International Journal of Engineering Trends and Technology
ISSN: 2231 – 5381 /doi:10.14445/22315381/IJETT-V69I9P215

Volume 69 Issue 9, 116-123, September, 2021

Reducing Fuel Consumption of a Passenger Car Towards Energy Efficient Vehicle by using Belted Alternator StarterTechnology

Shaiful Fadzil Zainal Abidin[1], Siti Nur Aizierah Mohd Rodzi[1], Amir Khalid[1,*], Izzarief Zahari[2],
Rifqi Irzuan Abdul Jalal[3], Mohd Azman Abas[4]

[1]*Centre of Automotive and Powertrain Technology, Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, Pagoh Education Hub, Johor 84600, Malaysia*
[2]*Perusahaan Otomobil Nasional Sdn. Bhd. Hicom Industrial Estate, 47600 Shah Alam, Selangor, Malaysia.*
[3]*Universiti Kuala Lumpur - Malaysia France Institute (UniKL MFI), Section 14, Jalan Damai, Seksyen 14, 43650 Bandar BaruBangi, Selangor.*
[4]*Automotive Development Centre, School of Mechanical Engineering, Faculty of Engineering, Universiti Teknologi Malaysia, 81310 Johor Bahru, Malaysia.*
amirk@uthm.edu.my

Abstract — *Many car companies are currently looking into developing hybrid electric vehicles (HEV) and electric vehicles (EV) to address global warming issues and current stringent emission legislation. Thus, this research presents a 48V mild-hybrid technology feasibility study to reduce vehicle fuel consumption to achieve the ASEAN roadmap 2025 target as the automotive industry worldwide moves toward energy-efficient vehicles in the future. The research aims to design and develop a 1-D full vehicle model equipped with a 48V belted alternator starter (BAS) as a mild-hybrid solution and understanding the impact on overall vehicle fuel consumption in the drive cycle. This research's vehicle model is a mid-sized sedan powered by a 1.8L engine coupled to a 6-Speed Automatic Transmission (6AT). The baseline vehicle model is developed using industrial vehicle simulation software. The results have been compared and correlated with actual vehicle measurements. The models with and without the BAS system are then reviewed in a few aspects related to fuel consumption, according to NEDC and WLTP drive cycles. Implementing mild-hybrid systems is expected to reduce the overall vehicle fuel consumption by approximately 7.3% in NEDC and 3.5% in WLTP. The fuel consumption assessment of both drive cycles has proven that the BAS system's implementation could reduce fuel consumption. The research's significant findings are valuables for further development in strategizing the hybrid technologies and its control strategy in supporting low carbon footprint initiatives by the local authority and ASEAN roadmap.*

Keywords — *Belted alternator starter, Fuel consumption, Mild-hybrid, NEDC, WLTP.*

I. INTRODUCTION

An automobile fuel economy relates to the distance a car travels with fuel consumed through the driving event. Fuel consumption is measured in the fuel volume required to travel a specific distance. The CO2 emission emits from the exhaust pipe is directly related to the amount of fuel consumed. Thus, the more the fuel, the more the CO2 is produced and released into the air, resulting in poor air quality. Due to that, most researchers from vehicle manufactures introduced an add-on technology to the current conventional combustion engine to cut down the fuel in specific driving conditions [1-9]. Apart from that, vehicle optimization and driving behavior also play a significant role in reducing total emissions. The fuel energy is required to overcome the vehicle losses, which includes wind, weight, tire, and internal friction resistance. Different techniques may be implemented to reduce losses at each transition between the fuel's chemical energy and the vehicle's kinetic energy. Fuel economy is also influenced by driver behavior, such as sudden acceleration, maneuvering, and heavy braking waste. Thus, the technology implementation into the vehicle must align with the target and the requirement for fuel consumption and emissions. Focusing on ASEAN, the couries members have come out with the proposal for fuel consumption target for the light-duty vehicle with an average of 5.0 L/100 km by 2025 [3].

The study concentrates on a passenger car's fuel economy and vehicle performance as the worldwide automotive industry moves toward Energy Efficient Vehicle (EEV). On top of that, Malaysia also seeks to achieve targeted vehicle fuel consumption in Malaysia by 2030 to be an average of 5.0 L/100 km, in line with the ASEAN Fuel Economy Roadmap [3]. Therefore, this study analyzed the best vehicle optimization configuration that meets global fuel efficiency standards and emission legislation. The vehicle model used is a 1.8L engine coupled to a 6-Speed Automatic Transmission (6AT). A 48V mild-hybrid BAS system is added to vehicle models as an add-on technology to reduce fuel consumption. The entire vehicle model is developed and optimized to achieve the target. Thus, both vehicle models were analyzed: with and without BAS for each driving cycle [10-14]. The BAS uses an electrical machine mounted on the front-end accessory drive (FEAD) connected via a belt to the internal combustion engine. It is the most common approach for mild-hybrid electric vehicles. The engine start-up and electrical re-generation function are realized by a single electric motor, which also can act as a generator [10-12]. The engine-stop start technology functions by shutting down the engine when operating at idle speed to reduce fuel consumption and emissions. The BAS system shuts down the engine's fuelling when the vehicle stops at rest (for example, stops at traffic light), at the cruising speed where the BAS torque is enough to drive the vehicle, and during deceleration state, where the vehicle coasts down the hill [15-19].

The controller helps it cut off the fuel and stop the engine. The conditions typically vary from vehicle to vehicle. Battery state of charge (SOC) and engine temperature are crucial. To prevent early battery aging, the SOC is generally kept under strict limits. Suppose the battery SOC is low from the previous discharge stages. In that case, the engine must not be turned off because it can drop below the lower limit during the corresponding cranking. Regenerative braking converts kinetic energy into electrical energy during vehicle braking phases associated with fuel cut-off. The converted energy is stored in the batteries and then used to provide electrical power assist during the idle stop and launching state. It is possible to reduce battery charging during fuel cruising by maximizing the regenerative braking control, reducing fuel used [19-23]. The BAS system also can react as an electric power-assist, also known as a torque booster, supplying extra torque to assist the engine during transients, such as beginning and rapid accelerations, to assist the engine. The electric motor produces the torque required without needing to gear down to satisfy the driver's requirement. This programmed gear shift schedule helps the engine work more effectively with an apparent fuel efficiency advantage. Battery energy, mechanical motor features, and thermal limitations restrict the power and length of electrical assistance [24-27].

II. MATERIALS AND METHODS

This study's main objective is to design and develop a 1-Dimensional vehicle model for fuel consumption analysis using a simulation tool. According to the case study, the vehicle is modeled using a GT-SUITE vehicle modeling software then analyzed with GT-POST. The complete drive cycle analysis is conducted to evaluate the vehicle's fuel consumption at different selected driving cycles.

A. Vehicle Modelling in GT-SUITE

A complete vehicle model is simulated to run in different driving cycles in determining a passenger vehicle's fuel consumption and performance characteristics. Figures 1 and 2 show the model used for the GT-SUITE simulation. The vehicle used in this study is a mid-sized front-wheel drive (FWD) vehicle model driven by a 1.8L engine coupled to a 6-Speed-Automatic Transmission. A small BAS motor is attached to the engine to give the vehicle stop-start capability for the mild-hybrid vehicle model.

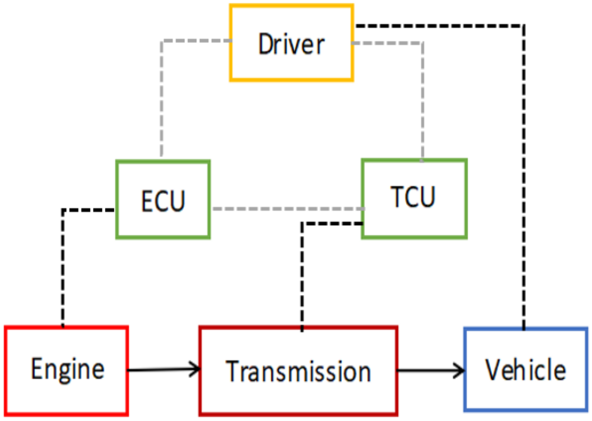


Fig.1 Conventional vehicle model schematic layout in GT-SUITE (without BAS)

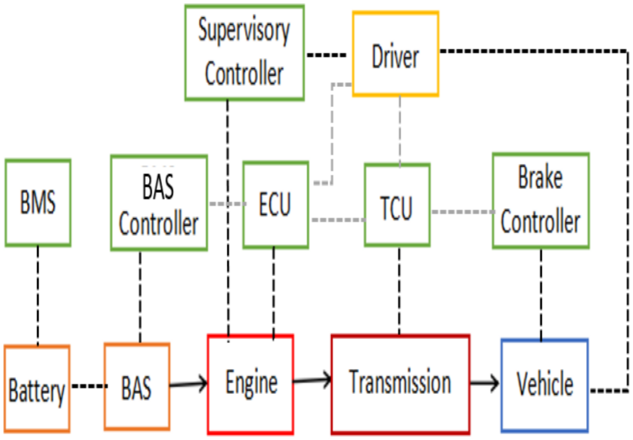


Fig.2 Mild-hybrid vehicle model schematic layout in GT-SUITE (with BAS)

B. Vehicle Model Specifications

Table 1 below shows the vehicle model's specifications in this study. The vehicle specifications for both models with BAS and BAS are the same.

TABLE 1. VEHICLE MODEL SPECIFICATIONS

Item	Description
Engine	1.8L Turbocharged and Gasoline Direct Injection (TGDI)
No. of Cylinders	4-cylinder
Induction	Forced, Turbocharger
Transmission	6-speed AT
TotalDisplacement	1801 cc
Min. Engine Speed	750 RPM
Max. Engine Speed	5500RPM
Max. BMEP	23.4 bar @ 4000 rpm
Max. Power	173kW @ 5000 rpm
Max. Torque	335Nm @ 4000 rpm
Kerb Weight	1500 kg

Figure 3 shows the process's overall flow from the beginning of designing and developing 1-D vehicle models in simulation software to data analysis and till the end of the study.

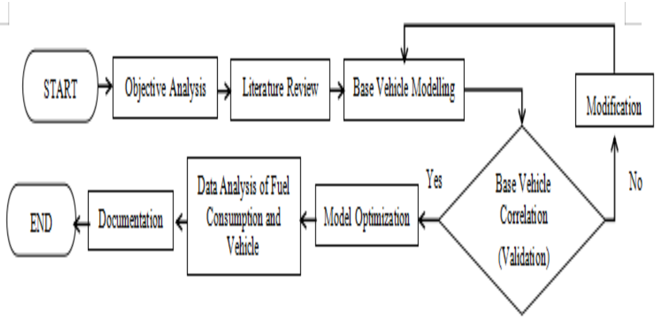


Fig.3 Methodology flowchart

Modeling and simulation are steps forward in predicting vehicle performance that uses computers and software to replicating the physical phenomena. The software, such as GT-SUITE, provides real-life research based on the user's feedback experience. It would shorten the time taken for an inaccurate design flaw to be found compared to traditional tests such as road checks.

III. RESULTS AND DISCUSSION

Two drive cycles are selected, NEDC and WLTP, to study the performance and evaluate vehicles' fuel consumption with and without BAS. The results are presented in time-based for both cycles for data comparison.

A. Drive Cycles

A driving cycle is a series of data points that indicate a vehicle's speed versus time. This study's vehicle models are simulated in two different driving cycles, which are NEDC and WLTP. The NEDC comes from the New European Driving Cycle designed in the 1980s and introduced in 1990 to replicate how a car is usually used in Europe. The velocity profile of the NEDC is visualized in Figure 5. The cycle was last revised in 1997. It became ineffective due to technology evolutions and different driving conditions for each country and city.

Consequently, the European Union has established a new test called the Worldwide Harmonized Light Vehicle Test Procedure (WLTP). The European automotive industry supports the change to WLTP and has actively created this new test cycle. Although the old NEDC calculated test values based on a theoretical driving profile, the WLTP process was developed using data gathered worldwide. Furthermore, WLTP reflects better daily driving profiles [16]. The WLTP driving cycle analysis is divided into four parts with average velocities: low, medium, high, and extra high. The growing component includes several phases of driving, stops, acceleration, and braking. Figure 4 shows the velocity profile of WLTP, while Table 2 provides the drive cycles' details, respectively.

TABLE 2. PARAMETERS OF NEDC AND WLTP

Parameter	NEDC	WLTP
Cycle Time [s]	1180	1800
Distance [km]	11.00	23.24
Maximum Speed [km/h]	120	131.2
Average Velocity [km/h]	33.57	46.5

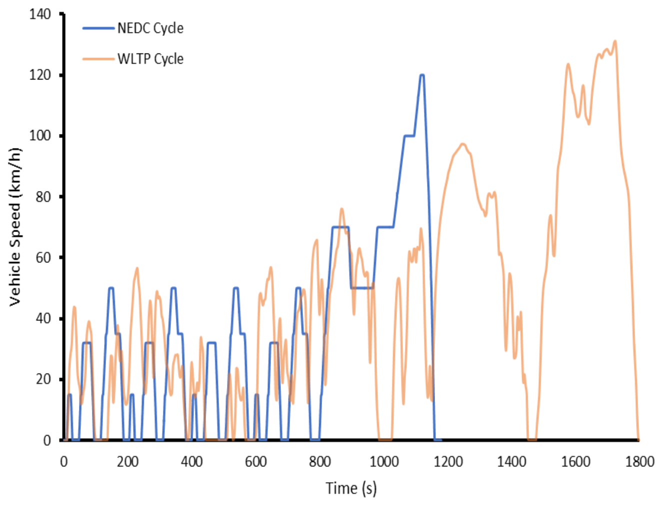


Fig. 4 Velocity profile of NEDC and WLTP

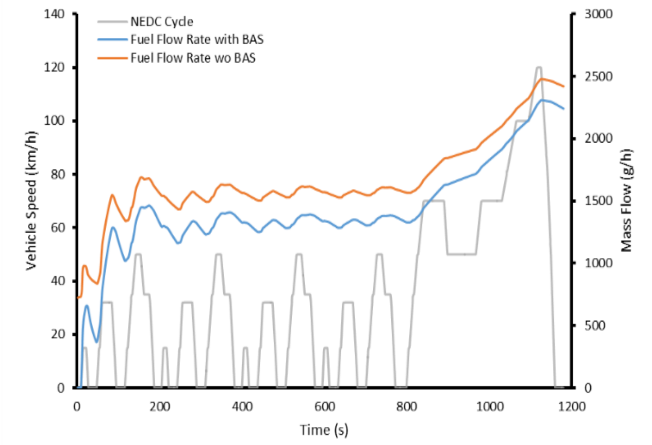
A comparison of fuel consumption in L/100km analysis for 1.8L with and without BAS is shown in Table 3.

TABLE 3. FUEL CONSUMPTION COMPARISON ON EACH CYCLE IN L/100KM

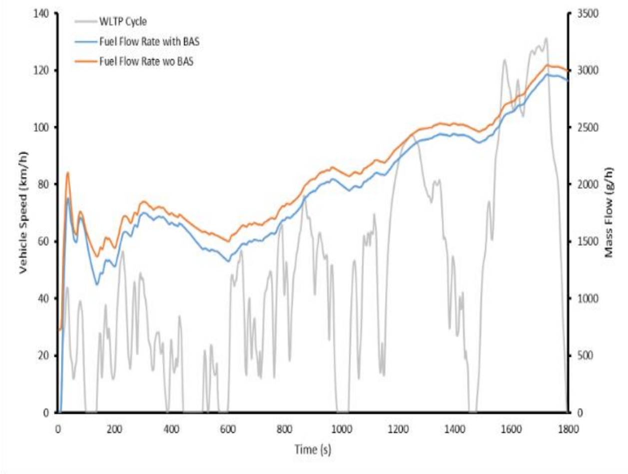
Drive Cycle	Vehicle A (with BAS)	Vehicle B (without BAS)	Improvement
NEDC	8.9	9.6	7.29%
WLTP	8.3	8.6	3.49%

B. Fuel Mass Total And Fuel Flow Rate

The vehicle simulation on NEDC and WLTP driving cycles is designed to analyze the total fuel mass total and fuel flow rate for both vehicle models, with and without BAS.



(a)



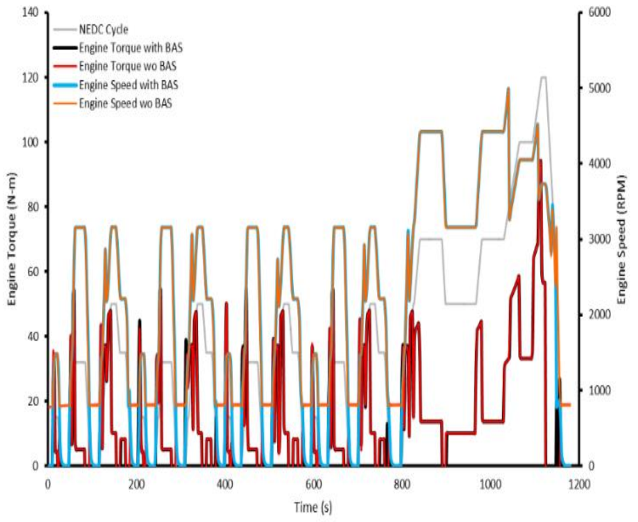
(b)

Fig.5 Fuel flow rate with cycle profile (a) NEDC. (b) WLTP

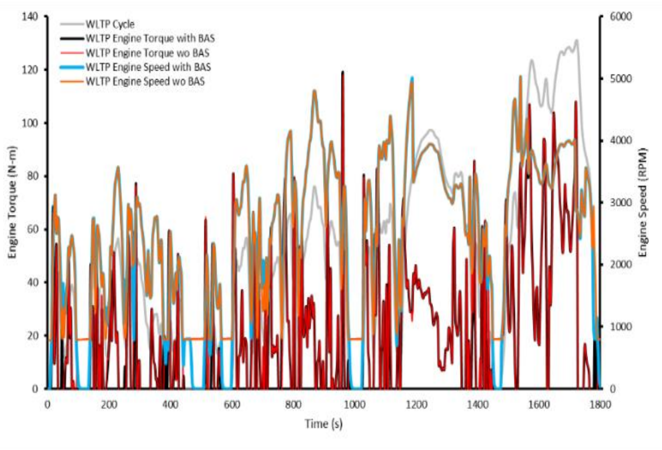
Figure 5 shows the fuel flow rate with cycle profile under NEDC and WLTP. The vehicle without BAS (vehicle B) has consumed more fuel than the vehicle with BAS (vehicle A) since the beginning of the cycle. Vehicle A has a stop-start function where the engine stops running at an idle state. When the engine is off, there is no combustion happening inside the engine. Hence no fuel is consumed at that time, proven in the graph for vehicle A in both cycles. Since the zero-second cycle, there is a significant difference between vehicles A and B. The vehicle model's fuel mass total is remarkably reduced with the stop-start function application.

C. Engine Torque And Engine Speed

Figure 6 shows the engine speed and engine torque for both vehicles A and B on each cycle. The vehicle is at an idle state based on the cycle profile when the speed is 0 km/h. Thus, at idle state, vehicle B's engine speed is at 800 rpm while vehicle A's engine speed is 0 rpm.



(a)



(b)

Fig.6 Engine torque and engine speed with cycle profile (a) NEDC (b) WLTP

The engine is still running for vehicle B, but not for vehicle A. When the engine is still running, combustion still occurs in the cylinders chamber, which consumes fuel. The engine remains at stop conditions for vehicle A until the driver presses the clutch pedal (for manual transmission) or depresses the brake pedal (for automatic transmission) to triggers the BAS system to crank up the engine.

Torque is a spinning force generated by the crankshaft of the engine. The more torque an engine creates, the greater its capacity to do work. Figure 7 shows that vehicle B's engine produces more torque than vehicle A. It is more distinctive at idle state, where vehicle A has no torque value because the engine is turned off. Meanwhile, vehicle B has significant torque because it is still running at the idle state to avoid stalling. During re-launching, vehicle B produces more torque to propel the vehicle, resulting in more fuel. Meanwhile, vehicle A receives extra torque from BAS that acts as a torque booster during this state conditions. Hence, the engine produces less torque than conventional ICE to propel the vehicle for re-launching resulting in lower engine speed.

D. State Of Charge

Based on Figure 7, at the start of each cycle, the battery is 80%. It was noted that the SOC increased gradually due to the charging strategy until both cycles reached almost 85%. Depending on the pedal position acceleration, the charge state will decrease (indicates discharging) during cruising. Due to the high propulsion required, the system discharged, causing SOCs to drop marginally at high vehicle speed, at about 1000 to 1100 seconds of the NEDC cycle and around 1200 seconds for the WLTC cycle. Nevertheless, the SOC increased significantly by the end of both driving cycles due to the regenerative braking system.

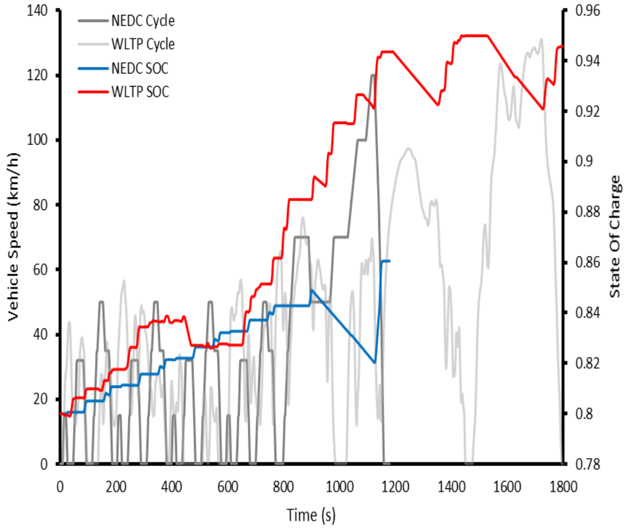


Fig.7 State of charge for vehicle model

With the same mild-hybrid vehicle model used in this study (vehicle A), the SOC of the vehicle was set to 20% and simulated with the NEDC cycle. The result obtained from the simulation concluded that the vehicle acted the same as a conventional vehicle. The BAS system could not function fully at low initial SOC. Thus, the amount of fuel consumed is in the same range as conventional vehicles without BAS.

E. Bas States And Bas Torque

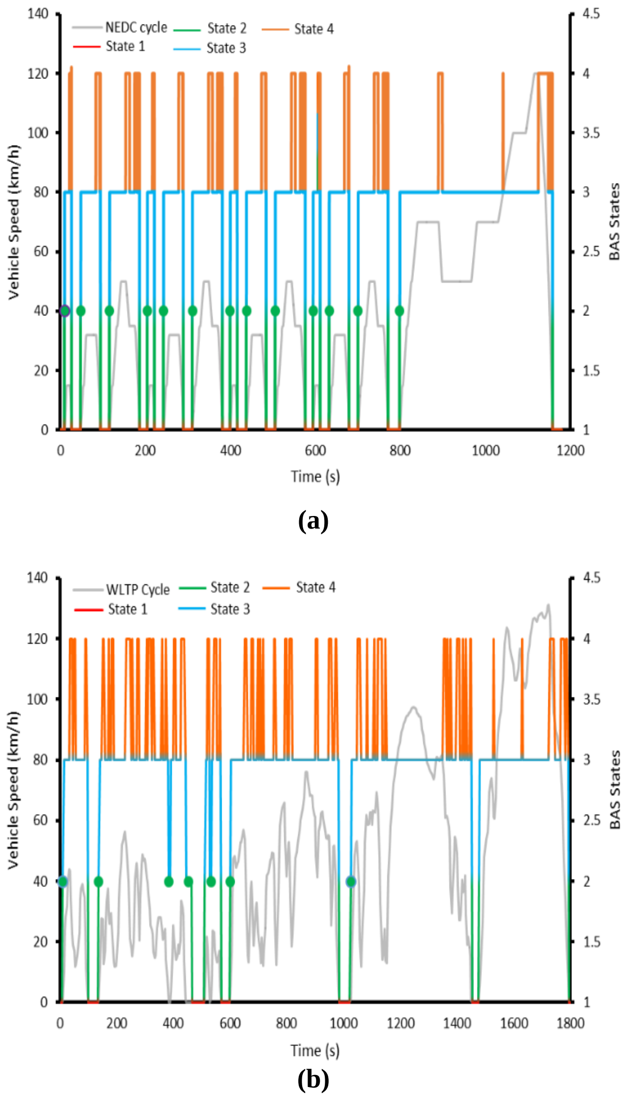
Figure 8 shows the BAS states with cycle profiles for NEDC and WLTP. The condition in percentages of the vehicle's state for both cycles is presented in Table 4.

TABLE 4. THE BAS STATES IN DRIVING CYCLES

BAS States	1	2	3	4
Colour	Red	Green	Blue	Orange
States Condition	Engine off	Launching	Engine Only	Regenerative braking
State % on NEDC	8.95	0.58	69.98	20.49
State % on WLTP	3.58	2.10	68.00	26.30

Figure 8 shows that when the vehicle is idle (State 1), the BAS system triggers the stop-start function. No fuels are injected into the engine cylinders during this phase since the engine is fully turned off. The occurrence of state 1 in NEDC is about 9% of the total cycle. Meanwhile, only 3.58% of the entire cycle is in state 1 for WLTP. The WLTP test cycle is more aggressive with more acceleration and deceleration events, developed based on actual transient driving conditions.

The BAS system acts as a torque booster by supplying extra torque to restart the engine and accelerate the vehicle. The engine receives extra torque from BAS and lowers the overall fuel consumption during the launching state. A significant spike of BAS torque is observed during the acceleration state (State 2), as shown in Figure 9. Thus, the overall engine speed is slightly lower than the conventional vehicle without the BAS system. The benefit of the BAS system in the WLTP test cycle is more significant than NEDC due to the cycle pattern with more launching from rest events.

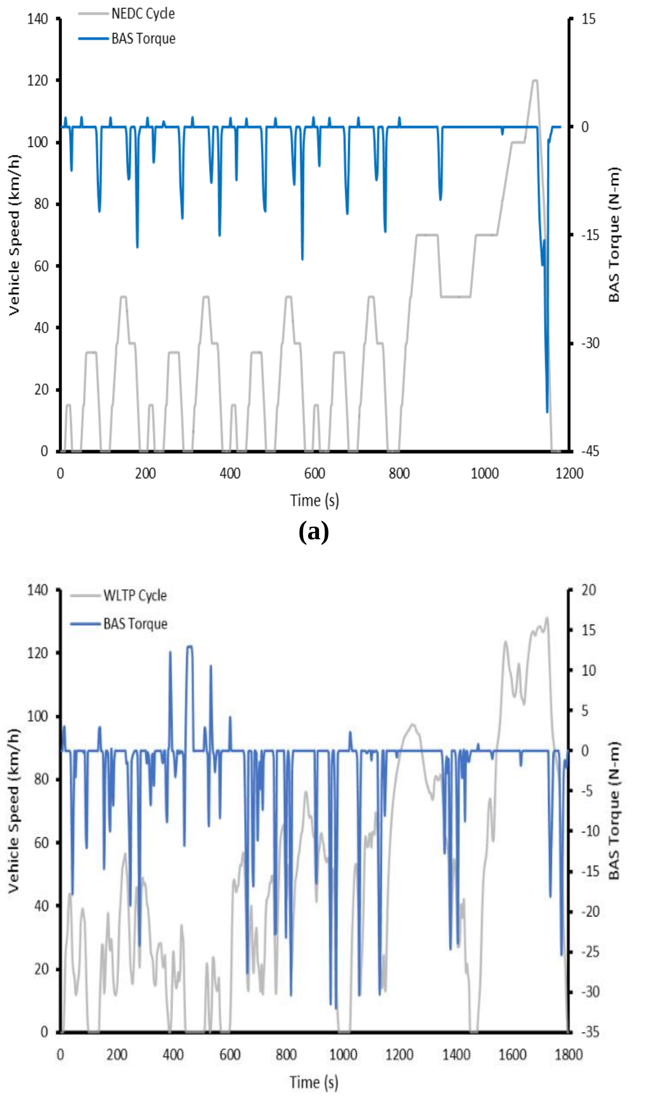


(a)

(b)

Fig.8 BAS states with cycle profile (a) NEDC(b) WLTP

At acceleration conditions (State 3), the vehicle is powered purely by the engine without any assistance from BAS, and it covers almost 70% of the total cycle for both NEDC and WLTP. The BAS system produces no torque at this condition. This is due to the power available from the engine is enough to accelerate the vehicle. Furthermore, the power capacity of the BAS system is small. Thus it won't give any advantages to the engine. Next is regenerative braking, which is state 4. It occurs when the vehicle starts braking and when the vehicle decelerates throughout the drive cycle. The BAS reverses its function in regenerative brakes, acting as a generator charging the battery. As shown in Figure 9, this negative torque slows down the rotating motor shaft connected to the vehicle's wheels. It recaptures the load available kinetic energy by recharging the battery with a regenerated current.



(a)

(b)

Fig.9 BAS Torque with cycle profile (a) NEDC (b) WLTP

The regenerative state covers approximately 26.3% in WLTP and 20.5% in NEDC. It is important to maintain the battery SOC so that the BAS system can assist the engine in driving the vehicle where it is needed, especially during acceleration and engine restart states.

In this study, the vehicle model for fuel economy and performance analysis was successfully designed and developed using the GT-SUITE simulation tool. The vehicle model was also optimized by implementing the 48V mild-hybrid system and achieving its target and legislation requirements. The vehicle model was simulated through two driving cycles, NEDC and WLTP, then both data have been compared. The comparison of overall fuel consumption obtained through this study for both driving cycles is shown in Table 5.

TABLE 5. OVERALL IMPROVEMENT OF FUEL CONSUMPTION IN L/100KM

Drive Cycle	Vehicle without BAS	Vehicle with BAS	Reduction	Improvement
NEDC	9.6	8.9	0.7	7.29%
WLTP	8.6	8.3	0.3	3.49%

IV. CONCLUSION

The 48V Belted Alternator Starter (BAS) is a promising add-on technology with cost-effective solutions in the modern vehicle to reduce fuel consumption and CO2 emissions. The vehicle model for fuel economy and performance analysis was successfully developed using the GT-SUITE simulation tool. The model has been correlated with the actual vehicle performance on laboratory testing to maintain the model accuracy. The vehicle model was also optimized by implementing the 48V mild-hybrid system and achieving its target and legislation requirements. The vehicle model was simulated through two driving cycles, NEDC and WLTP, then both data have been compared. It can be concluded that there is an improvement in fuel consumption between vehicles without BAS and with BAS. The fuel consumption has been improved by an average of 7.29% from 9.6L/100km to 8.9L/100km in the NEDC drive cycle. For the WLTP cycle, fuel consumption improved by an average of 3.49% from 8.6L/100km to 8.3L/100km. In other words, the implementation of mild-hybrid technology successfully reduced the fuel consumption for 0.7L/100km and 0.3L/100km for each cycle, respectively. These findings are valuables for further development in strategizing the hybrid technologies and its control strategy in supporting low carbon footprint initiatives by the local authority and ASEAN roadmap.

ACKNOWLEDGEMENT

The authors would like to thank the Ministry of Higher Education (MOHE) through fundamental Research Grant Scheme No. FRGS/1/2019/TK10/UTHM/02/10 Vot K224 and Universiti Tun Hussien Onn Malaysia (UTHM) through tier 1 (H793). The authors would also like to thank the Automotive Development Centre, Universiti Teknologi Malaysia, and Automotive Engineering Section, Universiti Kuala Lumpur (UniKL-MFI), for their support.

REFERENCES

[1] Mustaqim, M. S., Hashim, M. S. M., Shahriman, A. B., Razlan, Z. M., Zunaidi, I., Wan, W. K., Nagaya, Y. (2018). Comparative Study on Fuel Consumption and Different Driving Cycles for a Passenger Car in Malaysia via 1-D Simulation. IOP Conference Series: Materials Science and Engineering, 429, 012057. doi: 10.1088/1757-899x/429/1/012057

[2] Zhou, M., Jin, H., & Wang, W. (2016). A review of vehicle fuel consumption models to evaluate eco-driving and eco-routing. Transportation Research Part D: Transport and Environment, 49, 203–218. doi: 10.1016/j.trd.2016.09.008

[3] ASEAN Secretariat. (2019, February). ASEAN Fuel Economy Roadmap for the Transport Sector 2018-2025: with Focus on Light-Duty Vehicles. Jakarta.

[4] Ministry Of International Trade And Industry. (2020). National Automotive Policy 2020 (2nd ed.). Kuala Lumpur, Malaysia.

[5] Shahridzuan Abdullah, I., Khalid, A., Jaat, N., SaputraNursal, R., Koten, H., &Karagoz, Y. (2021). A study of ignition delay, combustion process, and emissions in a high ambient temperature of diesel combustion. Fuel, 297 doi:10.1016/j.fuel.2021.120706.

[6] Anton OlegovichBorovlev, Aleksey Vasilyevich Skrypnikov, Vyacheslav Gennadievich Kozlov, Vladimir AnatolyevichZelikov, Galina AnatolyevnaPilyushina, Valery Alfeyevich Burmistrov, Maria NikolaevnaKazachek. Intelligent Design System for Logging Truck Roads, International Journal of Engineering Trends and Technology, 69(8) (2021) 89-95.

[7] R. Narayanamoorthy, S. Sivaprakasam, P. Sivaraj. Nallusamy. Experimental Analysis of Engine Characteristics of Spark Ignition Engine FuelledBy Low Cetane Fuel. International Journal of Engineering Trends and Technology, 68(12) (2020) 58-65.

[8] Sanchit Shrivastava, Roopesh Tiwari, Suman Sharma (2019). “Design and Analysis of Heavy Commercial Vehicle Chassis Through Material Optimization”, International Journal of Engineering Trends and Technology, 67(12),33-36.

[9] Khalid, A., Mustaffa, N., Manshoor, B., Zakaria, H., Alimin, A. J., Leman, A. M., &Sadikin, A. The comparison of preheats fuel characteristics of biodiesel and straight vegetable oil doi:10.4028/www.scientific.net/AMM.465-466.161 (2014).

[10] Shaiful Fadzil Zainal Abidin, Amir Khalid, Siti Nor Zulaikha Shafai@Shafie, IzzariefZahari, RifqiIrzuan Abdul Jalal, Vehicle Fuel Economy Improvement through Vehicle Optimization in 1-D Simulation Cycle towards Energy Efficient Vehicle (EEV), International Journal of Integrated Engineering, 12(8) (2020) 365-375.

[11] Abidin, S.F.Z., Khalid, A., Latip, M.F.A., Zahari, I., Jalal, R.I.A. , Gear Ratio Optimization of Manual Transmission for Passenger Vehicle Using 1D Simulation Cycle and Statistical Analysis, International Journal of Advanced Trends in Computer Science and Engineering, 9(2020).

[12] Environmental Protection Agency, U. S.. Your Mileage May Vary. Retrieved from https://www.epa.gov/greenvehicles/your-mileage-may-vary (2018)

[13] Nicolas, R. (2013). The different driving cycles. Retrieved from https://www.car-engineer.com/the-different-driving-cycles/

[14] Barlow, T. J.. A reference book of driving cycles for use in the measurement of road vehicle emissions: version 3. doi: 978-1-84608-924-4 (2009).

[15] Rus, T. (2018, June 22). Explained: WLTP vs. NEDC - what are they, how do they work. Retrieved from https://drivemag.com/news/explained-wltp-vs-nedc-what-are-they-how-do-they-work

[16] Ciuffo B, Marotta A, Tutuianu M, Anagnostopoulos K, Fontaras G, Pavlovic J, Serra S, Tsiakmakis S, Zacharof N. (2015), Development of World-Wide Harmonized Test Procedure for Light-Duty Vehicles: Pathway for Implementation in European Union Legislation. Transportation Research Record 2503, 110-118.

[17] Daimler. Part II: WLTP and NEDC: Comparing the measurements. Retrieved from https://www.daimler.com/sustainability/climate/wltp/wltp-part-2.html (2019).

[18] Ministry Of International Trade And Industry. National Automotive Policy 2014 (1st ed.). Kuala Lumpur, Malaysia (2014).

[19] Clark, J., & Daigle, G. The importance of simulation techniques in ITS research and analysis. Proceedings of the 29th conference on Winter simulation(1997).

[20] M. ShAsfoor, A. M. Sharaf, and S. Beyerlein,, Use of Gt-Suite To Study Performance Differences Between Internal Combustion Engine (ICE) and Hybrid Electric Vehicle (HEV) Powertrains, (2014) 27–29,

[21] Singh, K.V., Bansal, H.O. & Singh, D. A,, comprehensive review on hybrid electric vehicles: architectures and components. J. Mod. Transport. 27 (2019) 77–107.
[22] Aditya Kumar Kumawat, Amrit Kumar Thakur,(2017). A Comprehensive Study of Automotive 48-Volt Technology. SSRG International Journal of Mechanical Engineering 4(5), 7-14.
[23] Budde-Meiwes, H., Drillkens, J., Lunz, B., Muennix, J., Rothgang, S., Kowal, J., & Sauer, D. U. A review of current automotive battery technology and future prospects. Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering, 227(5) (2013) 761–776. doi: 10.1177/0954407013485567
[24] Bao, R., Avila, V., & Baxter, J. Effect of 48 V Mild Hybrid System Layout on Powertrain System Efficiency and Its Potential of Fuel Economy Improvement. SAE Technical Paper Series. doi: 10.4271/2017-01-1175, (2017).
[25] Baldizzone, S.. Performance and Fuel Economy Analysis of a Mild Hybrid Vehicle Equipped with Belt Starter Generator. Electronic Theses and Dissertations. 4790. https://scholar.uwindsor (2012).
[26] Kim, J. S., & Kim, J. W. (2016). Effects of Initial SOC of 270-Volt Battery on Operating Performance of Gasoline Engine and Electric motor in a Parallel Hybrid Vehicle under IM240 Driving Cycle Mode. Advances in Automobile Engineering, 01(S1) (2016). doi:10.4172/2167-7670.s1-008
[27] Skydel, B., Morgan, B., Jones, B., Sickels, B., Crissey, B., & Staff, B. (2020). Slow it down: How maximum torque at lower RPMs can lead to fuel efficiency gains (2020).