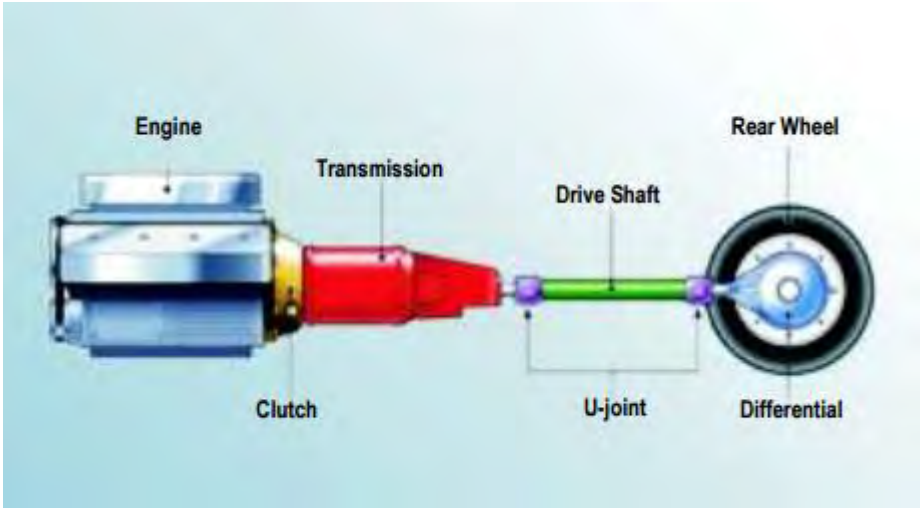

Figure 2.1: The Powertrain System (Amir 2007)

In powertrain system, transmission is very important to transmit the torque at the same amount to the wheel, and in transmission it have gear ratio and shifting, their give big impact to produce the torque. The location of transmission is between the clutch and the drive shaft. Figure 2.1 is about the transmission system. Refer picture, the engine is connected with the transmission, it produced the power and the transmission can transmit the power to the wheel by the drive shaft and the differential with the same amount of power or rpm.

The purpose of powertrain or transmission is to move the vehicle under the velocity and load condition by giving the torque needed by changing the gear ratio between the engine crankshaft and the drive wheel. The next purpose is can shift to the reverse or the car can move backward, but in the race car the reverse gear not use. There only have the six gears without a reverse gear. The engine can run without turning the drive wheel by the shifter at gear neutral. (Amir 2007)

The transmission needs to perform the all of the purposes for the refined manner. The structural of the casing in powertrain is important for the race car to get lowest noise and vibration. The noise and vibration can affect the performance of race car or another car. The position of the powertrain component and the driveline component can give the effects of the space available in powertrain and the weight distribution. In powertrain, less weight and space can give better performance for the race car. The other effect is the structure to support the powertrain and react the driving torque, also the vehicle handling and ride from weight distribution and location driven wheel then safety structure and passenger protection. This effect can give the high performance for the race car. (David A. Crolla, 2009)

In powertrain operation, the engine produces torque at a range of crankshaft speed in condition idle (minimum) and rev limit (maximum). The speed crankshaft is referred from throttle butterfly angle from driver input. This information increased the engine rotating inertia. The transmissions transmit the torque from the engine crankshaft to the differential at a selectable gear ratio from the driver input to the given wheel speed same amount of torque. The wheel speed can give the effect for acceleration race car either fast or slow. (Muller, 2005)

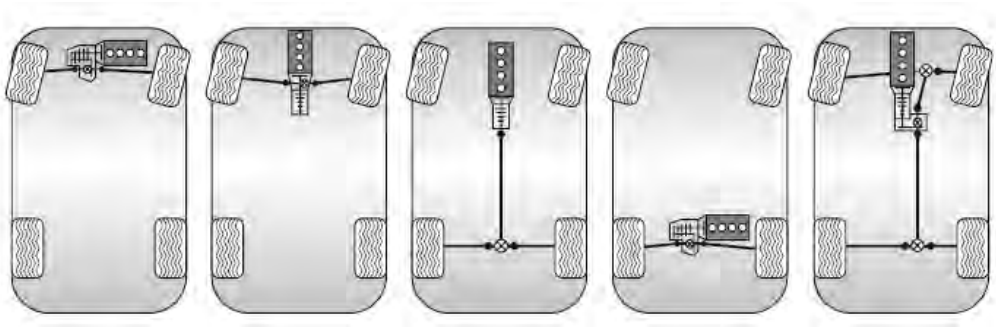

Figure 2.2: Powertrain configuration (David A. Crolla, 2009)

The vehicles have many powertrain configurations, but for the race car engine and transmission are transversely mounted to the rear of the vehicle to drive the rear wheels. The advantage of using the rear wheel drive is its small weight and size. The race car needs the less light and the engine size small to get the high performance and increase the traction force for accelerating. The rear wheel drive also not complex in the making of powertrain system, more efficient drive train and the differential can integrate directly with the transmission. The transmission has two types; it is the automatic transmission and manual transmission. The automatic transmission uses a combination of a torque converter and a planetary gear system to change gear ratios automatically. The manual transmission is an assembly of gears and shafts that transmits power from the engine to the drive axle, and changes in gear ratios are controlled by the drive and the manual transmissions are constant mesh, fully synchronized transmissions (Delmar, 2011)

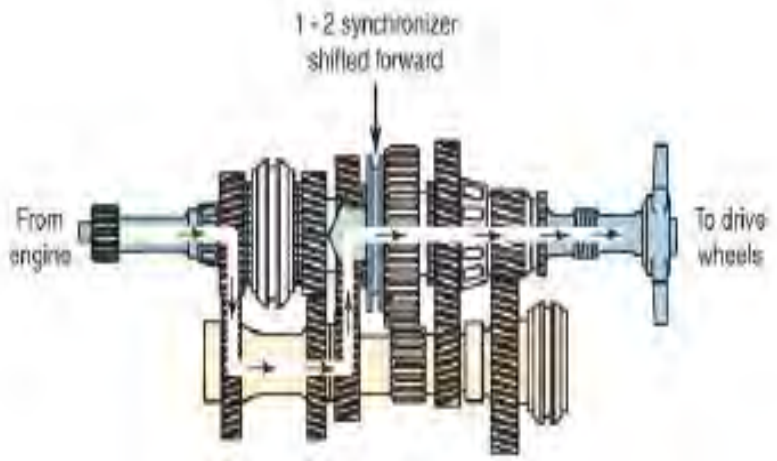

Figure 2.3: The Synchronized gear (Delmar, 2011)

The synchronized function is to synchronize the speed by acting as brake or clutch through the frictional surface before engage to the gear ratio. The synchronized connect the drive input shaft to the gear to confirm the input shaft is engaged with the selected the gear. The purpose of synchronized is to prevent the noise or damage in gear and the teeth gear can easy connect each other. (Matthew, 2005)

2.1 Parameter Involve In Powertrain

The parameters are involved in powertrain system is, gear ratio, gear shifting also the differential and final drive ratio.

2.1.1 Gear ratio

The gear ratio is defined as the input speed relative to the output speed. The gear ratio is important in produce the high top speed to increase the acceleration for the race car. The first ratio of transmission in race car should not be made too large. The effect when the first gear ratio made at large is it can be the transmission becomes difficult to shift. The first gear ratio also can't give the high-speed performance but can increase the top speed. Figure 2.4 show the increase in the first gear ratio, there are more engine-use points moving to the low-speed region.

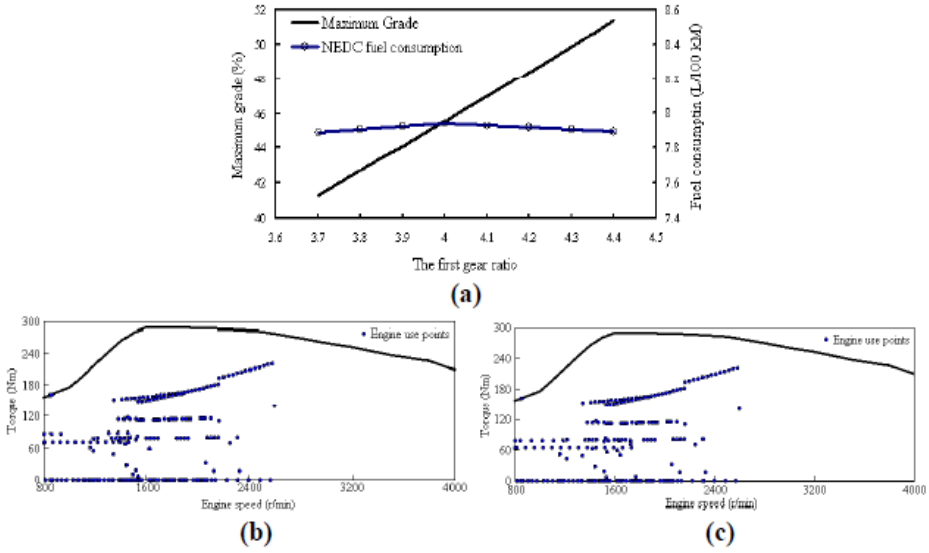

Figure 2.4: The First Gear Ratio Effect (Wenlin Wang, Chunju Chen, 2013)

The fifth gear ratio of transmission can give the impact on the maximum vehicle speed and the fuel economy. The fifth gear ratio refers to the last gear or the transmissions have the fifth gear. When the fifth gear ratio is increased, the speed of a vehicle and the fuel consumption is the increase. For example, when the fifth gear ratio is 0.6, the engine-use the points gather in the economic region with lower reserve power; when the fifth gear ratio is increased to 0.9, the engine-use points move to the non-economical region with higher reserve power. The fifth gear is the most often to use in vehicle and it is the choice ratio in transmission. Figure 2.5 show the fifth gear ratio impact in vehicle speed and fuel consumption.

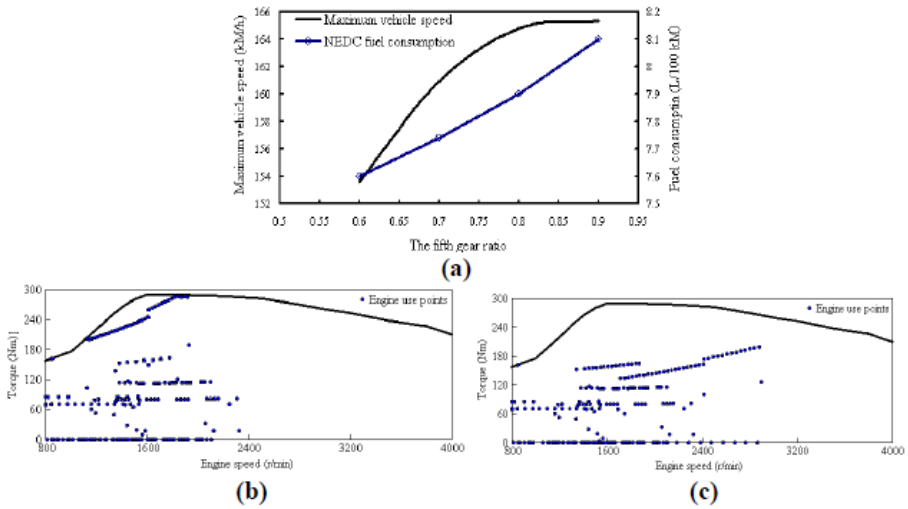

Figure 2.5: The Fifth Gear ratio (Wenlin Wang, Chunju Chen, 2013)

The numerous transmission ratios are selected for this study. The gear span is gear between the maximum and minimum gear ratio was increased the transmissions with a higher number of gears. The gear span gives the effect of top gear ratio when gear span is increasing; the top gear ratio is decreased. The transmission technology was selected various technology and this research and analysis result do by using MATLAB software, GT-Power, AMESim and CarSim software. Table 2.1 show the gear ratio for various transmission ratios. (Moawad et al, .2012)

Table 2.1: Transmission Ratio for automatic speed (Moawad et al, .2012)

	1	2	3	4	5	6	7	8
5- speed	2.56	1.55	1.02	0.72	0.52			
6- speed	4.15	2.37	1.56	1.16	0.86	0.52		
8- speed	4.6	2.72	1.86	1.46	1.23	1	0.82	0.52

In the race car, the first gears give the effect of the acceleration of a car. The first gear ratio takes a time to change to the second gear ratio. The first gear ratio is the longest and slowest gear to change, the race car it eliminated the fist gear ratio. The starting the race car is the second gear ratio to give the big effect and eliminate the possible accident to change the neutral gear when acceleration slow at the corner and prevent the driver error. The research in average speed was found the optimum gear ratio operate in only second gear. The chance final ratio can give the significant torque. The higher gear ratio will affect the traction force at a wheel. But their advantage is the time to change the gear is shorter, and the torque can increase. (Harber, 2005)

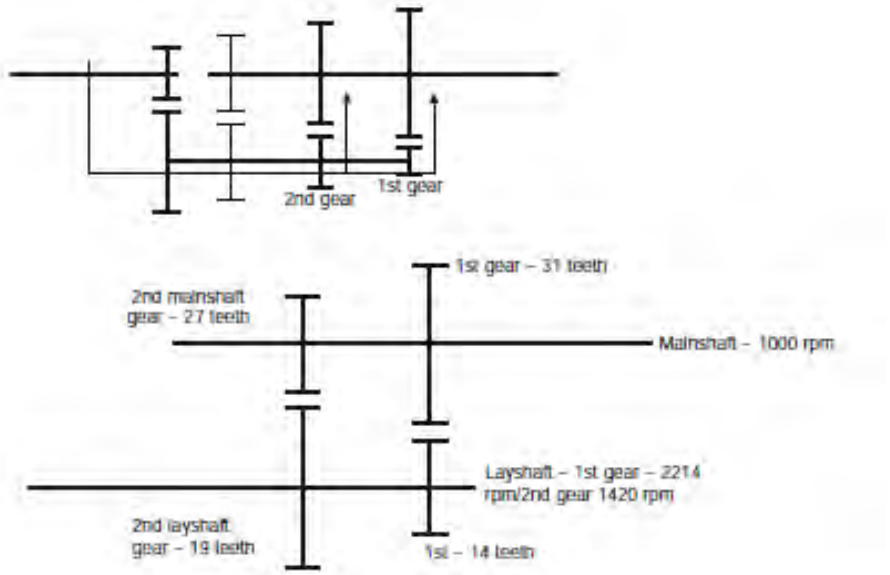

Figure 2.6: Diagram first gear change Second gear (David A. Crolla, 2009)

The first gear give the bigger impact for the performance of car, Kyle do the research compares the first ratio for manual transmission and automatic transmission. For the manual transmission the ratio is 4.2 and the automatic transmission is 2.82. The final drive ratio is same 3.55 and the both of transmission have the advantage. In this research, Kyle uses the mathematical solution to get the graph velocity versus time for both transmissions to compare the performance. In the graph velocity versus time have two functions, the first function is velocity with respect engine speed in radians and the second function is the time with respect the velocity and engine torque. The picture show the graph first gear manual transmission and auto transmission.

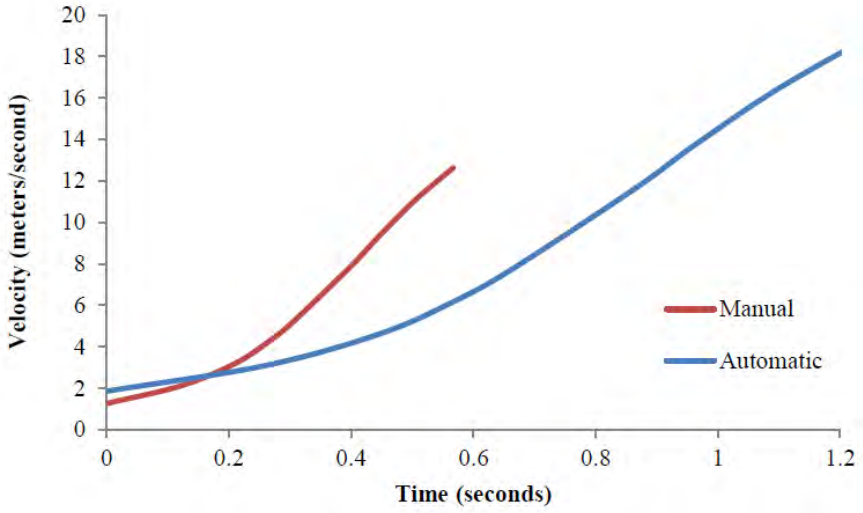

Figure 2.7: The graph manual and automatic transmission (Kyle, 2011)

From this graph, it shows that the manual transmission provides the higher acceleration but low top speed compare with the automatic transmission. The manual transmission is acceptable for the faster acceleration and because of this the racing cars use the manual transmission. The automatic transmission must have high top speed for each gear to get the faster acceleration. This method is cheaper and faster either the using dynamometer method. (Kyle, 2011)

2.1.2 Gear Shifting

In a transmission system, the shifting gears give the big impact to the acceleration. The shifting is require changing the drive power and ordered to match the engine power condition. The gear shift decision is expected to be consistent such that the vehicle can remain in the next gear for a period of time without deteriorating the acceleration capability. The up-shift is for the changing high gear and the down-shift for the low gear. (Ngo Dac Viet, 2012)`

The shift gear depends on the driver accelerator and the vehicle speed. The shifting changed at the various RPM. The figure 2.8, show the up-shift and down-shift setting for each gear. The change point between two gears needs some hysteresis to prevent the hunting phenomena. The basic shift is modified for the driver follow the suitable condition like the straight line or corner line. (David A. Crolla, 2009)

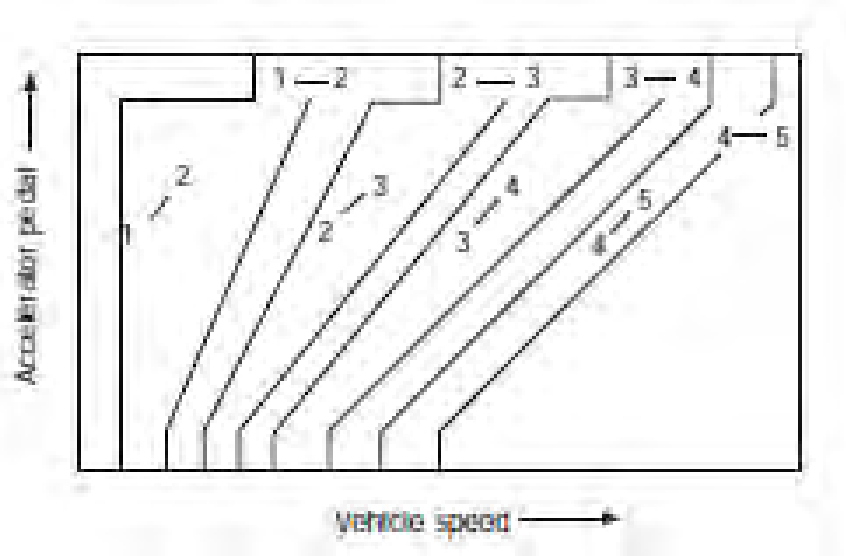

Figure 2.8: The Shifting diagram (David A.Crolla, 2009)