International Journal of Research In Vocational Studies (IJRVOCAS)
VOL. 3, NO. 1, April 2023, PP. 58~63
Print ISSN 2777-0168| Online ISSN 2777-0141| DOI prefix: 10.53893
https://journal.gpp.or.id/index.php/ijrvocas/index

Studying Toyota Prius Vehicle System by Simulation with Advisor

Nguyen Huu Huy
Dong Nai Technology University, Bien Hoa, Viet Nam
Email address:
nguyenhuuhuy@dntu.edu.vn

*Corresponding author

To cite this article:

Nguyen, H. H. Studying Studying Toyota Prius Vehicle System by Simulation with Advisor. International Journal of Research in Vocational Studies (IJRVOCAS), 3(1), 58–63. https://doi.org/10.53893/ijrvocas.v3i1.167

Received: 01 12, 2023; **Accepted:** 03 06, 2023; **Published:** 04 25, 2023

Abstract: Nowadays, reducing fuel consumption and greenhouse gases are top priorities for automotive manufactures because of environmental hazards and running out fossil fuels all over the world. These reasons are the key factors that lead to the creation of hybrid cars. This article discusses the intervention in hybrid vehicle's content parameters, which were conducted on the simulation software ADVISOR, by changing the value of the vehicle according to certain rules. We also use the Vietnamese's driving cycle of to set the ADVISOR program up. The simulation results showed that we have successfully re-established Toyota Prius's driving cycle using Vietnam's Road condition and lowest the fuel consumption and emission with the setup driving cycle, by changing the parameters of the car.

Keywords: Research Improvements, Toyota Prius, ADVISOR

1. Introduction

Currently, hybrid cars are produced mainly to serve major markets such as the US and some European countries, so hybrid cars in Vietnam have not yet reached the most optimal performance, that is, fuel consumption and emissions are the lowest.

The topic of research on improving the Toyota Prius hybrid vehicle's powertrain in accordance with Vietnamese conditions is a priority for reducing environmental pollution and reducing dependence on fossil energy while increasing the efficiency of using hybrid vehicles in the future. current conditions in Vietnam. In order to ensure that hybrid vehicles operating in Vietnam meet the highest technical requirements and need technical improvement, the manufacturer offers technical solutions, and at the same time, experimentally and optimally tests the solution. there. One of the solutions to reduce the effort and time to test the experiment is to use the numerical simulation method, in which we use simulation software [1-3].

Research on improving the Toyota Prius hybrid vehicle's powertrain system to suit Vietnam's conditions using a digital tool, the ADVISOR simulation program, which is free to use, is the basis and condition for scientific ideas to develop research topics. Science.

2. Content

2.1 Theoretical basis

2.1.1 Foundation base

ADVISOR models all types of vehicles, including conventional vehicles using internal combustion engines, electric vehicles, and hybrid electric vehicles, based on the basic equation of motion of a rigid body (Newton's second law), the scalar equation is expressed in the formula:

$$F = ma \quad (1)$$

When moving, the vehicle is affected by rolling resistance $F_{rr} = \mu_{rr} mg$, wind resistance $F_{ad} = \frac{1}{2}\rho A C_d v^2$, climbing resistance $F_{hc} = mgsin(\psi)$, acceleration resistance $F_{la} = ma$, inertial resistance of rotating parts $F_{wa} = I\frac{G^2}{n_g r^2}a$. At the same time, in order for the vehicle to move, the total traction force F_{te}. So, the equation is rewritten:

$$F_{te} = F_{rr} \pm F_{ad} \pm F_{hc} \pm F_{la} \pm F_{wa} \quad (2)$$

The hybrid vehicle simulation model is described in the block diagram.

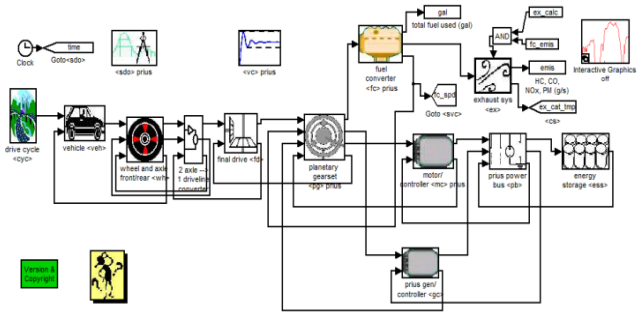

***Figure 1**: Hybrid vehicle simulation block diagram*

2.1.2 Equation for HC and CO

- The operating cycle will be divided into small equal segments, called Time Step:

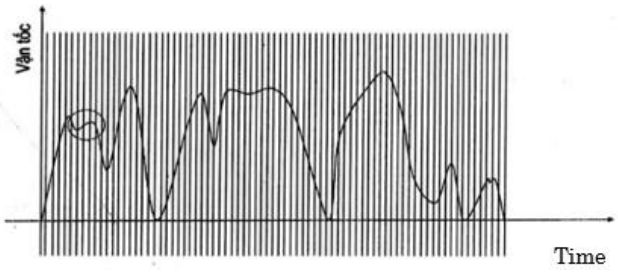

***Figure 2:** Time Steps on the operating cycle*

- Calculate average velocity and acceleration at each Time Step

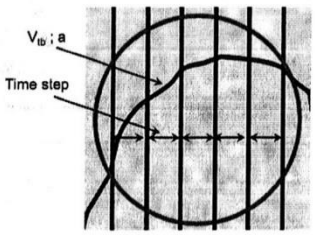

***Figure 3:** Velocity and acceleration at each Time Step*

HC emissions for the whole operating cycle:

$$HC_{total} = \sum_{i=1}^{Step\_num} HC_{Step\_i} \quad (3)$$

- The HC emission for each Time Step i is:

$$HC_{Step\_i} = HC_{Step\_i\_hot} \cdot C_{HC\_temp\_corr}$$

$$C_{HC\_temp\_corr} = 1 + \left(7{,}4 * \frac{fc\_tstat - T_i}{fc\_tstat - 20}\right)^{3{,}072}$$

CO emissions for the whole operating cycle:

$$CO_{total} = \sum_{i=1}^{Step\_num} CO_{Step\_i} \quad (4)$$

The CO emission for each Time Step i is:

$$CO_{Step\_i} = CO_{Step\_i\_hot} \cdot C_{CO\_temp\_corr}$$

$$C_{CO\_temp\_corr} = 1 + \left(9{,}4 * \frac{fc\_tstat - T_i}{fc\_tstat - 20}\right)^{3{,}21}$$

2.1.3 Introducing the Toyota Prius

Toyota Prius has a complex hybrid structure, front-wheel drive (FWD), power distribution (PSD) that allows the heat engine and electric motor to work together to drive the vehicle or allow the engine to the electric motor works independently of the heat engine to transmit power to the active wheels.

The output of the heat engine will connect to the planetary gear through the lead, the generator will connect to the sun gear, and the electric motor will connect to the ring gear, and the ring gear will also connect to the final drive and to the gear. active car.

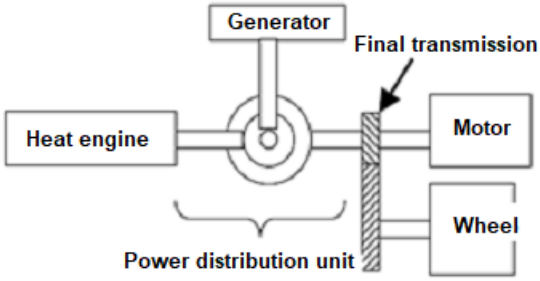

***Figure 4:** Powertrain of Toyota Prius [4]*

According to the diagram of Figure 3.29, the 4 parts of the heat engine, electric motor, and generator of Toyota Prius are considered basic and their size has a great influence on the economic performance of the fuel and the content of substances. pollutant present in exhaust gas and vehicle dynamics.

2.1.4 CECDC Operation Cycle

In Vietnam, the CECDC (Centre for Environmental Monitoring Car Driving Cycle) operation cycle was developed by the Military Institute of Technology in conjunction with the University of Hong Kong to suit the road conditions in Vietnam. Male. Data collection was carried out in Hanoi to develop a representative operating cycle for the road conditions and driving styles of major cities in Vietnam. The CECDC cycle has been developed for passenger cars respectively, using them as the main cycle for testing and measuring car pollution, and 5 different routes have been selected to represent traffic. Usually in Vietnamese cities. The length of the test-driving distance was determined based on the interviews of 3,000 drivers to reflect the behavior of Vietnamese drivers. The process of collecting data on vehicle speed over time is conducted 20 times continuously during weekdays and weekends, the test time of the day is carried out in both peak and non-peak hours.

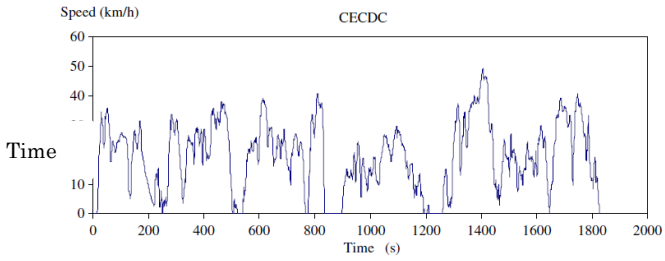

***Figure 5:** CECDC Operation Cycle [5]*

2.1.5 Set up CECDC operation cycle in ADVISOR

To improve the Toyota Prius according to the road conditions in Vietnam, the car must be run according to Vietnam's CECDC operating cycle.

In ADVISOR software, we must add this cycle after we

have set it up at the drive cycle position in the selection of cycles in Figure 7.

After we select the CECDC drive cycle, the drive cycle graph appears on the right exactly like the CECDC cycle that we have just set up.

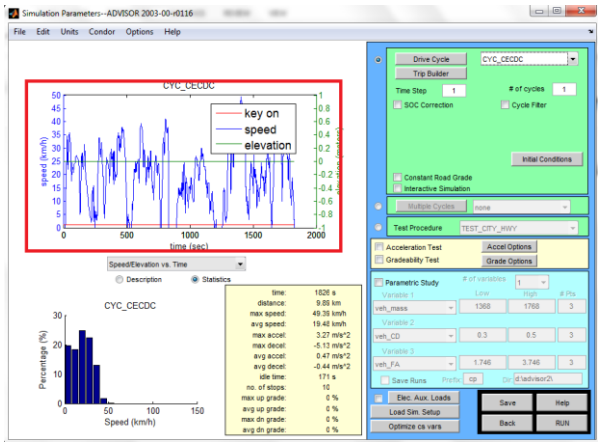

Figure 6: *CECDC driving cycle in ADVISOR*

2.1.6 Hybrid coefficient

The power ratio of the ICE and EM in the hybrid powertrain is expressed by the hybrid coefficient (HF), which is defined as follows [6-8]:

$$HF = \frac{N_{em}}{N_{em}+N_{ice}} = \frac{N_{em}}{N_{total}} \quad (5)$$

In which: Nem and Nice - the largest useful capacity of EM and ICE; Ntotal - total power required.

Table 1: *Hybrid coefficients of some vehicles.*

Vehicle name	N_{em} $[kW]$	N_{ice} $[kW]$	N_{total}	*HF*
Toyota Prius 1998 - I	*31*	*43*	*74*	*0,42*
Toyota Prius - III	*50*	*53*	*103*	*0,49*
Honda Insight 2000	*10*	*50*	*60*	*0,17*
Honda Civic	*10*	*63*	*73*	*0,14*
Honda CR-Z	*10*	*83*	*93*	*0,11*
BMW i8	*98*	*107*	*268*	*0,37*
Lexus RX 450h	*173*	*183*	*356*	*0,49*

Table 1 shows some statistics on the HF values of some of today's most commercially successful hybrid car models.

To date, there is no standard to determine the value of HF. Table 1 shows that the HF coefficient of hybrid cars tends to increase in newer car models. Through the survey, there have been no cases of parallel and mixed hybrid cars with Nice > Nem . In the experimental simulation of the thesis will choose the limit HFmin = 0.1 and HFmax = 0.5.

2.2 Conduct simulation

2.2.1 Set initial parameters on ADVISOR for Toyota Prius 1998 [9-11]

In the article, we run simulations for Toyota Prius 1998 and evaluate the vehicle's dynamic characteristics such as acceleration, fuel consumption, emissions...

ADVISOR software is used to simulate hybrid vehicles, including Toyota Prius, so the parameters for 1998 Toyota Prius in ADVISOR software are built-in.

Figure 7: *ADVISOR main interface*

In the initial setup window, we select the vehicle model to conduct the simulation.

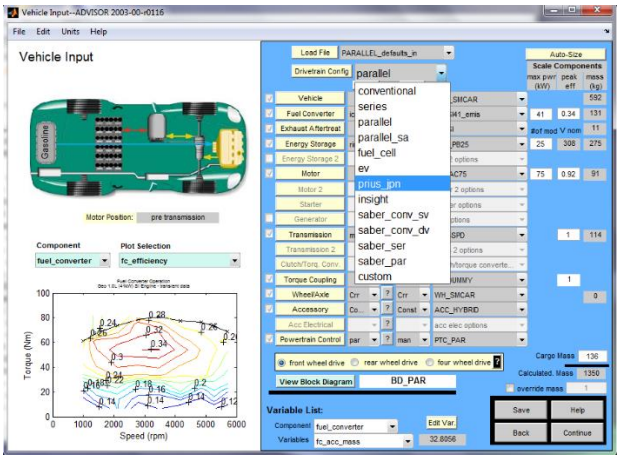

Figure 8: *Choosing a Toyota Prius model in ADVISOR*

Select parameters suitable for Toyota Prius 1998 in all sections in ADVISOR software such as: vehicle parameters, fuel converter parameters, exhaust system with catalytic converter (exhaust). after treat), energy storage system, generator, transmission parameters, wheel and axle parameters (wheel/axle), component parameters auxiliary (accessory), control parameters of the entire powertrain (powertrain control). After setting all the parameters, we conduct the simulation.

2.2.2 Select a run cycle.

After setting the vehicle's parameters for the software, then to the window to select the test cycle for the vehicle, in this window there are many different driving cycles included in the software such as: UDDS (Urban Dynamometer Driving Schedule), HWFET (Highway Fuel Economy Test)

In addition, in ADVISOR, there is a Vietnamese driving cycle called CECDC (Centre for Environmental Monitoring Car Driving Cycle) when we optimize according to Vietnamese conditions, we must run simulations according to this cycle.

Running according to Vietnam CECDC cycle:

In the drive cycle section, we select the CYC_CECDC item in the run option to run, we get the following results:

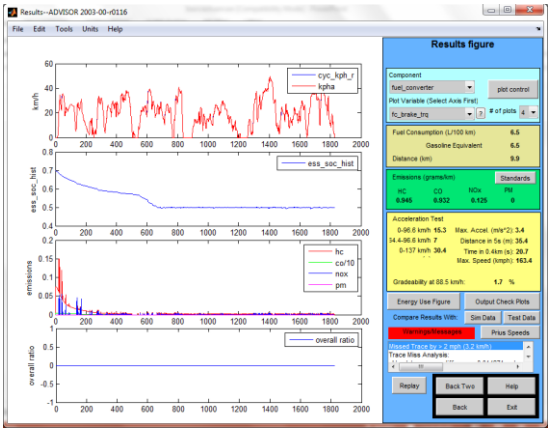

Figure 9: *Simulation results running according to CECDC cycle*

Evaluation of simulation results according to Vietnam's CECDC driving cycle:

The fuel consumption of the 1998 Prius when running the CECDC cycle is 6 L/100 km, which is quite low compared to today's traditional vehicles.

The acceleration of the car (Acceleration Test) from 0-96.6 km is 15.3 seconds, from 64.4 to 96.6 km is 7 seconds, from 0-137 km is 30.4 seconds. The maximum acceleration achieved by the car is 3.4 m/s^2 the distance traveled in 5s is 35.4m, the travel time in 0.4 km is 20.7 seconds, the maximum speed achieved by the vehicle is 163.4 km/h

Emissions (Emissions) in which HC emissions are 0.945 g/km, CO is 0.932g/km, NOx is 0.125.

When the Toyota Prius 1998 runs on Vietnam's CECDC driving cycle in ADVISOR, the emissions are relatively high, so to reduce emissions and vehicle power as well as acceleration, the maximum speed remains unchanged. Many of us proceed to improve the car as follows.

2.2.3 Optimize the parameters of the Prius 1998

In this topic, we study to change two important parameters in the vehicle, namely the maximum power of the internal combustion engine and the maximum power of the motor, in the process of changing the power of the two engines above, the change the total power and coefficients HFmin = 0.1 and HFmax = 0.5 as shown in chapter 3.

After calculating the HF value, we make the following table:

Table 2: *List of Nem and Nic parameters by coefficient HF*

HF	Nem (kW)	Nic (kW)	Ntotal (kW)
0,5	37	37	74
0,4865	36	38	74
0,473	35	39	74
0,4595	34	40	74
0,4459	33	41	74
0,4324	32	42	74
0,4189	**31**	**43**	**74**
0,3919	29	45	74
0,3649	27	47	74
0,3378	25	49	74
0,2973	22	52	74
0,2568	19	55	74
0,1081	8	66	74

In Table 2, we list the power values within the allowable limits of the HF factor running from 0.1 to 0.5. The values in bold in Table 2 are the values of the internal combustion engine and electric motor power of the original Toyota Prius, the remaining values are for improvement.

We conduct vehicle simulation with power values in Table 2.

After simulating the vehicle running on ADVISOR software, we obtained the results corresponding to the values in Table 2.

From the result table 3, we see that the power value of 37kW internal combustion engine and 37kW electric motor is the lowest exhaust gas content and fuel consumption.

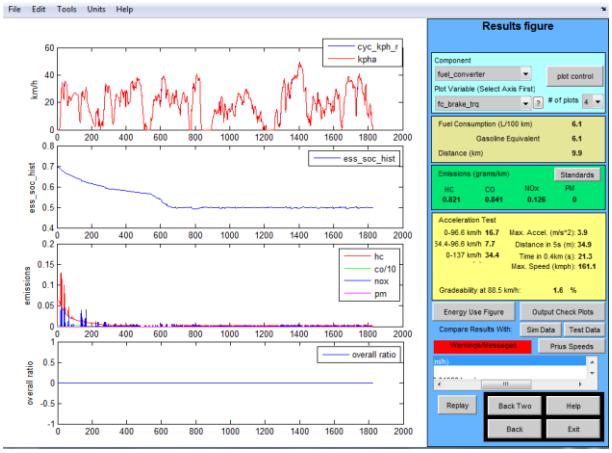

Figure 10: *Simulation results running under the improved CECDC cycle*

The fuel consumption of the 1998 Prius when running the CECDC cycle is 6.1 L/100 km.

The acceleration of the car (Acceleration Test) from 0-96.6 km is 16.7 seconds, from 64.4 to 96.6 km is 7.7 seconds, from 0-137 km is 34.4 seconds. The maximum acceleration achieved by the vehicle is 3.9 m/s^2 the distance traveled in 5s is 34.9 m, the travel time in 0.4 km is 21.3 seconds, the maximum speed achieved by the vehicle. is 161.1 km/h

Emissions (Emissions) in which HC emissions are 0.821 g/km, CO is 0.841g/km, NOx is 0.126 g/km.

Table 3: *Results of fuel consumption and HC, CO emissions*

HF	Consumption (l/100 km)	HC (g/km)	%HC	CO (g/km)	%CO
0,5	6,1	0,821	-13%	0,841	-9,7
0,486	6,2	0,842	-12,2 %	0,857	-8%
0,473	6,2	0,863	-10,9 %	0,872	-6,4 %
0,459	6,3	0,874	-7%	0,873	-6,3 %
0,445	6,4	0,904	-4%	0,901	-3,3 %
0,432	6,5	0,929	-1%	0,919	-1,3 %
0,418	**6,5**	**0,945**	**0%**	**0,932**	**0%**
0,392	6,7	0,972	+2%	0,933	+0,1 %
0,365	6,9	1,052	+11%	1,013	+8,7 %
0,338	7	1,104	+16,8 %	1,057	+13, 4%

0,297	7,2	1,1 84	+25,2 %	1,11 7	+19, 8%
0,256	7,5	1,2 27	+29,8 %	1,12 2	+20, 3%
0,108	8,4	1,4 85	+57%	1,31 5	+41 %

In Table 3, the values shown in bold are the value of the original car without improvement with HF = 0.4189 and fuel consumption of 6.5 l/100km, HC = 0.945 g/km, CO = 0.932 g/km. After the improvement, we found that with the coefficient of HF=0.5, the fuel consumption is 6.1 l/100km (less consumption than the unimproved car), HC = 0.821 g/km (reduced gas volume). emissions 13% compared to the unmodified vehicle), CO = 0.841 g/km (9.7% emission reduction compared to the unmodified vehicle). For HF=0.1081, the level and fuel consumption are 8.4 l/100km, HC=1,485 g/km (57% increase in emissions compared to unimproved vehicles), CO=1,315 g/km (increase emissions by 41% compared to unmodified vehicles)

To have a more general view of the fuel consumption and emissions of the 1998 Toyota Prius, we conduct more car simulations with the ECE_EUDC operating cycle [3] when the vehicle has been improved with a change in combustion engine power. in from 43 kW to 37 kW and electric motor from 31kW to 37 kW.

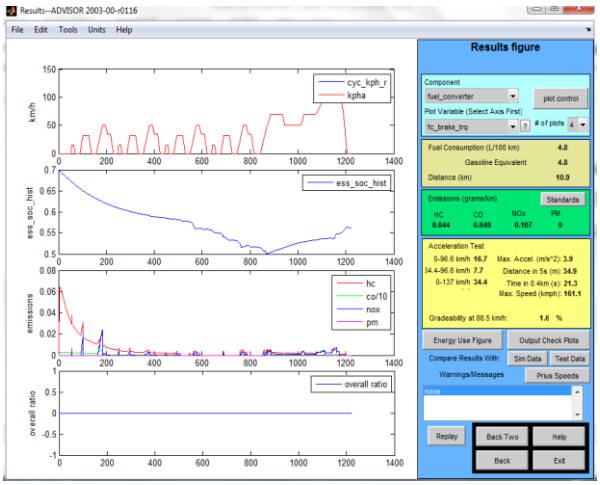

Figure 11: *Simulation results following the improved ECE_EUDC cycle*

The fuel consumption of the 1998 Prius when running the ECE_EUDC cycle is 4.8 L/100 km.

The acceleration of the car (Acceleration Test) from 0-96.6 km is 16.7 seconds, from 64.4 to 96.6 km is 7.7 seconds, from 0-137 km is 34.4 seconds. The maximum acceleration achieved by the vehicle is 3.9 m/s^2 the distance traveled in 5s is 34.9 m, the travel time in 0.4 km is 21.3 seconds, the maximum speed achieved by the vehicle. is 161.1 km/h

Emissions in which HC emissions are 0.644 g/km, CO is 0.649 g/km, NOx is 0.107 g/km.

2.2.4 Summary

After performing simulations, analyzing and evaluating the results obtained from simulating Toyota Prius, we have the following conclusions:

When the Toyota Prius runs on the UDDS operating cycle, the exhaust gas content and fuel consumption is relatively less than when the vehicle runs on the CECDC cycle, due to the road conditions in Vietnam, many intersections have signal lights and often Due to frequent traffic jams, the exhaust gas and fuel levels are relatively high compared to vehicles operating under the UDDS cycle.

Toyota Prius cars run according to the CECDC operating cycle in different modes, the fuel consumption and exhaust emissions are also different. Therefore, improving the Toyota Prius by changing the power of the internal combustion engine from 43 kW to 37 kW and the electric motor from 31kW to 37 kW is the most optimal. After conducting simulations with the above change plan, the fuel consumption is quite low at 6.1 l/100 km, reducing 0.4 l/100km, HC emissions of 0.821 g/km, reducing 13%. Compared with the unimproved car, the CO is 0.841g/km, which is 9.7% lower than that of the unimproved car.

To have a more general view of the cycles, so that the ECE_EUDC cycle is simulated according to the most optimized parameters for the thesis to easily compare with the CECDC cycle in Vietnam, we find that when running with the ECE_EUDC operating cycle, the fuel consumption and emissions are lower than the CECDC operating cycle, the reason the CECDC operating cycle has more acceleration and deceleration points in general is that the vehicle is not stable in speed. temperature, resulting in more fuel consumption and more exhaust gas.

Therefore, the Toyota Prius improvement plan with an internal combustion engine capacity of 37 kW and an electric motor capacity of 37 kW is the most optimal solution.

3. Conclusion

This article has clearly outlined the development history and general structure of hybrid vehicles as well as Toyota Prius, basic parameters of Toyota Prius.

The topic has stated the capabilities and limitations of the ADVISOR simulation program, the ADVISOR program is used to simulate and give results to evaluate the dynamics and emissions of hybrid vehicles. Present the parameters of the ADVISOR program and their meanings.

Outlining the theoretical basis to serve the method of improving and simulating Toyota Prius.

Based on the obtained simulation results, the thesis also analyzes and evaluates the obtained simulation results, compares the results in different operating cycles.

From the best simulation results and choose the most optimal parameters for improving Toyota Prius cars to suit the road conditions in Vietnam.

The feasibility of the project can be applied to consulting Toyota to change the parameters of equipment and control methods to optimize fuel consumption and emissions in operating conditions in Vietnam. Male.

In order to study and change the vehicle parameters accordingly, the simulation method is the method applied by researchers and scientists today, because they want to let the car run in reality and get the experimental results to get the results. The most optimal results are extremely expensive in terms of money and time, to overcome those costs, the simulation method according to this topic is the most feasible method.

References

[1] Nguyen Huu Can, Du Quoc Thinh, Pham Minh Thai, Nguyen Van Tai, Le Thi Vang, Theory of tractors, Scientific and technical publishing house, 2007.

[2] Tong H. Y., Tung H. D., Hung W. T., Nguyen H. V. (2011), "Development of driving cycles for motorcycles and light-duty vehicles in Vietnam", Atmospheric Environment 45, 5191-5199

[3] T J Barlow, S Latham, I S McCrae and P G Boulter (2009), "A reference book of drinving cycles for use in the measurement of road vehicle emission",

[4] Kelly K.J., Rajagopalan A., (2001), "Benchmarking of OEM Hybrid Electric Vehicles at NREL", National Renewable Energy Laboratory, Golden, Colorado, USA.

[5] K. Wipke, M. Cuddy, D. Bharathan, S. Burch, V. Johnson, A. Markel, and S. Sprik. (1999), "ADVISOR 2.0: A Second - Generation Advanced Vehicle Simulator for Systems Analysis", National Renewable Energy Laboratory

[6] NREL (2001), Documentation - ADVISOR software 3.2, National Renewable Energy Laboratory

[7] T. Markel, A. Brooker, T. Hendricks, V. Johnson, K. Kelly, B. Kramer, M. O'Keefe, S. Sprik, K. Wipke(2002), "ADVISOR: a systems analysis tool for advanced vehicle modeling", National Renewable Energy Laboratory, Golden, CO 80401, USA

[8] Fan B.S.M. (2011), *Multidisciplinary Optimization of Hybrid Electric Vehicles-Component Sizing and Power Management Logic*, Doctoral Thesis, Waterloo, Ontario, Canada.

[9] Husain I. (2005), *Electric and Hybrid Vehicles - Design Fundamentals*, Taylor& Francis e-Library, I S B N 0-203-00939-8.

[10] Huang B., Shi X., and Xu Y. (2006), *Parameter Optimization of Power Control Strategy for Series Hyrbrid Electric Vehicle*, IEEE Congress on Evolutionary Computation, Vancouver, BC, Canada,1989-1994.

[11] Zhang B., Chen Z., Mi C., and Murphey Y.L. (2009), *Multi-objective Parameter Optimization of a Series Hybrid Electric Vehicle Using Evolutionary Algorithms*, Vehicle Power and Propulsion Conference, Dearborn, MI, 961-925.