Basrah Journal for Engineering Sciences, Vol. 20, No. 1, (2020), 15-22

Basrah Journal for Engineering Sciences

Journal homepage: www.bjes.edu.iq
ISSN (Online): 23118385, ISSN (Print): 18146120

OPEN ACCESS

Comparison of CVT Performance with the Manual and Automatic Transmission for Evaluation the Fuel Consumption and Exhaust Emissions

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Received: 18 September 2019; Accepted: 18 November 2019; Published: 2 February 2020

Abstract

The Continuously Variable Transmission (CVT) is the blends of the efficiency of a manual transmission with the ease of using the automatic transmission. Furthermore, the CVT is a developed technology that has infinite gear ratios with a high fuel economy and high capabilities of acceleration. In this paper, a comparative study was performed of the CVT performance with the manual and automatic transmission for evaluation the fuel consumption and exhaust emissions in the parallel hybrid electric vehicle (HEV). In addition, the parallel HEV with the CVT gearbox is selected from the Advisor software and their simulation methods, and then replaced with manual and automatic transmission. Moreover, the pollutants of the catalytic converter were recorded with all the molecules reactions of the exhaust emissions. The performance evaluation of the CVT was conducted by using the different worldwide standard driving cycles to simulate driving conditions and evaluation the fuel consumption and exhaust emissions. The CVT gearbox produced the best performance results in fuel economy with a marked reduction in exhaust emissions compared with some of the results obtained from the manual and automatic transmission due to the high efficiency of controlling speed ratio, in addition to the great effect in the performance than other transmissions. Finally, the CVT gearbox is considered as a favorite in travel inside the cities for the hybrid vehicle, due to a little fuel consumption and high efficiency of controlling variant speed ratio.

Keywords: CVT Gearbox, Automated Manual Transmission, Automatic Transmission, Parallel HEV, Fuel Consumption, Exhaust Emissions.

1. Introduction

A continuous variable transmission (CVT) has a continuously variable reduction ratio within a certain range, and providing an infinite number of gear ratios. Accordingly, the engine operates at the most economical conditions over a wide range of vehicle speeds [1]. Furthermore, many types of CVTs were developed, which have a high efficiency and presented better performance than other common transmissions. Generally, the CVTs have two pulleys the major and minor with a variable radius to transmit the power and have the combination of the chain or metal belt but they are not as widely used as a belt and chain CVTs. The two pulleys each including a pair of pulleys, one of which is fixed and the other is moved axially. In addition, to achieve better speed regulation, the effective radius of the major pulleys is reduced and increasing the radius of the minor pulleys or vice versa [2].

Therefore, several researchers are working to develop the CVT for using the features of CVT in all the vehicles. Where, Jian and Chau [3] in 2009, they proposed a novel Electronic-Continuously Variable Transmission (E-CVT) propulsion system using coaxial magnetic gearing. This propulsion system can achieve optimal fuel economy with minimum exhaust emission in addition to a good propulsion performance. The coaxial magnetic gears present a non-contact transmission torque, which overcoming of audible noise aroused from the mechanical planetary gears and low transmission efficiency. Finally, the operation modes were discussed and analyzed for the proposed system.

Dragos et al. [4] in 2010, they presented the driving cycle model and control strategy of two types of transmission systems in vehicular with the continuously variable transmission. In addition, the CVT presents a continuous of infinitely variable gear ratios compared with the automatic transmission, which has five gear ratios. Finally, the simulation results are presented for five driving cycles to validate testing the developed control strategy for one driving cycle.

Naderi et al. [5] in 2011, they presented a new fuzzy logic controller to promote the control speed of CVTs in vehicles. The simulation results of the controller demonstrate a low power consumption and root mean square error of output surface compared with results obtained from MATLAB.

Hofman et al. [6] in 2012, they compared the moderate efficiency CVT push-belt with high efficiency automated manual transmission (AMT). In addition, the results showed that a significantly improving CO_2 emission reduction of the switching topology, particularly for the hybrid electric vehicles that is depending on CVT. Furthermore, improving the relative CO_2 emission reduction by selecting the optimal fixed topology.

Kazemi et al. [7] in 2014, they designed the gear ratio changing strategy and control rules based on optimal control. Furthermore, the Matlab/Simulink was used to design the driver model for simulation of the driving cycle. In addition, implementing results of the optimal control rules in vehicle movement simulation to reduce fuel consumption are represented. Finally, the advantage of the presented method to reduce fuel consumption compared with the other approaches for gear ratio change strategies.

Zhang et al. [8] in 2015, they analyzed the strain energy losses that affect the transmission efficiency of the metal belt of CVTs and developing the mechanical model of the pulley and deformation. The finite element method was used to analyses performed strain energy, pulley stress, and strain. The results show increasing the transmission ratio, decreases strain energy of the driving pulley, whereas increasing the driven pulley after initially decreasing and increasing strain energy induced of total power loss. Deduce that when the transmission ratio is one the strain energy loss is minimum and compatible with the real behavior of these pulleys.

Alzuwayer et al. [9] in 2016, they investigated the implementation of a hydraulic pressure controller model to obtain the desired CVT gear ratios. In addition, the Optimal Operating Line (OOL) strategy is used to estimation gear ratios map that minimizing the fuel consumption depending on the cost function and the constraints. The controller of the vehicle model was tested on two driving cycles. Finally, the results show the effectiveness of the control strategy and hydraulic pressure controller that keeping the internal combustion engine operates at high efficiency.

Aulakh [10] in 2017, developed a simulation approach based Genetic Algorithm (GA) for tuning of the CVT. In addition, the balancing force was used for modeling the behavior of the CVT and the GA is used to optimize the CVT output variables. The variables tuned are the profiles of the primary and secondary cam and the primary and secondary spring stiffness in addition to the mass. The simulation behavior of CVT was tuned compared with the traditional method that was tuned experimentally. Finally, results obtained show that the simulation of the GA tuned method is similar to the traditional method in terms of accuracy.

Wu et al. [11] in 2018, they proposed a control strategy to optimized clamping force in the pulley to improving the transmission efficiency of the CVT under different driving conditions. In addition, the simulation model is established for simulation of the road conditions and the acceleration conditions. The simulation results show that the control strategy can optimize the transmission efficiency of CVT and therefore increasing the fuel efficiency of the vehicle.

Li et al. [12] in 2019, they proposed an optimal control strategy using CVT in the parallel configuration of hybrid electric vehicles. In addition, a quasi-static vehicle model was constructed, and the optimal torque split factor determines by dynamic programming, and the continuously variable transmission speed ratio for saving maximum fuel economy. The simulation results are conducted under different worldwide driving cycles conditions and indicate that the proposed method enhanced the drivability of the vehicle with maximum fuel economy.

The present paper aims to compare the performance of the CVT with the manual and automatic transmission for evaluation the fuel consumption and exhaust emissions in the parallel hybrid electric vehicle.

2. Vehicle Configuration

Generally, the parallel hybrid electric vehicle consists of the internal combustion engine connected with the fuel tank. In addition, the CVT gearbox is placed between the speed-coupling device and the driveshaft, the other side is connected to the differential and the wheels. The CVT gearbox allows the engine in optimal transmission operation to propelling the vehicle.

The IC engine is coupling with the electric motor by flywheel, the battery is considered as a supply power source connected to the DC-DC voltage converter on the other side. This configuration has the ability to propel the vehicle by the IC engine and the electric motor.

Fig.1 shows the configuration of the parallel hybrid electric vehicle with (a) CVT, (b) manual transmission, (c) automatic transmission. Table 1 shows the main parameters of the vehicle from Advisor software.

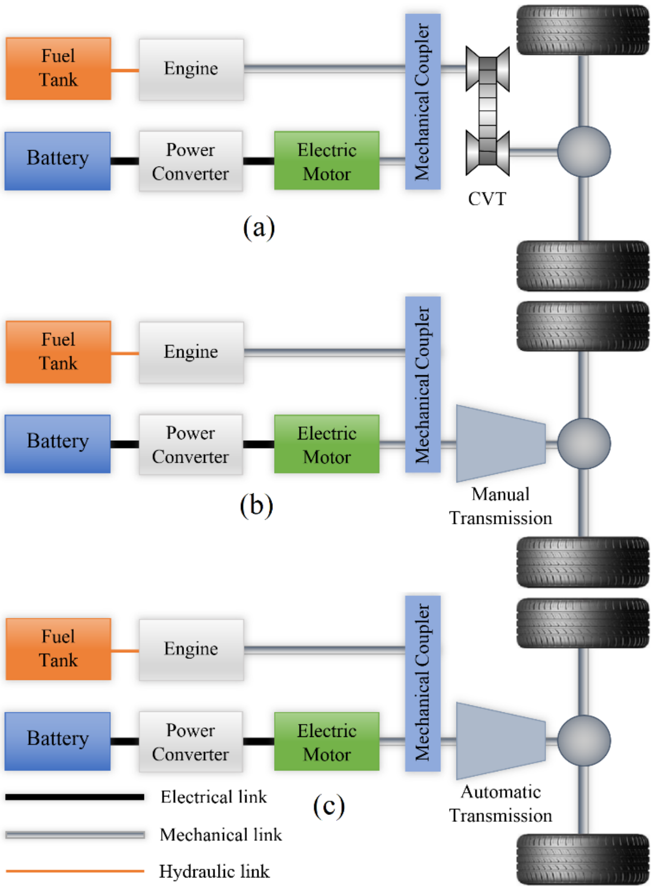

Fig.1 Parallel Hybrid Electric Vehicle with (a) CVT, (b) Manual Transmission, (c) Automatic Transmission.

Table 1 The main parameters of the vehicle from Advisor software.

Parameters	Value
Engine FC-SI41emis	Displacement: 1.0 L Max. power: 41 kW @ 5700 rpm Max. torque: 81 Nm @ 3477 rpm
Battery ESS-PB25	Capacity: 26 Ah Voltage: 308 V Max. power: 25 kW
Motor MC-PRIUS-JPN	Max. power: 31 kW
Frontal area	1.746 m^2
Aerodynamic drag coefficient	0.3
Coefficient of rolling resistance	0.01
Total vehicle mass	1635 kg

3. Continuous Variable Transmission (CVT)

The CVT provides varying drive ratios by varying the position of a high-strength steel belt between two metal pulleys. The sides of the pulleys are controlled by hydraulic pressure. One pulley is connected to the output of the engine and the other is connected to the power output side of the transmission [13]. The CVT can be changed the speed ratio continuously according to the working condition. In addition to controlling the speed ratio, the CVT greatly affects the fuel economy [12]. Fig. 2 shows the CVT configuration with input/output shaft.

The most common type in CVT is the push belt type, which has a belt consist of steel blocks segments collected on a steel ribbon. In addition, the CVT push belt has up to 400 steel components as shown in Fig. 3. This push belt transfers the torque from one of the pulleys to the other.

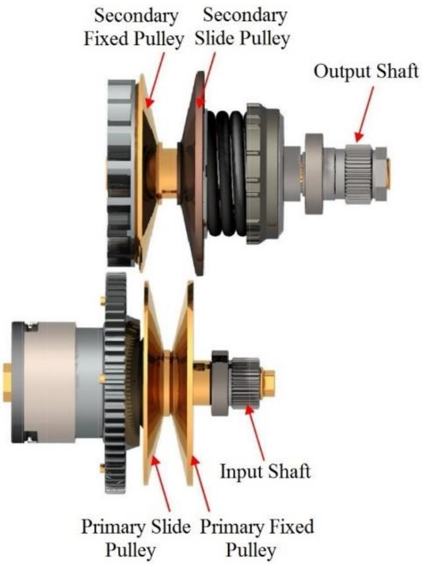

Fig. 2 CVT configurations with input/output shaft [15].

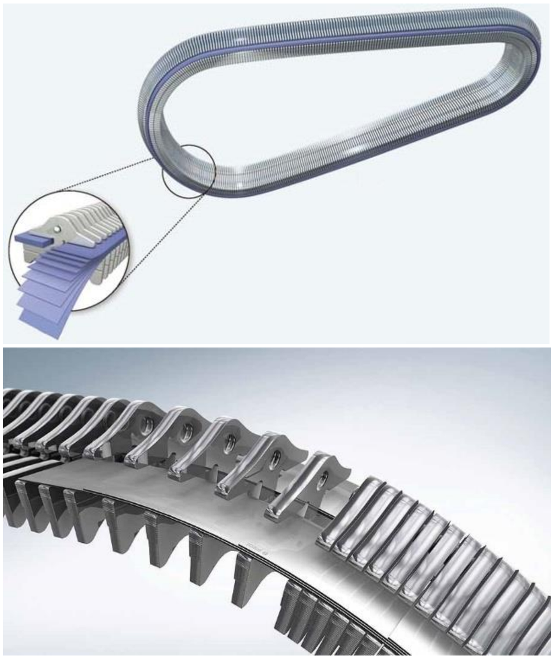

Fig. 3 CVT push belt up to 400 steel components [16].

This type of belt uses an electronic circuit for continuously changing the distance between the pulleys depending on the engine output.

This push belt type has drawn more attention to automakers due to high advantages [14].

The belt is clamped between the sheaves of each pulley by the oil pressure in a hydraulic chamber that leads to tensile force in the string. The CVT allows transmitting power by combined with pushing force between the push belt elements. Generally, a hydraulic actuation system is used to control the ratio of the CVT operation and implemented the clamping controlling force. In addition to controlling pressurized the fluid into and out of the piston for each pulley [17].

4. The Advisor Software Package

Advisor is software used to perform a comprehensive analysis of performances of a wide range of vehicles and it has script text files in addition to a set of data and different vehicle models. Advisor is flexible enough to operate on most computer platforms in the Matlab/Simulink software environment. Basically, it is designed for analysis and predicts fuel economy performance and exhaust emissions, in addition to the acceleration performance of conventional, electric, and hybrid electric vehicles [18].

5. Simulation Results and Discussion

5.1. Worldwide standard driving cycles conditions

In order to verify the performance of the CVT, manual transmission, and automatic transmission are simulated under different worldwide standard driving cycles conditions in Advisor software. In addition to three types of driving cycles were used to verify the performance of the vehicles as Urban Dynamometer Driving Schedule (UDDS), Highway Fuel Economy Test (HWFET), and US EPA Federal Test Procedure (FTP). Where, the vehicles are redesigned to make Advisor software work at different models of the transmission gearbox. Fig. 4, 5 and 6 show the UDDS, HWFET, and FTP driving cycles is used to verify the performance of the transmission gearbox in Advisor software.

Table 2 Driving cycle characteristic parameters from advisor program.

Parameters	UDDS	HWFET	FTP
Time (s)	1369	765	2477
Dist. (km)	11.99	16.51	17.77
V_{max} (km/h)	91.25	96.4	91.25
V_{avg} (km/h)	31.51	77.58	25.82
Acc_{max} (m/s^2)	1.48	1.43	1.48
$Dece_{max}$ (m/s^2)	- 1.48	- 1.48	- 1.48
Acc_{avg} (m/s^2)	0.5	0.19	0.51
$Dece_{avg}$ (m/s^2)	- 0.58	- 0.22	-0.58
Idle time (s)	259	6	360
No. of Stops	17	1	22

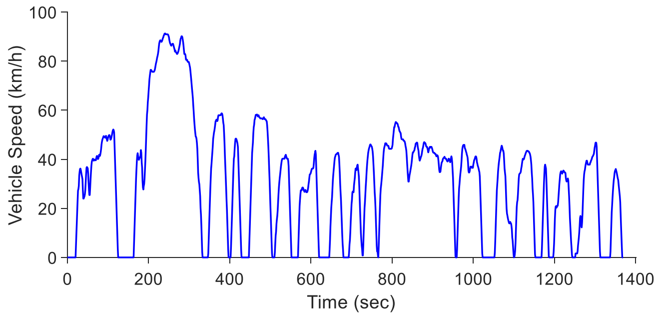

Fig. 4 UDDS driving cycle in Advisor software.

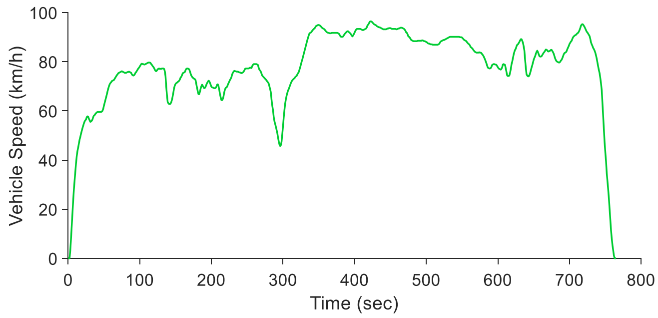

Fig. 5 HWFET driving cycle in Advisor software.

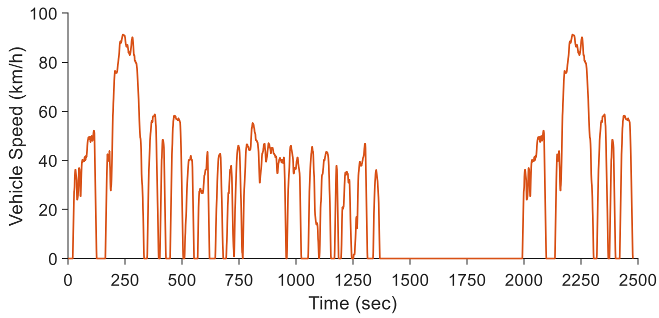

Fig. 6 FTP driving cycle in Advisor software.

5.2 Effect of the CVT on the Economic Performance for Evaluation the Fuel Consumption and Exhaust Emissions

In this work, the result of the UDDS driving cycle only reviewed to avoid repetition. However, the UDDS consider as the important driving cycle is used for testing CVT, manual and automatic transmission. This driving cycle is used for testing the vehicle fuel consumption and exhaust emissions at time intervals reach (1369 sec) and at maximum speed (91.25 km/h). The parameters of the UDDS driving cycle are presented in Table 2.

In order to investigate the effect of the CVT on the economic performance for evaluation the fuel consumption and exhaust emissions, the advisor software package were used. In addition, Fig. 7 shows the interface of advisor software and Fig. 8 shows the simulation of the parallel HEV model connected with the CVT. The gear ratios needed to minimize fuel consumption for each different case of the CVT, manual and automatic transmission as shown in Fig. 9. In addition, noticed from Fig. 9 that the CVT and the manual transmission both are operating at high gear ratios, whereas the automatic transmission operates at low gear ratios, this is due to the behavior of the driving conditions such as acceleration and load.

Fig. 10 shows the comparison of the CVT performance with manual and automatic transmission of the fuel consumption for the UDDS driving cycle. Accordingly, observed that the fuel consumption is higher when using the automatic gearbox than the manual transmission and CVT due to the complicated structure. In addition, exhibits less fuel consumption when using the CVT than the others due to the higher efficiency of controlling speed ratio, in addition to the greatly effect in the performance than other common transmissions.

Fig. 11 shows the comparison of the CVT performance with manual and automatic transmission of the battery state of charge (SOC) for the UDDS driving cycle. Accordingly, observed that the battery SOC is higher when using the manual gearbox compared with CVT and automatic transmission. Furthermore, when using the CVT demonstrate higher depleting of the battery SOC than the other gearboxes.

Fig. 12 shows the vehicle overall emissions when using the CVT as the transmission for the UDDS driving cycle. The overall emissions including Hydrocarbons (HC), Carbon Monoxide (CO), Nitrogen Oxides (NOx). Where observed that the overall emissions are less when using the CVT as a gearbox than the manual and automatic transmission. This due to the complete combustion of fuel and less fuel consumption, which leads to minimizing pollutant emissions.

Fig. 13 shows the vehicle overall emissions when using manual transmission for the UDDS driving cycle. Also observed that the overall exhaust emissions are higher when using manual transmission compare with CVT and less than the automatic transmission.

Fig. 14 shows the vehicle overall emissions when using automatic transmission for the UDDS driving cycle. In addition, observed that the overall exhaust emissions when using automatic transmission are greater than the CVT and manual transmission. Table 3 shows the economic performance and exhaust emissions of all transmission for different driving cycles.

In this work, observed variation in values of the comparison results obtained from the CVT with the manual and automatic transmission. The results obtained can be summarized as follows:

1. The results of all the driving cycles, UDDS, HWFET and FTP, which tested show minimum fuel consumption of the CVT compared with the other transmissions. This saving of fuel is due to the higher efficiency of controlling speed ratio, which reduces fuel consumption.
2. When using the CVT as a gearbox, noticed reduced the exhaust emissions of the Hydrocarbons (HC), the Carbon Monoxide (CO) and Nitrogen Oxides (NOx) under all the driving cycles conditions due to the complete combustion of fuel compared with the manual and automatic transmission, where reaches to (0.326 g/km), (2.118 g/km) and (0.239 g/km) respectively. Furthermore, low fuel consumption led to depleting the battery state of charge more than the other transmissions reaches to (0.596).
3. Under HWFET driving cycle conditions and when using the CVT as a gearbox, noticed reduced all the exhaust emissions of (HC), (CO) and (NOx) compared with the other gearboxes where is reaches to (0.259 g/km), (0.984 g/km) and (0.213 g/km) respectively. Whilst, the battery state of charge is approximately the same as the other transmissions, where reaches to (0.639).
4. Under FTP driving cycle conditions and when using the CVT as a gearbox noticed different values for all the exhaust emissions of the (HC), (CO) and (NOx) compared with the other gearboxes where is reaches to (0.253 g/km), (1.649 g/km) and (0.208 g/km) respectively. The battery SOC is consumed more than the other transmissions, where reaches to (0.565).

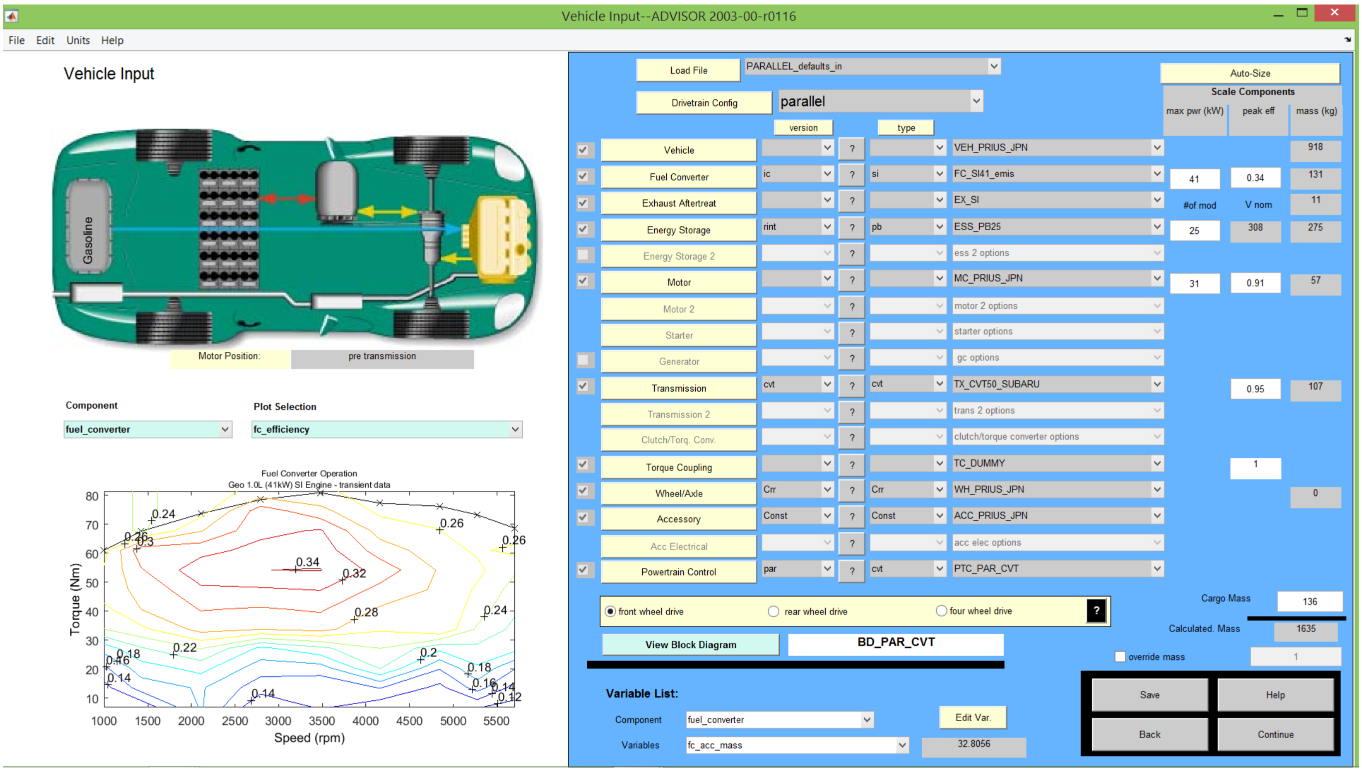

Fig. 7 the interface of advisor software for parallel HEV.

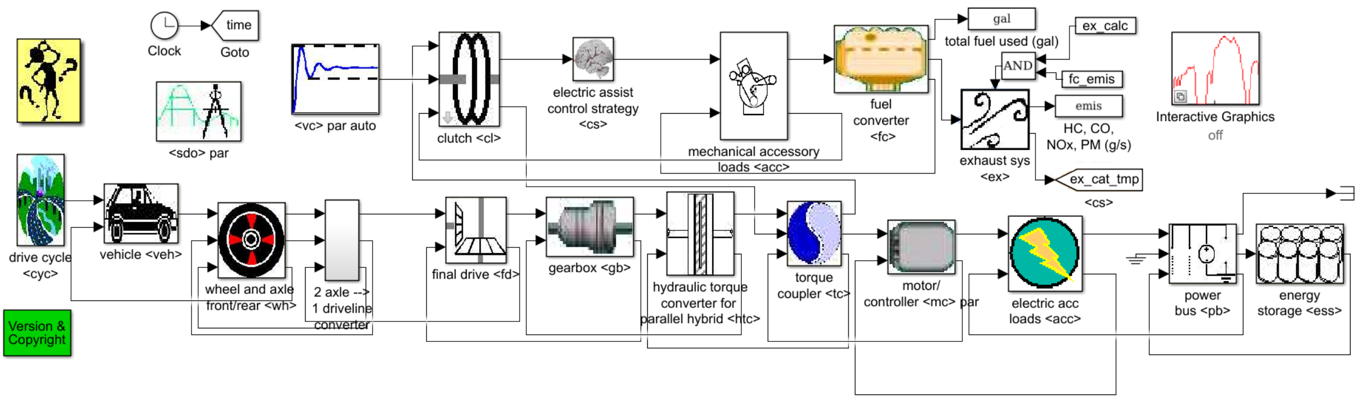

Fig. 8 Simulation of the parallel hybrid electric vehicle model.

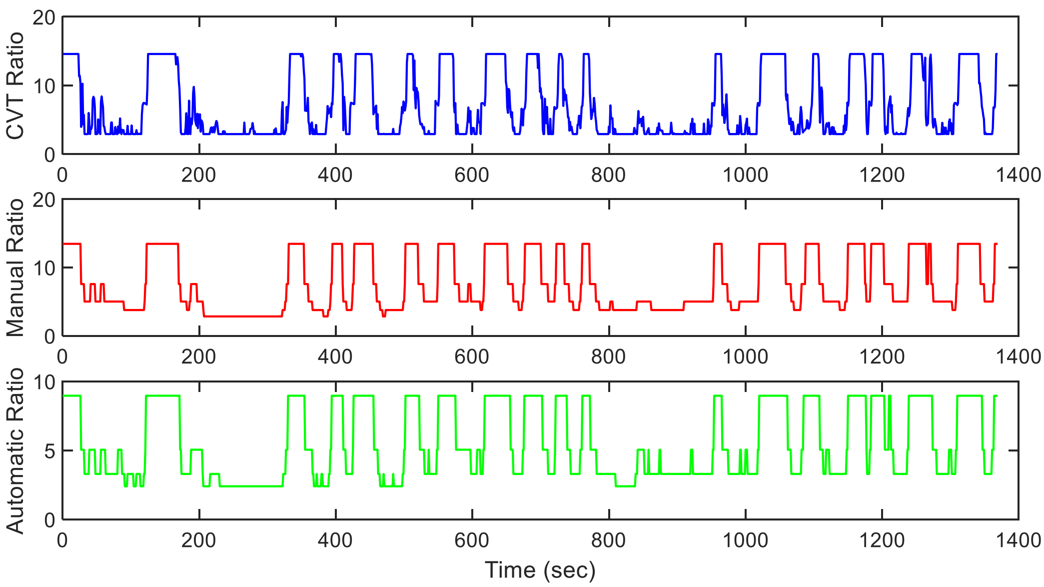

Fig. 9 Gear ratios for the CVT, manual and automatic transmission for UDDS driving cycle.

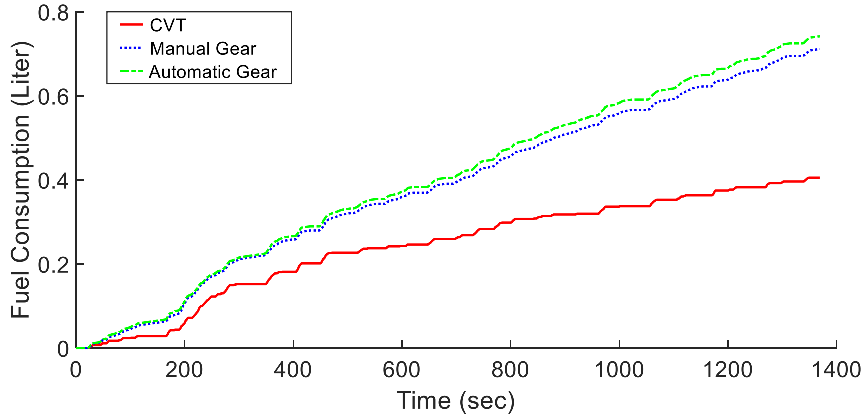

Fig. 10 Overall fuel consumption for UDDS driving cycle.

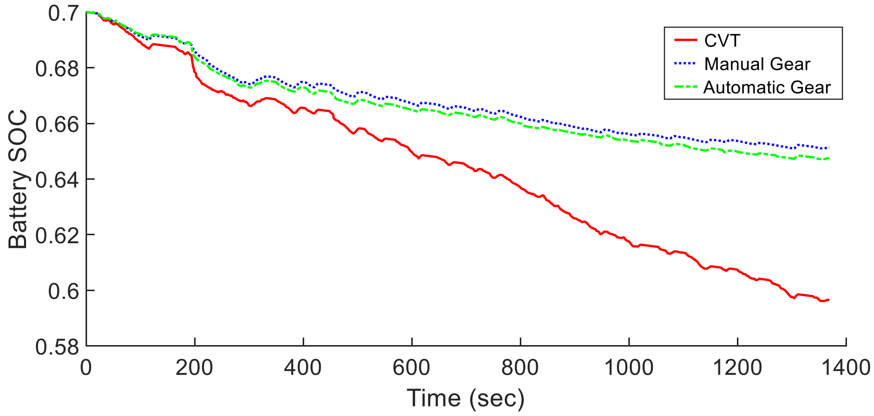

Fig. 11 Overall battery SOC for UDDS driving cycle.

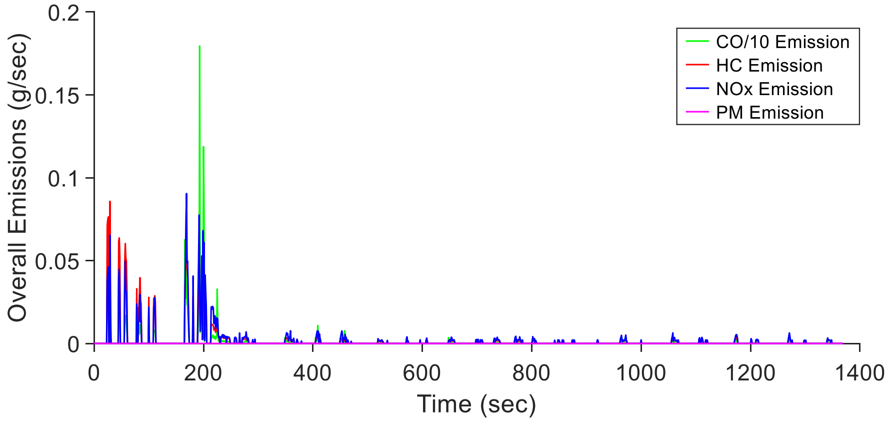

Fig. 12 Overall emissions of the CVT for UDDS driving cycle.

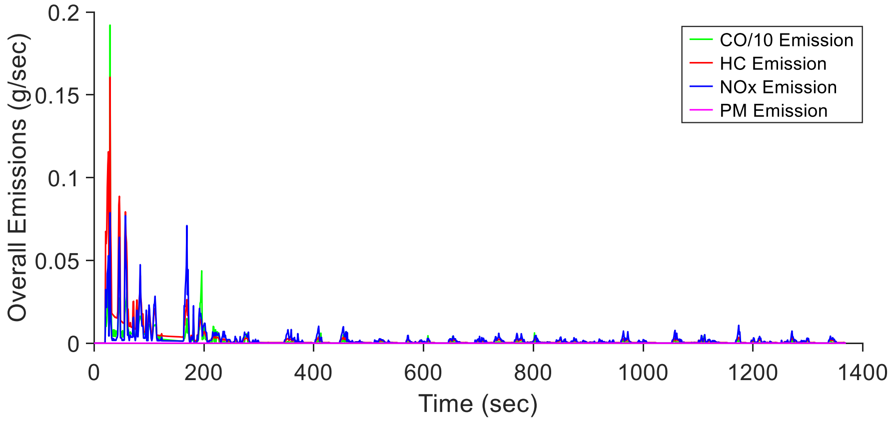

Fig. 13 Overall emissions of the manual transmission for UDDS driving cycle.

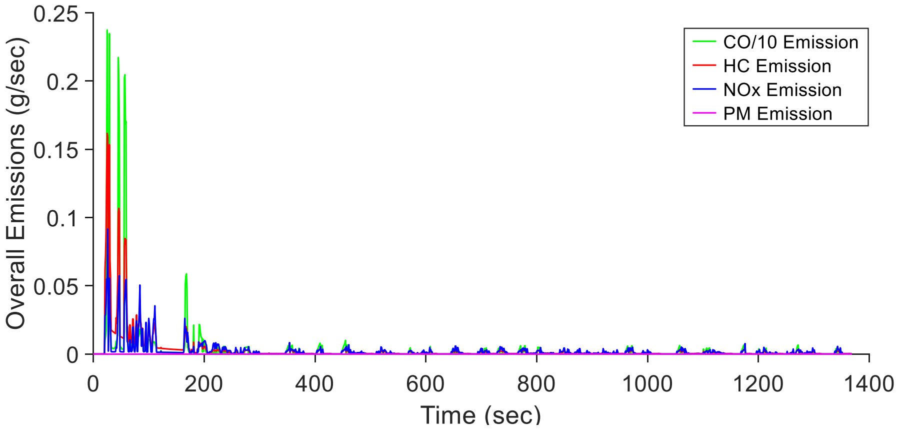

Fig. 14 Overall emissions of the automatic transmission for UDDS driving cycle.

Table 3 The economic performance and exhaust emissions of all transmission for different driving cycles.

Driving cycle	CVT					Manual Transmission					Automatic Transmission				
	FC (L/100km)	HC (g/km)	CO (g/km)	NOx (g/km)	SOC	FC (L/100km)	HC (g/km)	CO (g/km)	NOx (g/km)	SOC	FC (L/100km)	HC (g/km)	CO (g/km)	NOx (g/km)	SOC
UDDS	3.4	0.326	2.118	0.239	0.596	5.9	0.337	2.658	0.276	0.651	6.2	0.363	3.229	0.258	0.648
HWFET	3.6	0.259	0.984	0.213	0.639	4.4	0.263	1.163	0.221	0.649	4.3	0.273	1.79	0.237	0.648
FTP	3.6	0.253	1.649	0.208	0.565	6	0.264	1.811	0.233	0.647	6.2	0.28	2.55	0.214	0.635

6. Conclusions

The CVT is the blends of the efficiency of a manual transmission with the ease of using the automatic transmission. The CVT is a developed technology it has infinite gear ratios and higher fuel efficiency in addition to high capabilities of acceleration. Therefore, the important conclusions obtained from this work as:

1. The CVT and the manual transmission both are operating at high gear ratios, whereas the automatic transmission operates at low gear ratios.
2. The fuel consumption is less when using the CVT as a gearbox than the other transmissions due to the high efficiency of controlling speed ratio, in addition to the great effect in the performance than other common transmissions.
3. The battery state of charge showed higher depleting when using the CVT compared with the other automatic and manual transmission.
4. The overall emissions when using the CVT as a gearbox is less than the manual and automatic transmission. This due to less fuel consumption and the complete combustion of fuel, which leads to minimizing exhaust emissions.
5. The CVT gearbox is considered a favorite in travel inside the cities for the hybrid vehicle, due to the little of fuel consumption and higher efficiency of controlling variant speed ratio.

References

[1] Ali Emadi, Advanced Electric Drive Vehicles, CRC Press, Taylor & Francis Group, ISBN-13: 978-1-4665-9770-9, LLC, 2015.

[2] Shouqi Chen, Linsen Xu, Hong Xu, Jinfu Liu, Gaoxin Cheng, and Kai Cao, "Principle, Design and Simulation of a Novel Continuously Variable Transmission for Robots", 2019 IEEE 8th Joint International Information Technology and Artificial Intelligence Conference (ITAIC), pp.73-78, 24-26 May 2019. https://doi.org/10.1109/ITAIC.2019.8785689

[3] Linni Jian, and K. T. Chau, "A Novel Electronic-continuously Variable Transmission Propulsion System Using Coaxial Magnetic Gearing for Hybrid Electric Vehicles", Journal of Asian Electric Vehicles, Vol. 7, No. 2, December 2009. https://doi.org/10.4130/jaev.7.1291

[4] C.-A. Dragos, S. Preitl, R.-E. Precup, C.-S. Nes, D. Pirlea, and A. S. Paul, "Control Solutions for Vehicles with Continuously Variable Transmission", 11th IEEE International Symposium on Computational Intelligence and Informatics, Budapest, Hungary, 18-20 November 2010. http://dx.doi.org/10.1109/CINTI.2010.5672256

[5] Ali Naderi, Mortaza Aliasghary, Alireza Pourazar, Hadi Ghasemzadeh, "A 19MFLIPS CMOS Fuzzy Controller to Control Continuously Variable Transmission Ratio", 7th Conference on Ph.D. Research in Microelectronics and Electronics, Trento, Italy, 3-7 July 2011. http://dx.doi.org/10.1109/PRIME.2011.5966213

[6] Theo Hofman, Soren Ebbesen, and Lino Guzzella, "Topology Optimization for Hybrid Electric Vehicles with Automated Transmissions", IEEE, Transactions on Vehicular Technology, Vol. 61, No. 6, July 2012. http://dx.doi.org/10.1109/TVT.2012.2196299

[7] Reza Kazemi, Mohsen Rafat, and Amir Reza noruzi, "Nonlinear Optimal Control of Continuously Variable Transmission Powertrain", Hindawi Publishing Corporation, ISRN Automotive Engineering, Volume 2014, Article ID 479590, 11 pages. http://dx.doi.org/10.1155/2014/479590

[8] Wu Zhang, Wei Guo, Chuanwei Zhang, and Farong Kou, "Loss of strain energy in metal belt for continuously variable transmission (CVT) pulley", Springer, Journal of

Mechanical Science and Technology, Vol. 29, No. 7, pp. 2905-2912, 2015. http://dx.doi.org/10.1007/s12206-015-0621-0

[9] Bashar Alzuwayer, Aviral Singh, Prasanth Muralidharan, and Zhijun Han, "Model Based Pressure Control of a Push Belt Continuously Variable Transmission", Scientific Research Publishing, Modern Mechanical Engineering, Vol. 6, pp. 99-112, 2016. http://dx.doi.org/10.4236/mme.2016.64011

[10] Deepinder Jot Singh Aulakh, "Development of simulation approach for CVT tuning using dual level genetic algorithm", Taylor & Francis, Cogent Engineering, Vol. 4, No. 1398299, 2017. https://doi.org/10.1080/23311916.2017.1398299

[11] Wu Guang-bin, Lu Yan-hui, and Xu Xiao-wei, "Optimization of CVT Efficiency Based on Clamping Force Control", Elsevier, Science Direct, IFAC Papers Online, Vol. 51, No. 31, pp. 898-903, 2018. http://dx.doi.org/10.1016/j.ifacol.2018.10.087

[12] Hangyang Li, Xiaolan Hu, Bing Fu, Jiande Wang, Feitie Zhang, and Yunshan Zhou, "Effective optimal control strategy for hybrid electric vehicle with continuously variable transmission", Advances in Mechanical Engineering, Vol. 11, No. 3, pp. 1-11, 2019. http://dx.doi.org/10.1177/1687814018824811

[13] Jack Erjavec, Hybrid, Electric & Fuel-Cell Vehicles, Second Edition, Delmar, Cengage Learning, ISBN-13: 978-0-8400-2395-7, 2013.

[14] Rushikesh Chaware, V. H. Bansode, "Trends in Continuously Variable Transmission System: A Literature Review", 3 International Conference on Ideas, Impact and Innovation in Mechanical Engineering (ICIIIME 2017), Vol. 5, Issue 6, pp. 222-226, June 2017.

[15] B.B.M.F. Kuijpers, "Implementation of a Suzuki Electronically controlled Continuously Variable Transmission in a Formula Student racecar", Bachelor Final Project, Eindhoven University of Technology, Department Mechanical Engineering, Dynamics and Control Technology Group, December 2009.

[16] https://www.hybridcars.com/basic-cvt-insight/

[17] Sameh Bdran, Samo Saifullah, and Ma Shuyuan, "An Overview on Control Concepts of Push-Belt CVT", IACSIT International Journal of Engineering and Technology, Vol. 4, No. 4, August 2012.

[18] Haider S. Najem, Qahtan A. Jawad, Abdulbaki K. Ali, and Basil S. Munahi, "Developing a General Methodology and Construct a Driving Cycle with an Economic Performance Evaluation for Basrah City", International Journal of Engineering & Technology, Vol. 7, No. 4.19, pp. 939-944, 2018. http://dx.doi.org/10.14419/ijet.v7i4.19.28074

Biographies

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