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***Abstract*- The transportation division is a main cause of worldwide carbon emissions and represents a significant contributor to air quality issues, particularly in metropolitan areas. To address the enormous carburization issues, the transportation sector must embrace low-emission vehicle technology. The team is presently developing a passenger electric hybrid car with the goal of reducing the environmental pollution. Hybrid electric vehicles (HEVs), which have a record of success in lowering hydrocarbon usage, stand as an intermediary technique between fully electric cars and internal combustion engines. In the present work, the conventional gasoline car has been tested on road at different trips condition. The gasoline fuel consumption as well as the SI engine emissions has been tested. A complete Hybrid electric system has been impeded instead of conventional driving gasoline engines and tested at a different charging rate of the battery. A comparison between the tested systems shows increased fuel efficiency as a key advantage of using HEVs technology. However, there are still unresolved issues about the system's energy reliability. HEVs emit up to 21.0, 5.8, 9.0-, and 23.3-times lower NOx, UHC, CO, and particle number emissions than comparable gasoline vehicles. The development of after-treatment systems, enhanced engine management methods and the use of renewable fuels are emerging as research strategic priorities.**

Keywords: Hybrid electric vehicles; Emission; Internal combustion engine; Gasoline fuel; Diesel fuel; Greenhouse gas emissions

I. INTRODUCTION

Several decades ago, researchers were seeking for applying new technologies to improve car engine efficiency and emissions [1, 2]. To achieve these goals low temperature combustion has been applied with a new and renewable resource of fuel was investigated [3-5]. Even using nanotechnology as a new trained does not improve engine performance and emission behaviors until now with an acceptable level [6-8]. For that reason, the transportation industry is one of the world's top-rising industries [9, 10]. The transportation sector consumes about 30% of the world's total delivered energy[11]. Most of the present transportation system relies on liquid hydrocarbon fuels [12, 13]. It uses about 60% of global oil demand and produces a huge amount of excessive GHG and other air pollution emissions [14-16]. Road vehicles are consuming most of the transportation oil demand[17]. It represents about 89% of transportation energy demand in 2020 [15, 18]. Light-duty vehicles consumed the highest amount of energy (57%) in the world as presented by the previous research [19, 20]. It is also predicted that the number of vehicles will more than double by 2050 compared with 2000 [21]. In European Area, the transportation industry is largely blamed for the pollution of air in highly populated urban areas. It is dependable for nearly a quarter of all CO emissions and about one-third of overall energy consumption [22, 23]. These air pollutants have a significant negative influence on the ecosystem and people's health. New legislation has been promoted and affected the European transportation sector through Euro I–VI, which restricts emissions of CO, HC, NOx, and particulate issues. As Euro VI became into force, the focus is nowadays on CO_2 emissions. The European Commission has set up a 130 g/km of CO_2 target for 2015 and reduced it to 95 g/km of CO_2 in 2021 [24, 25]. Similar strategies have been enacted in other automotive markets, such as the USA, Japan, and China[26].

With the ability to reduce greenhouse emissions and other harmful emissions using technologies of hydrogen-fuel cell vehicles, enhanced biofuel and internal combustion engine (ICE) technologies as well as batteries in electric cars [27, 28]. Hybrid Electric powertrains are considered an attractive and competitive transportation technology. It has been believed the most liable and immediate choices by automotive manufacturers due to its benefits of great energy saving and low exhaust emissions producing. That is a suite for motorized transportation in urban areas [29]. Hybrid electric vehicles (HEVs), stand for an intermediate technology between modern ICEs and fully electric cars [30]. With the help of the electric motor, power HEVs are able to consume less fuel, especially for vehicles used in an urban environment where higher accelerations and lower average speeds[31, 32]. The electric motor may be considered the primary mover as the internal combustion engine runs at a lower efficiency point under these conditions [7, 33]. So, the most important property of hybrid vehicle systems is that fuel economy can be noticeably increased to meet increasingly stringent emission standards besides drivability requirements. Thus, hybrid vehicles could play a vital role in saving the world's environment and the problem of growing energy insecure needs since the ICE isn't needed to run all over the trip [34]. Battery capacity, Electric Motor power limits, and grid charge ability define several levels of electrification [35]. Hybrid electric car can be classify like micro-hybrid, mild hybrid, full hybrid, or plug-in hybrid electric vehicles. Table 1 shows the differences between types of hybrid electric vehicles.

The type of Plug-in HEVs (PHEVs) is the ultimate technology of HEVs. All functions and benefits of other HEVs are been included at PHEVs. It can be recharged directly from the electric grid which allows the integration of a high-capacity battery and powerful EM to drive the vehicle. By only running at high speeds, PHEVs make it possible for the Internal Combustion Engine (ICE) to be used close to its maximum efficiency. As a result, PHEVs have a larger efficiency improvement margin than other types of HEVs. [36]. By 2040, it is expected that the market deployment of HEVs would increase up to 8% of all new automotive sales due to limited petroleum supplies and future predictions of fuel cost increases [37].

Over the entire fuel cycle, PHEVs may produce less greenhouse gas emissions than ICE vehicles and other types of HEVs [36, 38]. Assuming that electricity for the grid can be produced from a cleaner source than petroleum fuels [38]. PHEV greenhouse gas emissions could be reduced with a high battery completed distance and a regular full charge. Despite the fact that the amount of CO_2 produced by electric generation largely determines this conclusion [39]. If the electricity used to propel PHEVs comes from a zero-emission energy source like solar, wind, hydropower, and so on, the vehicle's greenhouse gas emissions could be close to zero [40]. The fuel consumption and pollutant emission certification of combined PHEVs is a complicated challenge as it is related to both overall efficiency and depletion rate, depending on the trip distance[41].

The aim of this study is to examine the fuel saving and emission reduction of PHEV compared to a conventional vehicle. Measurement of fuel consumption and analysis of exhaust gas emissions for the conventional vehicle with a such desirable strategy depends on the selected route, road profile, congestion level, and available information through Global Position System (GPS), and PHEV impacts with analysis of energy flow and getting useful insights into fuel consumption reduction through the electrification level, with respect to the vehicle additional price and lower running cost.

The actual amount of fuel consumed is tightly coupled with the ability of the energy management system (EMS) to maximize electricity use and optimize the overall system efficiency. In practice, the fulfillment of optimal control of PHEVs depends on basic information about the driving cycle, which is needed to plan convenient battery depletion. The laboratory tests used to determine the operating requirements of HEVs typically expose significant benefits over regular ICE cars, such as (20%-60%) fuel consumption reduction (FCR) for the testing vehicle.

II. Experimental Testes and Methodology

A commercial small hatchback car shown in figure 1 “Hafei Lobo” has been used for measurements. The full technical specifications are shown in Table 2. The car has been modified and converted into a plug-in Hybrid-Electric Vehicle. The engine has been swapped into an electric motor that uses energy from the battery kit and electric generation set. The vehicle has been modified to take in the hybrid-electric system components after installing the measurement system in order to record all required data to assist the effect of the charging rate of the battery on the whole vehicle's performance and emissions behaviors. An electric motor-generator with 6.5 kW maximum power has been installed with a series of electric batteries and an electric motor to drive the car. The system was equipped with an electric loading panel which was used to load the battery at different charging rates.

Fig. 1: Vehicle layout

Table 1: Comparison of hybrid electric vehicles types

Function or component parameters	Types of HEV			
	Micro	Mild	Full	Plug-in
Idle Stop/Start	◆	◆	◆	◆
Electric Torque Assistance	-	◆	◆	◆
Energy Recuperation	-	◆	◆	◆
Electric Drive	-	-	◆	◆
Battery Charging (during Driving)	◆	◆	◆	◆
Battery Charging (from Grid)	-	-	-	◆
Battery Voltage (V)	12-48	48-200	> 150	200-400
Electric Machine Power (kW)	5	5-20	> 40	80-150
EV Mode Range (km)			5-20	30-100
CO2 Estimated Benefit	5-6%	7-12%	15-20%	> 20%

Table 2: Vehicle Specifications

Item	Description
Engine	In-line, 4-cylinder, Twin cam, 16 valves, 1075cc (MPFI) petrol engine.
Body/Seating	5 doors (Hatchback) / 5 adults
Transmission	5-speed manual transmission, front-wheel drive
Curb Weight	895 kg
Suspension	Front: Independent MacPherson strut Rear: Trailing arm with coil spring
Steering	Rack & Pinion with hydraulic power assist steering
Brakes	Servo Front: Discs, Rear: Drums
Dimensions (mm)	3618 (L) × 1563 (W) × 1533 (H)
Fuel Tank	40 Liters
Curb Weight	895 kg

A. *Pre-conversion*

The vehicle has been modified and prepared to measure fuel consumption and emission characteristics at different battery charging rates. The conventional engine performance and emission have been tested on the rod at different car routes. To examine fuel consumption and exhaust emission characteristics, some modifications, described as shown in figure 2, have been required for the fuel system and exhaust system such as:

- The fuel system has been modified using a calibrated tank with a fuel pump with an external fuel filter to provide the engine with commercial gasoline fuel needed to drive the vehicle.
- A small pipe system has been attached to the exhaust system to collect some exhaust gases that flow through the exhaust *gas analyzer (BrainBee AGS-688).*

To examine the essential characteristics of different modes of driving, a basic driving route shown in figure 3 is created for 10 km. The vehicle's First trip was driven at a constant speed of 60km/h. 80km/h was the speed of the second trip. Two more trips were done in midtown areas with moderate and light traffic conditions on different routes as shown in figure 4 and figure 5, respectively.

The fuel consumption volume in the calibrated tank was recorded at the beginning and the end of each tested trip. Then the difference between each value was calculated to get the net fuel consumption. The sampling line was attached to the vehicle exhaust pipe to supply gaseous emissions to the exhaust gas analyzer which was installed in the cabin of the vehicle. The exhaust gas analyzer data were recorded three times during the trip. In the beginning, middle, and end of every trip then the average values were calculated for each trip data. All tests were done under steady-state conditions of the engine when the coolant temperature reading was above 80 °C before the tests.

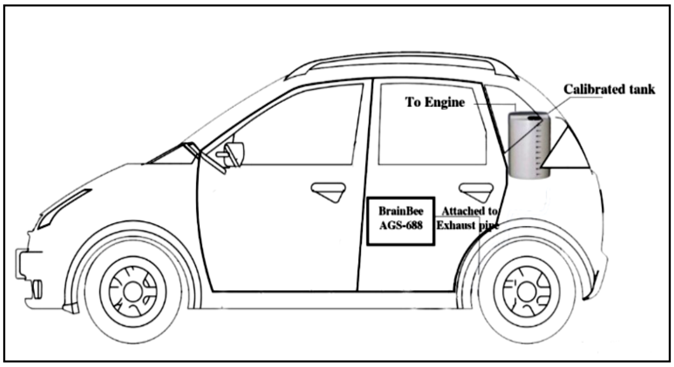


Fig. 2: Schematic diagram for car preparation

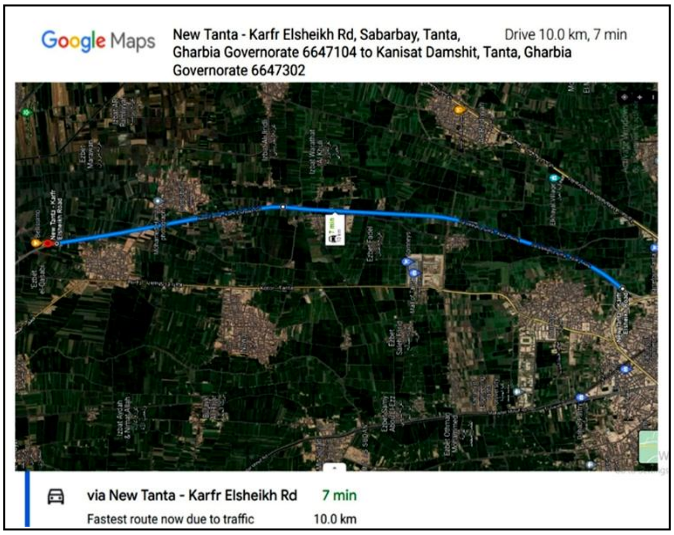


Fig. 3: Route (1): Go for 10km

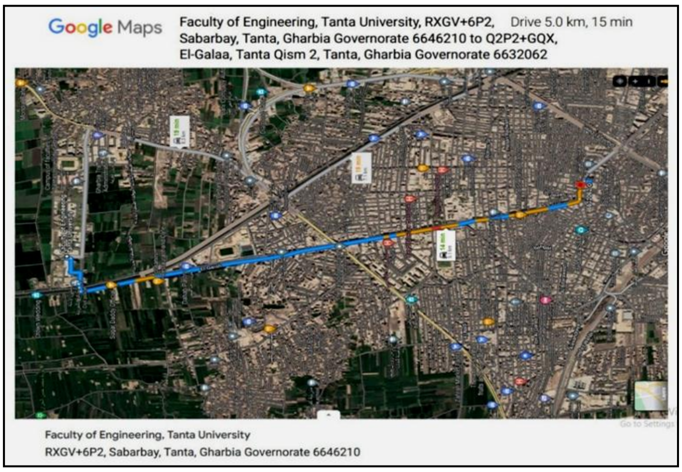


Fig. 4: Route (2): Go and return, Total trip 10km

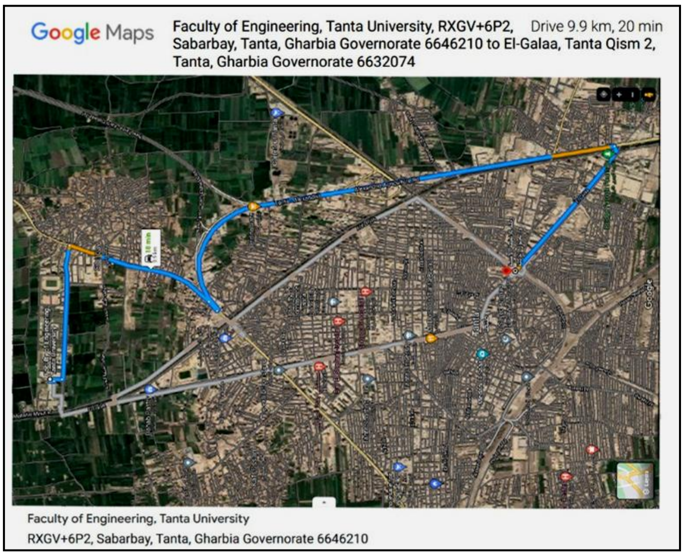


Fig. 5: Route (3): Go for 10km

B. Conversion process

To convert the vehicle into a plug-in Hybrid-Electric Vehicle, the engine has been swapped into a 10kW, 96V induction AC motor with 140N.m. Maximum torque that uses energy from 9.6kW/h deep cycle battery kit and 6 kVA generator-set. However, the system energy flow for PHEV has been described as shown in figure 6.

Vehicle construction has been redesigned and modified to determine batteries and Genset locations. Also, the system components have been technically distributed to achieve the best weight distribution as shown in fig (7. a-d). The suspension system was modified also to be suitable for the new weight of the vehicle. In addition, the steering system and braking system have been modified to give the best performance without the conventional engine.

A new electrical wiring system, body control, and HEV management system have been fabricated to meet the modifications and measure battery voltage capacity, charging/discharging current and better battery temperature. It also manages the Genset (auto start/stop, auto connect/disconnect the charger, and safely switch between charging power sources).

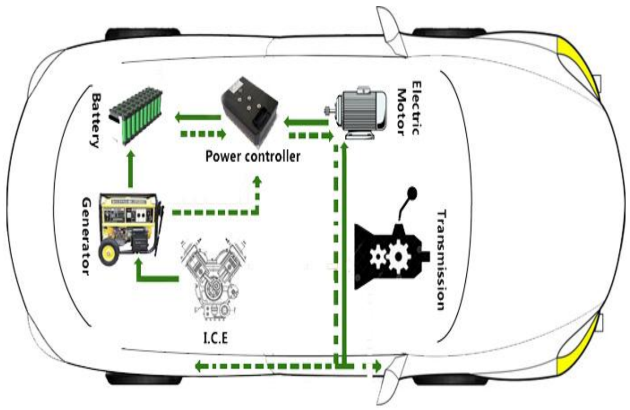


Fig. 6: Energy flow for PHEV

C. Post-conversion

The vehicle battery kit was first discharged by the external load to 20% of its total capacity. Then, the batteries were recharged using the Genset, and electric power stored in batteries was measured. The increase in battery kit capacity was recorded for every 350 mL of fuel consumed by the Genset during the recharging process and exhaust gases were also tested and analyzed. The complete system is shown in figure 8. The gasoline fuel tank is fixed in the car roof and the electric battery set is distributed after a static balance was reached.

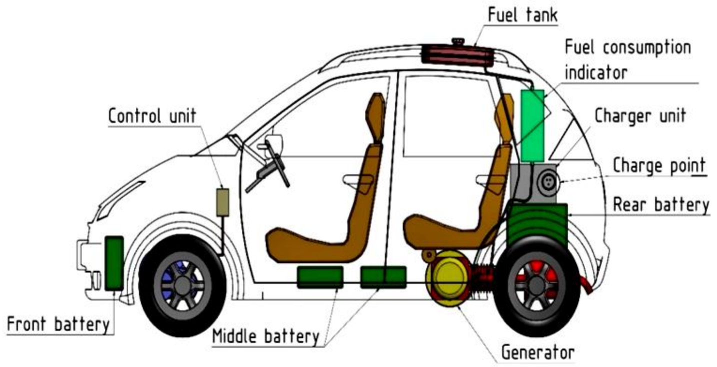
D. Measuring devices and uncertainty values

The emission analysis of UHC, CO, CO_2, and NOx emissions was measured by using the "BrainBee AGS-688" exhaust gas analyzer. The engine air stream rate was calculated by an airflow meter, where fuel consumption was measured by calibrated tank and flask. Figure 9 shows the qualifications, capacity range, and error of the SI engine "electric generator", gas analyzer, and calibrated tank and flask. The engine emissions were recorded at different test conditions in the case of conventional car and the case of HEV at different charging rate of the battery set.

The physical parameters of the engine have an effect on the measuring data, resulting in uncertainty in the recorded experimental data. To guarantee precision and accuracy, the gathered data were the subject of mathematical calculations. Equation (1) was used to evaluate the engine experimental responses using uncertainty analysis.

Table 3 displays the elements of the equation. Table 4 delineates explicit fuel utilization, NOx, UHC, charging power, speed, K-type thermocouple, wind current rate, fuel stream rate, and nano amount vulnerability values.

$$w_R = \left(\left(\frac{\partial R}{\partial x_1} w_1 \right)^2 + \left(\frac{\partial R}{\partial x_2} w_2 \right)^2 + \cdots + \left(\frac{\partial R}{\partial x_n} w_n \right)^2 \right)^{\frac{1}{2}} ----(1)$$



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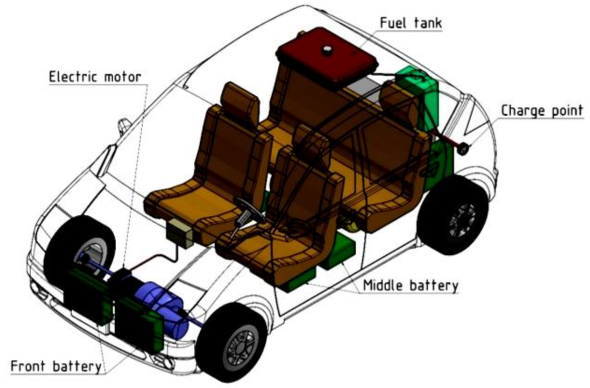

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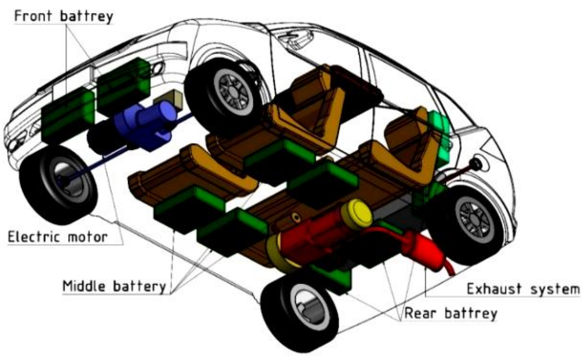

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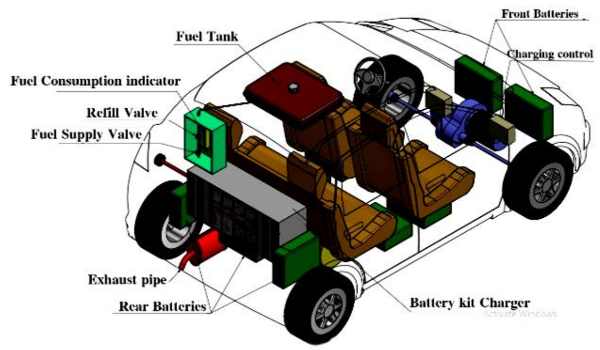


(d)

Fig. 7: Vehicle construction modifications; a) Side view of the vehicle showing the distribution of batteries and the location of the generator, b) Upper view of the vehicle showing the location of Electric Motor and fuel tank, c) The distribution of vehicle components, d) Showing the measurement pieces of equipment for fuel and electricity consumption

Table 3: Elements of uncertainty analysis equation

WR	Total uncertainty	W1, W2,……..,Wn	Doubts of engine working parameters
R	Result function	X1, X2,…….., Xn	SI Engine operating parameters

Table 4: Engine responses, operating parameters, and devices' uncertainty values

BFC	±1%	NOx	±2%
UHC	±1.5%	charging power	±0.5%
K-type thermocouple	±0.14%	speed	±0.3%
Air flow rate	±1.08%	Output power	±0.25%
Fuel flow rate	±0.65%		

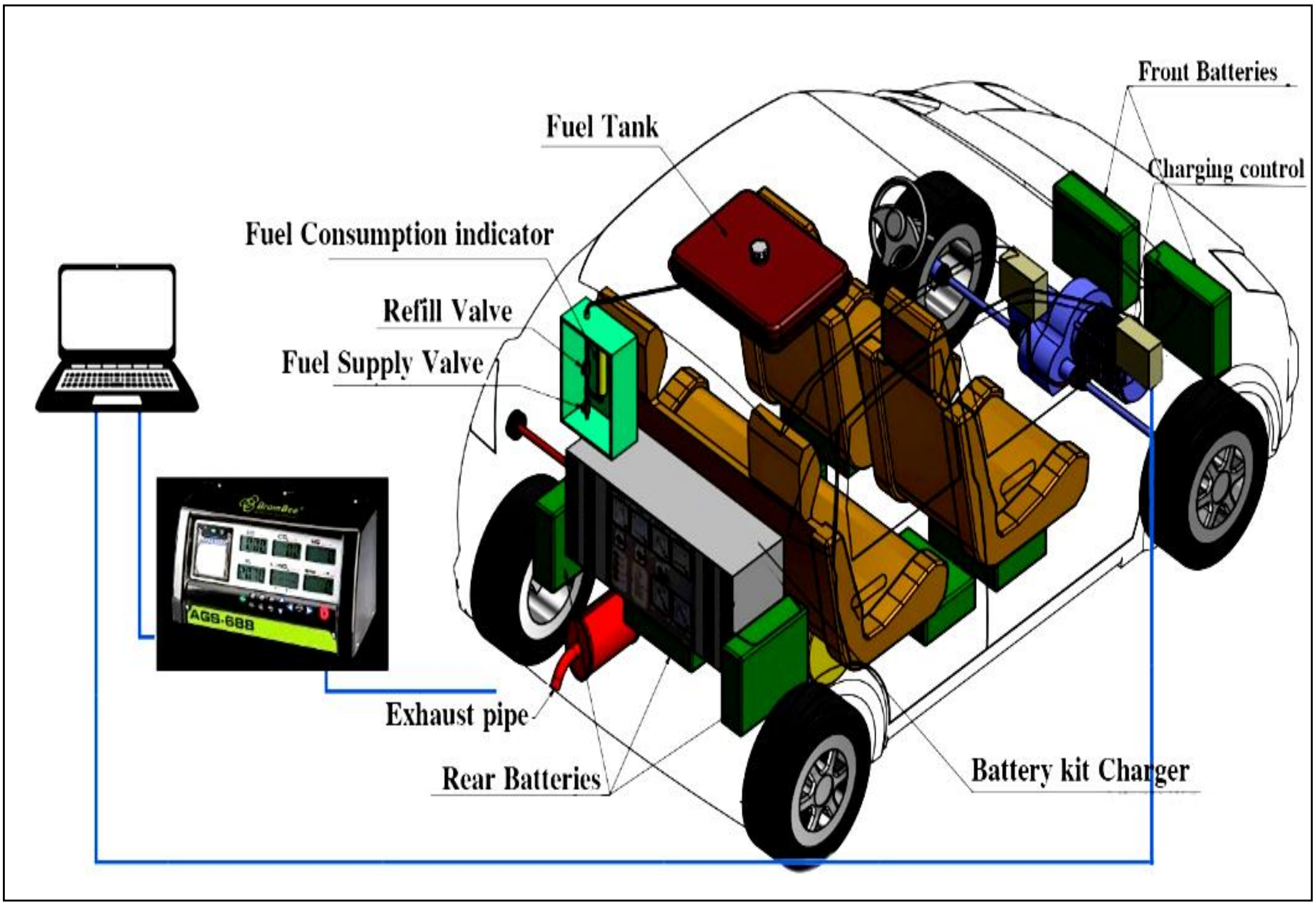


Fig. 8: Schematic diagram of the test system

Item Geometry	**Specifications**
 The engine of a conventional vehicle	In-line 4-cylinder Twin cam 16 valves 1075cc (MPFI) petrol engine Max. power: 48 kW (65 bhp) Best Fuel consumption: 22km/l. Max. torque: 88 Nm

Genset of EHVs

Model: SG6000-H
Max. AC Output(kW): 6.0
ELECTRIC SPECS.
AC Output Voltage(V): 230
Frequency (Hz): 50
Rated AC Output(kW): 5.5
MECHANICAL SPECS.
Power Factor: 1.0
Engine Type: OHV 4 Stroke; Air-cooled
Single Cylinder
Max. Power (HP)/rpm: 14.0/3600
Displacement Capacity(cc): 420

Exhaust Gas Analyzer

MEASURING FIELDS					
CO	0	+	9.99	% vol	Res. 0.01
CO_2	0	+	19.9	% vol	Res. 0.1
HC hexane	0	+	9,999	ppm vol	Res. 1
O_2	0	+	25	% vol	Res. 0.01
NO_x	0	+	5,000	ppm vol	Res. 1
Lambda	0.5	+	5		Res. 0.001
Revolutions Inductance/capacitance	300	+	9,990	rpm	Res. 10
Oil temperature	20	+	150	°C	Res. 1

Calibrated Tank

Calibrated flask

Fig. 9: System qualifications, measurement variety, and error of engines, gas analyzer, and calibrated tank and flask

III. Results and Discussion

A. *Charging profiles of the HEVs*

Figure 10 shows the instantaneous battery charging rate during the total charging period. If the electric motor is able to meet the demand for car power, the engine won't work, depending on the control strategy. Each mark on the X axis represents a constant amount of fuel (= 350 mL) used over a certain period of time to charge the battery. As time proceeds, the increased percentage of battery charge decreases for the same amount of fuel. Above 83% battery charge, the generator begins to consume the major part of the fuel to work on idling and to preserve constant current to the charger.

Figure 11 shows the instantaneous battery charging fuel consumption (fuel consumed in mL to increase battery charge by 1%) during the total charging period. Fuel consumption during the charging process experiences three different features. 1) First, when charging the battery to reach 83%, the fuel consumption is low. 2) For the shaded region (from 83% to 88 %) the fuel consumption starts to increase and deteriorate the charging efficiency. 3) above 88%, most of the fuel consumed by the generator is used to idle the engine.

B. *Effect of HEV Charging rate on Emissions behaviors*

HEV exhaust emissions variations during the charging process are shown in figure 12. Figure (12. a) shows that the highest level of CO_2 emissions was recorded at about 40% state of charge (SOC). CO emissions were increasing along the charging period as shown in figure (12. b) because of the decrease in the Genset engine load. Load decrease was the main reason to generate less NOx at higher SOC as shown in figure (12. c). Also, UHC emission profile is described as presented in figure (12.d) and shows that UHC rate was increasing along charging process.

C. *Effect of Real-driving on fuel consumption*

The real-driving performance of conventional and hybrid vehicles under various driving conditions is compared in Figure 13. In half-loaded conditions, show similar patterns of fuel consumption at 60 km constant speed and 80 km constant speed: Midtown moderate traffic ranks highest, followed by Midtown light traffic. This is determined by driving style and road traffic conditions: Fuel consumption is higher when driving aggressively and with a large vehicle. However, table 5 lists the examined cases.

For conventional vehicles, midtown driving gets the highest fuel consumption, which is about 32% higher than highway driving. Four levels of fuel consumption of constant-speed driving are 5.5 L/100 km for half-load conditions, 9 L/100 k, and 14 L/100 km for high-load conditions. For midtown driving for four periods, the fuel consumption is 11 L/100 km, 7 L/100 km at half load, 18.5 L/100 km, and 15 L/100 km at full load conditions.

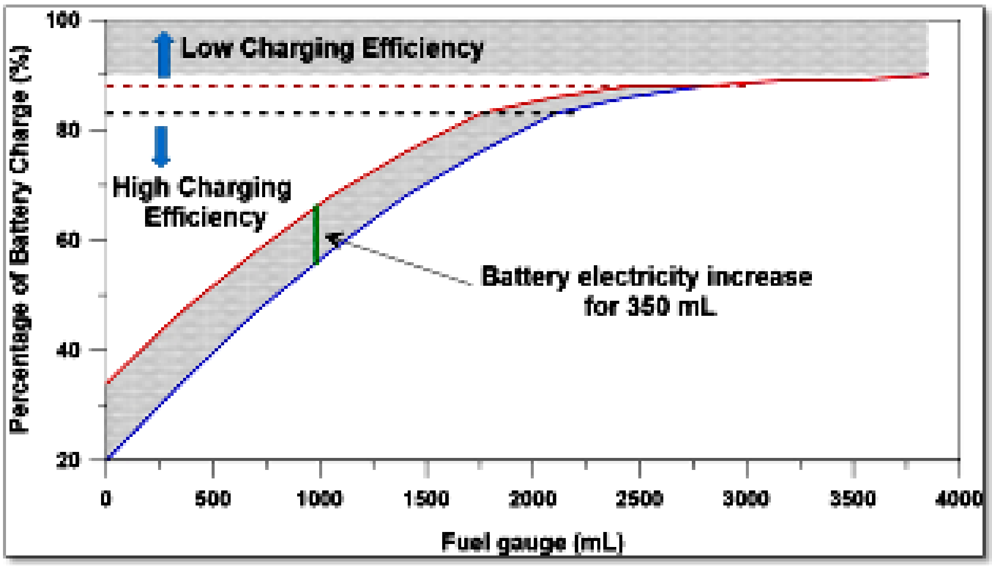


Fig. 10: Battery charging rate

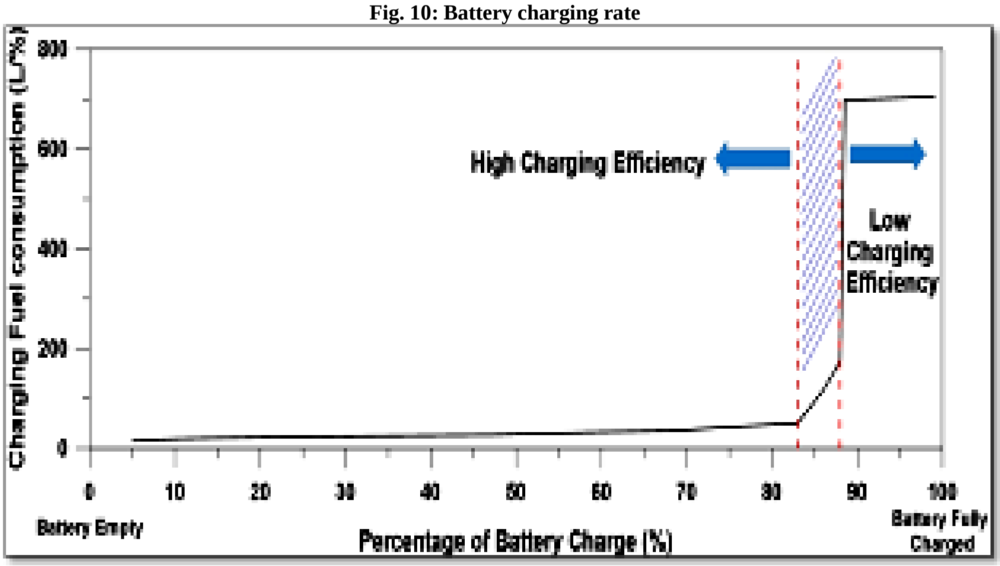
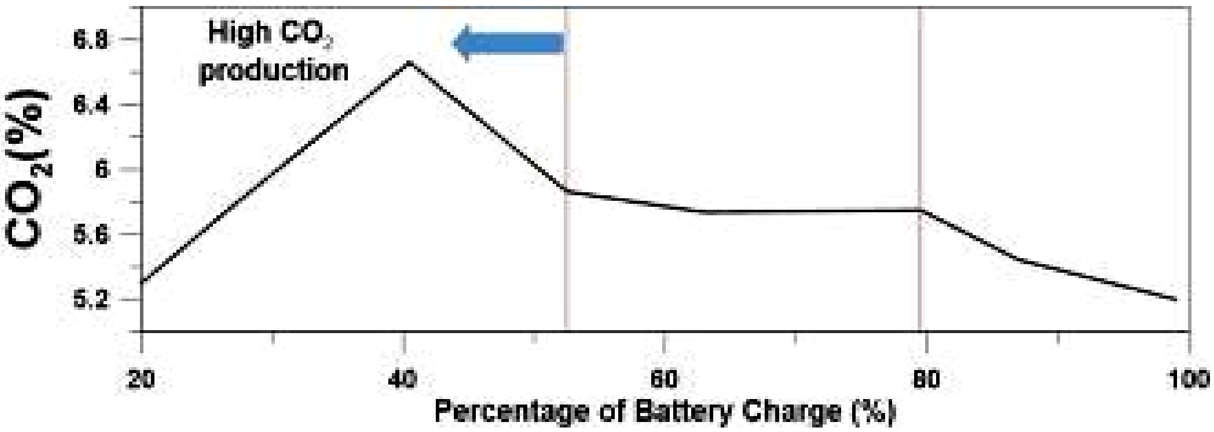


Fig. 11: Battery charging fuel consumption



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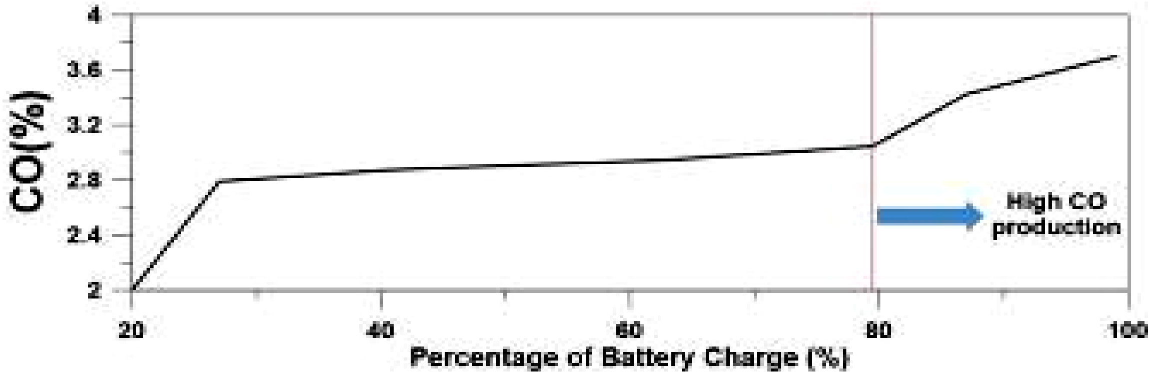

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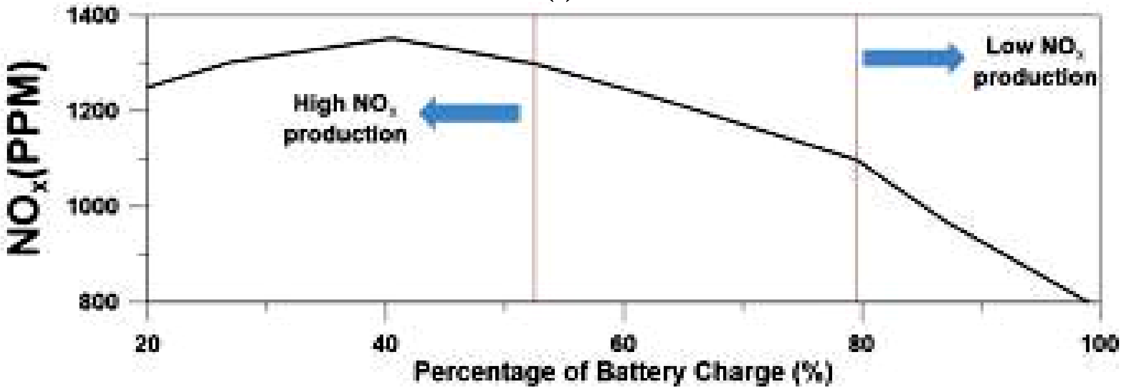

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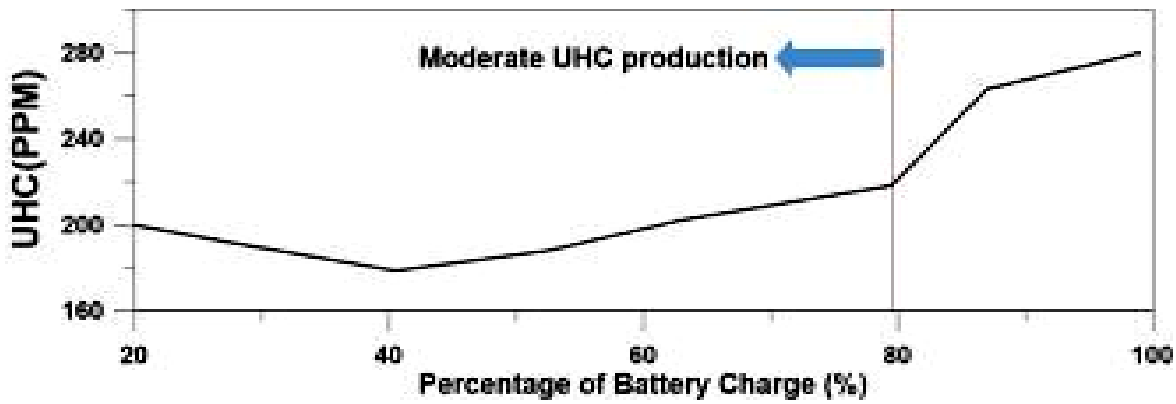

(d)

Fig. 12: HEV exhaust emissions variations during the charging process; a) CO_2 emissions, b) Co emissions, c) NOx emissions, d) UHC emissions

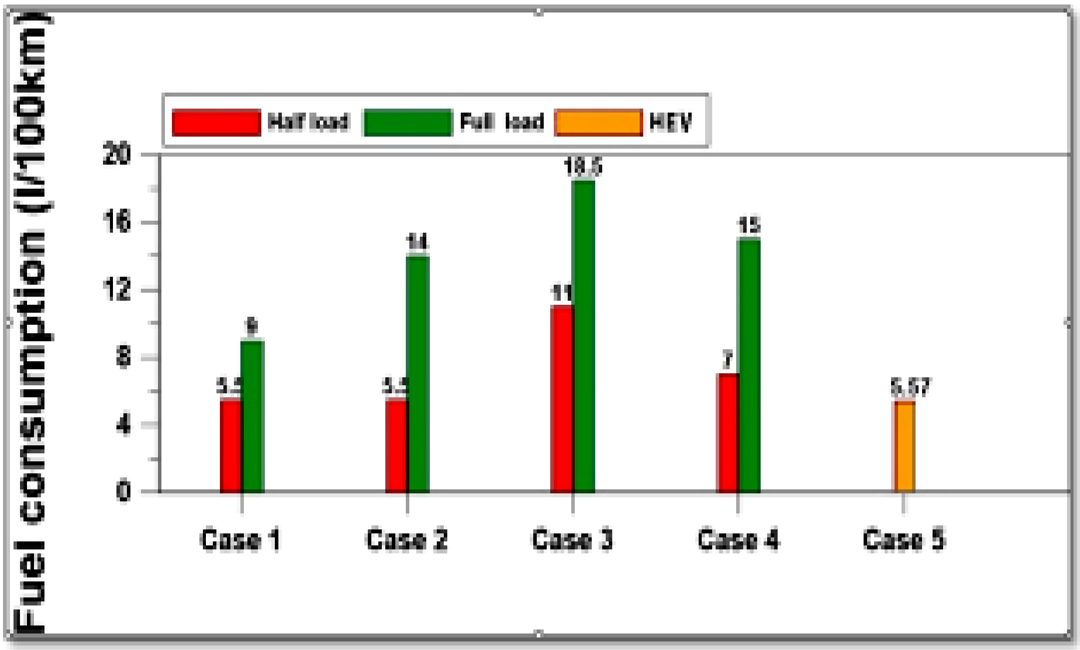

Fig. 13: Fuel consumption

Midtown's low-speed period significantly increases the total fuel consumption. The average speed of the midtown period is around 20-40 km/h. This means the engine speed and load are quite low and BSFC is quite high in these conditions [42]. That's why midtown driving gets the highest fuel consumption for the conventional. For the hybrid, Hewu Wang et al [43], the examined fuel consumption in the CS mode and electricity consumption in the CD mode for (PHEV) were compared. The average fuel consumption in the CS is 5.1 L/100 km, and the standard deviation of 0.50 L/100 km through driving cycles, whereas the average electricity consumption in the CD mode is 16.04 kW h/100 km and the standard deviation is 1.09 kW h/100 km.

For our testing HEV vehicle, the Genset consumed 2.1 L of fuel to charge the batteries with the amount of 6.05 kW h of electricity raising its state of charge from 20% to 83% within the high charging efficiency range. Since the vehicle consumes 16.04 kW h/100 km[43], which means that it consumes about 5.57 L/100 km. However, fuel consumption is 190 % lower than midtown moderate traffic at half-load conditions as described in table 5. At half load and full load, the HEV consumes 3.8 and 4.3 liters of fuel per 100 kilometers, respectively. Under conditions of lower power demand and the hybrid vehicle could be powered by an electric motor. As a result, HEVs consume less fuel than conventional vehicles because their engine restarts are less frequent. The main difference between the tested cases was compared in the table 6 as a conclusion to the obtained results. Also, the fuel consumption reduction is calculated by the following equation.

$$\text{Fuel Consumption Reduction}_i(\text{FCR}_i)\,(\%) = \frac{F.C_i - F.C_{HEV}}{F.C_{HEV}} \times 100$$

Table 5: Case description

Case number	Speed conditions	Trip distance	Fuel consumption (L)	
			Half load	Full load
Case 1	60 km/h constant speed	10 km	0.55	0.9
Case 2	80 km/h constant speed	10 km	0.55	1.4
Case 3	Midtown moderate traffic	10 km	1.1	1.85
Case 4	Midtown light traffic	10 km	0.7	1.5
Case 5	HEV charging	Generating 6.05 kW	2.1	

Table 6: Percentage difference in reduction of fuel consumption relative to HEV

Case (i)	Half load	Full load	FCR i (%) Half load	FCR i (%) Full load
HEV	3.9	4.2	---	---
60 km constant speed	5.5	9	29	53.3
80 km constant speed	5.5	14	29	70
Midtown Moderate Traffic	11	18.5	64.5	77.3
Midtown Light Traffic	7	15	44.3	72

D. Effect of Real-driving on Real-driving emissions

Figure 14 depicts the CO2 emission profiles of conventional and hybrid automobiles. Because the majority of the fuel had been converted into CO2, the results for the conventional vehicle showed the same trends as the rates of fuel consumption. Compared to other conventional operation conditions, the case of constant speed (80 km/h) full load shows the highest CO_2 emissions. This amount of CO_2 has been repeatedly reported in recent studies for different vehicle types [44, 45]. However, the HEV shows a higher reduction in CO_2 emissions since the dependence on fuel is for the battery charging process.

In all of the test cycles depicted in figure 15, the hybrid vehicle's CO emission factor is higher than that of the conventional vehicle. HEVs require significantly more time to warm up the engine for a number of reasons, one of which is the frequent start-stop rather than continuous running. Due to the enhanced fuel-air mixture, diminished fuel vaporization, and incomplete combustion, the warming period could significantly raise CO2 emissions. [46-49]. Due to the worse air-fuel mixture and incomplete combustion during re-start, frequent start-stop also increases CO emissions [50].

When the vehicle travels at a speed of 80 kilometers per hour, the instantaneous CO emission rises during times of high engine load. The fuel droplets have less time to mix and evaporate under high-speed conditions, resulting in locally rich regions and incomplete combustion [51]. In these locally rich areas, the CO formed during hydrocarbon combustion was unable to fully oxidize into CO_2, which led to high CO emissions. Figure 15 shows that during times of high power demand, CO emissions spike. The hybrid, in contrast to the conventional vehicle, will not immediately start the engine when the tests begin.

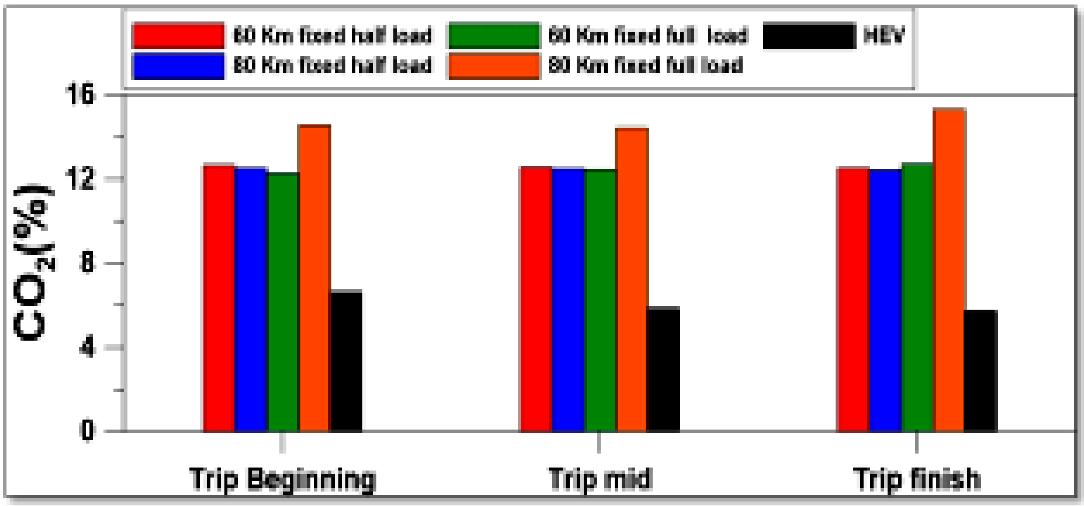

Fig. 14: CO_2 emission results

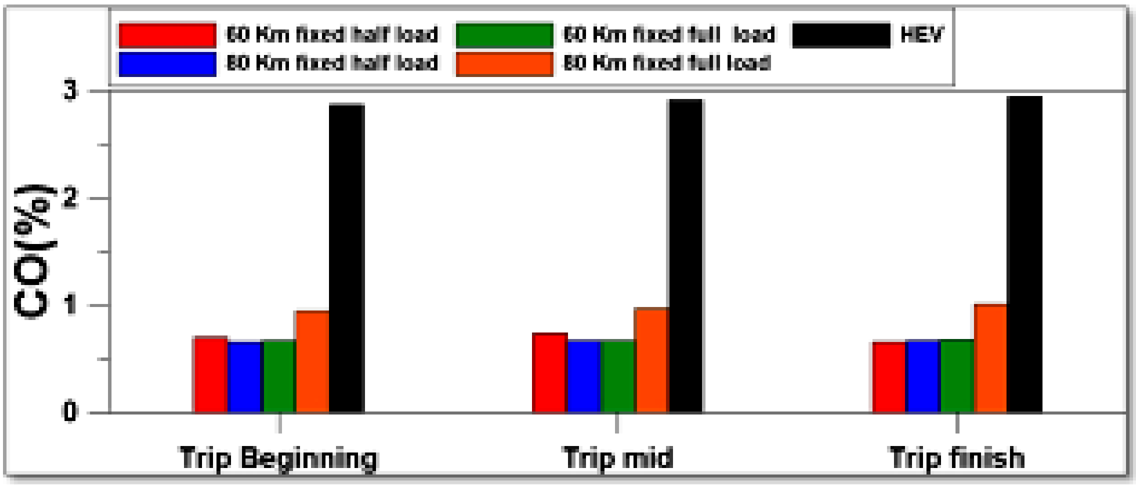

Fig. 15: CO emission results

When the battery needs to be charged, the engine will start. This indicates that the hybrid engine has no "Idle period" and will immediately power the generator when it is started. The hybrid's elevated cold-start emission spike is due to this [52]. From figure 16, there are significant spikes for the conventional and HEV operations. For a constant speed of 60 km/h, the average NOx emissions are 1022,1669,1484,1839,840 ppm. Speed HL, 80 Km/h const speed HL, constant 60 km/h speed FL, constant 80 km/h test cases for speed FL and HEV, respectively.

The NOx emissions of hybrid vehicles were clearly lower than those of conventional vehicles in the tests. One reason is that the vehicle is entirely driven by an electric powertrain. As a result, the HEV engine requires less power than a conventional engine, resulting in a lower in-cylinder combustion temperature [44]. A high enough temperature is one of the most important factors in the production of NOx; therefore, a lower temperature results in a lower production of NOx [36]. As depicted in figure 16, the hybrid vehicle's fuel was also less enriched, reducing the production of immediate NOx.

The majority of UHC emissions result from fuel combustion that is incomplete. In terms of determining the nature of combustion, it is one of the most significant parameters. Figure 17 depicts the variation in UHC emissions based on various driving scenarios. As previously mentioned, as the combustion time decreases, UHC emissions rise with vehicle load because combustion takes longer. We also note that UHC emissions had no great variation along the trip for each driving case, the highest UHC values were for 80 km/h constant speed at full load and the lowest values were for HEV.

IV. Conclusions

In this study, we measured on-road fuel consumption and exhaust emissions from a conventional vehicle at different trip conditions before converting the vehicle into (PHEV). Our obtained results show the data of the conventional vehicle fuel consumption variation due to vehicle speed and load as well as road characteristics. The recorded best fuel consumption rate was 5.5 L/100km, and it was recorded at half load and constant speed of 60 km/h and 80 km/h. At Midtown driving in moderate traffic, the worst fuel consumption rate was 18.5 L/100 km. For each operating mode, the average emission rates for all pollutant categories generally raise with vehicle load. Average exhaust emission factors of CO, UHC, NOx, and CO2 were 0.75±0.08 (%vol), 284±20 (ppm), 1432±350 (ppm), and 7.57±0.5 (%vol), respectively. With the help of electric energy, PHEV system was able to consume less fuel, although fuel consumption varies due to the battery state of charge (SOC). In this work the amount of electric energy stored in batteries for every 350 ml of fuel was recorded. The efficiency of charging decreases with a high state of charge (SOC), the best efficiency is below 83% SOC. The vehicle consumed 2.1 L to charge the batteries with the amount of 6.05 kW h of electricity raising its state of charge from 20% to 83% within the high charging efficiency range. However, PHEV was consumes 5.57 L/100km. Hybrid vehicles could play a vital role in saving the world's environment since they lower fuel consumption, especially for vehicles used in the urban environment where higher accelerations and lower average speeds, as ICE isn't needed to run all over the trip.

Average exhaust emission factors of CO, UHC, NOx, and CO2 were 0.79±0.06 (%vol), 207±12 (ppm), 840±210 (ppm), and 12.23±0.42 (%vol), respectively.

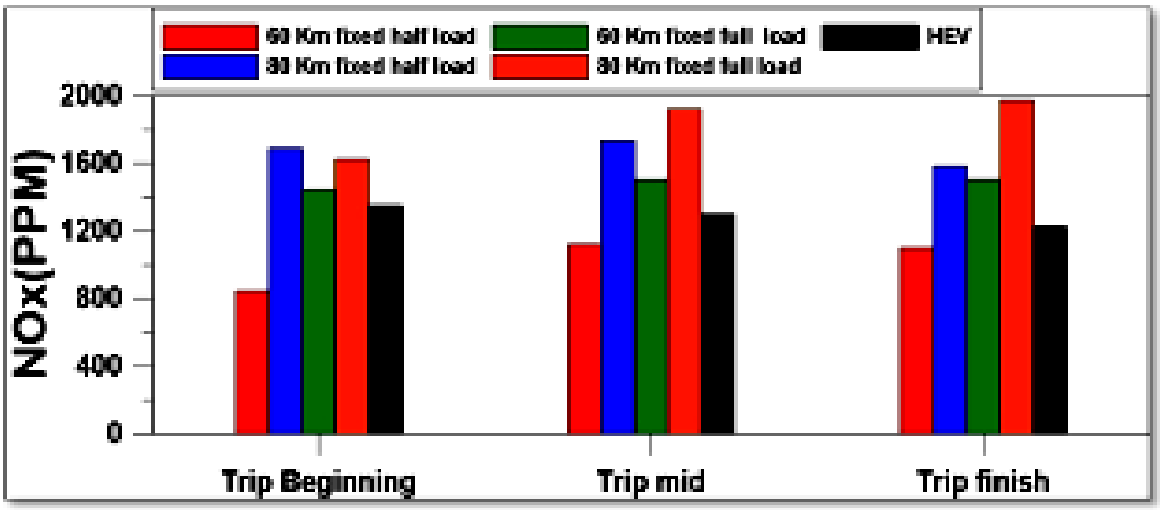

Fig. 16: NOx emission results

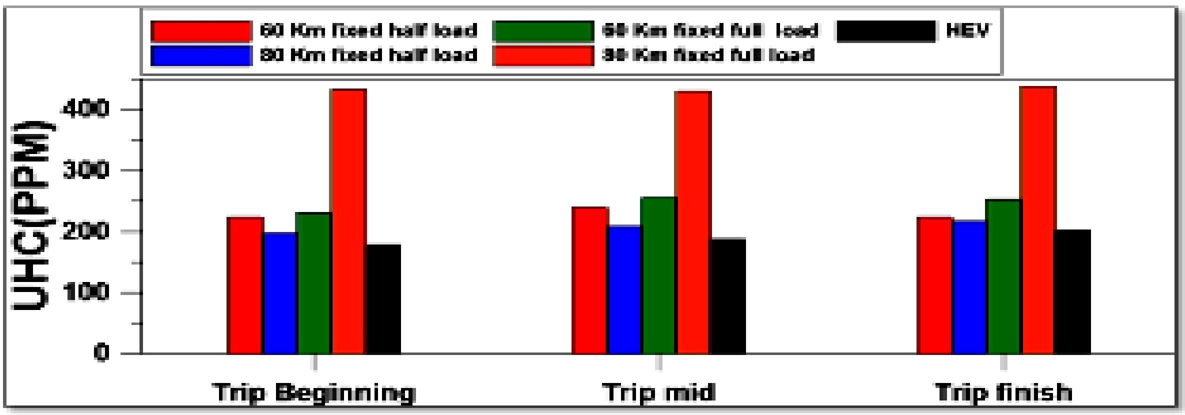

Fig. 17: UHC emission results

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ABBREVIATIONS AND SYMBOLS

HEV	Hybrid Electric Vehicle	GHG	Green House Gas Emissions standard
PHEV	Plug-in Hybrid Electric Vehicle	EURO I-VI	EURO Emission Standard
EMS	Energy Management System	ICE	Internal combustion Engine
MPFI	Multi Point Fuel Injection	SI Engine	Spark Ignition Engine
CS MODE	Charge Sustenance MODE	CD MODE	Charge Depletion MODE
SOC	State Of Charge	EM	Electric Motor
OHV	Over Head Valve	FCR	Fuel Consumption Reduction
CO	Carbon monoxide	CO2	Carbon dioxide
NOx	Nitrogen Oxides	UHC	Unburned Hydrocarbons
HL	Half Load	FL	Full Load

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