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A Comparative study of PHEV & Gasoline Engine Emissions

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ABSTRACT:

This paper provides a comparative study of the emissions generated by the gasoline engines & emissions generated by PLUG-IN HYBRID VEHICLES (PHEVs) . We have come a long way from the development of large external combustion engines to compact yet powerful internal combustion engines. With the technological advancement and the changing emission norms, we are trying to reduce the automobile exhaust emissions that are one of the major components of the air pollution. Automotive manufacturers are investing in development of fully electric vehicles, hybrid vehicles that deliver fuel-efficient and lower exhaust emissions solutions. Companies such as BMW, Ford, Nissan,Tesla are front runners to build hybrid vehicles for a drastically changing consumer world.

The automotive exhaust emissions are one of the main causes in the overall increase in the global air pollution level,GHGs being the main culprit.Huge increase in the use of fossil energy sources has caused increased pollution of the air. Exhaust emissions from vehicles have a significant contribution to the overall pollution. Toxicity of the exhaust gas constituents poses a considerable influence on human health and global ecology. Therefore an emerging necessity is felt world over to employ suitable measures to terminate them.With the increase in research in the field of hybrid energy technology the contribution for development of emission free solutions has increased multifold in the past decade. In this paper, there is a comparative study of the emissions generated by the various developed PLUG-IN HYBRID VEHICLES & GASOLINE ENGINES..

Keywords: Gasoline Engines, PHEVs, GHG, Emissions, Efficiency.

INTRODUCTION:

With the increasing difficulty in development of the conventional fueled vehicles due to the changing emission norms the concept of Plug-in Hybrid and Hybrid vehicles has gained significant attention from automobile manufactures all over the world in the past decade. Hybrid vehicles are basically conventional fuelled internal combustion engines in which an electric motor and generator, a battery pack, and regenerative braking is used to power the vehicle. The vehicle configurations for hybrid engines are described as “series” or “parallel” configurations. In the series configuration, the engine powers a generator, which powers a motor (or motors) and charges a battery (which in turn powers motors to supplement engine generator power), with only the motor(s) finally driving the wheels. In the parallel configuration, both the engine and one or more electric motors (using a battery previously charged by engine-generated electricity) mechanically power the wheels. The most important differences between a hybrid vehicle and a conventional vehicle are:

(1) The hybrid can eliminate fuel waste during idling (when a vehicle is at a stop or decelerating.

(2) It can retrieve kinetic energy during deceleration, through regenerative braking.

A plug-in hybrid is an electric vehicle that can call on gasoline to extend its range. The plug-in hybrid vehicles have three modes of operation. They are:

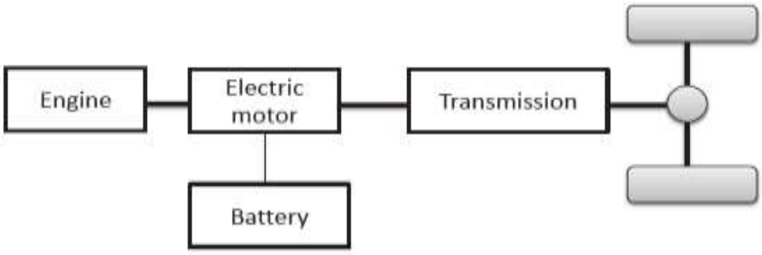
(1) Charge Depleting Mode
(2) Charge Sustaining Mode
(3) Blended or Mixed Mode

In charge Depleting mode the main source of the of power for the PHEV is the is the stored electricity because they used stored energy that is sourced from electricity grid.Charge-sustaining mode is used in PHEVs which combines the operation of the vehicle's two power sources in such a manner that the vehicle is operating in the most efficient way without allowing the battery state of charge to move outside a predetermined narrow band.Once the all-electric range of a plug-in hybrid is exhausted, it can switch into charge-sustaining mode automatically to store energy.

PHEV Vehicle architecture classification:

Parallel Configuration:

In Parallel hybrid architecture the wheels are powered by both the electric motor and the IC engine. The electric motor is placed between the output engine shaft and the wheels.A separate generator is not needed for these vehicles; the electric motor can be used as a generator to recharge the batteries. In a parallel HEV, the electric motor assists the engine during starting and acceleration.It is possible to downsize both the engine and the electric machine compared to series hybrids because the electric motor and the engine are both coupled directly to the wheels and they can share the power during accelerations.

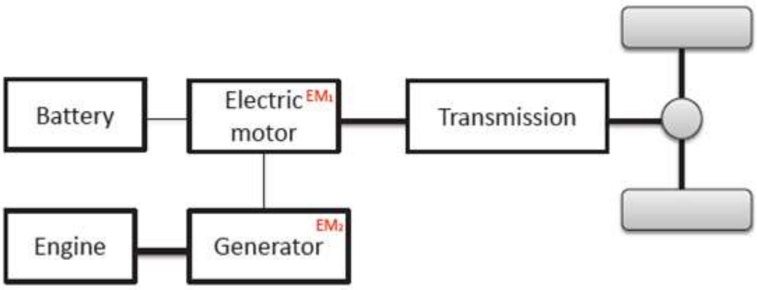


(Ref: Silvaş, E., Hofman, T. and Steinbuch, M., 2012. Review of optimal design strategies for hybrid electric vehicles. *IFAC Proceedings Volumes*, *45*(30), pp.57-64.)

Series Configuration:

In a series configuration, an electric generator is coupled with an engine. It supplies electricity to the motor to propel the car and to the energy storage system for recharging purpose.The engine-generator set keeps the energy storage system charged between 60–80% for batteries.

An advantage of this configuration is that engine and vehicle speeds are decoupled.Only the electric motor is connected to the wheels.As a result, the engine does not need to speed up or slow down according to loading.Hence, the engine can run at optimum performance (best engine efficiency area), which significantly improves the fuel economy. Moreover, the engine never idles, thus reducing overall emissions.Since the electric motor is the only one connected directly to the wheels and the engine-generator set is sized for sustained gradeability, this configuration requires large batteries, motor, and engine.In order to implement the system ,it must be highly efficient in terms of total power processing.



(Ref: Silvaş, E., Hofman, T. and Steinbuch, M., 2012. Review of optimal design strategies for hybrid electric vehicles. *IFAC Proceedings Volumes*, *45*(30), pp.57-64.)

Gasoline Engine Exhaust Emissions:

The combustion of hydrocarbon fuels such as gasoline removes O_2 from the atmosphere and releases equivalent amount of H_2O and CO_2 with trace amounts of other compounds like, carbon monoxide (CO), nitrogen oxides (NOx), hydrocarbons (CH_4, C_2H_2) and particulate matter(PM) etc.

NOx and CO are formed in the burned gases in the cylinder. Unburned HC emissions are generated when fuel escapes combustion due to processes such as flame quenching in narrow passages present in the combustion chamber and incomplete oxidation of fuel that is trapped or absorbed in oil layer. NOx is formed by oxidation of atmospheric molecular nitrogen. During combustion at high flame temperatures, nitrogen and oxygen molecules in the inlet air breakdown into atomic species which react to form NO. Some NO_2 is also formed and NO and NO2 together are called as NOx. CO results from incomplete oxidation of carbon in the fuel when insufficient oxygen is available to completely oxidize the fuel. CO rises steeply as the air-fuel (A/F) ratio is decreased below the stoichiometric A/F ratio. HC originates from the fuel escaping combustion process primarily due to flame quenching in crevices and on the cold chamber walls,and presence of liquid fuel in the cylinder during cold start. Air-fuel ratio is one of the most important parameter that affects the engine exhaust emissions.The other parameters that affect the exhaust emissions are swirl ratio, compression ratio, fuel injection pressure, fuel injection timing etc.

The ill effects of the exhaust emissions are not only limited to the human health but affect the environment adversely. Nitrogen oxides in the atmosphere contribute to photochemical smog, to the formation of acid rain pioneers, to the destruction of ozone layer in the stratosphere and global warming. The main source of emissions of NOx is attributed to increased combustion of and fossil fuels. The other pollutants such as UHC, CO and PM are hazardous to the human health and the environment as a whole. Hence it has become necessary to reduce the exhaust emission levels and newer, more stringent pollutions norms are being adapted all over the world.

The PHEVs are amongst one of the solutions to decrease the pollution levels and achieve the required norms that have been implemented by the various environmental protection associations all over the world.

Plug-In Hybrid Engine Exhaust Emissions:

A PHEV has an additional electric drive along with conventional gasoline or diesel engine. Emissions are a major concern of today's world. Vehicular emissions are one of the major source of air pollution. Still the Plug-in hybrid electric vehicles (PHEVs) emit less CO_2 and other pollutants over the entire life cycle as compared to the conventional vehicles (CVs). PHEVs might reduce the impact of emissions like CO_2 because in many regions electricity is considerably a cleaner source of fuel than gasoline. The construction phase emissions for the battery are smaller for PHEV. PHEV are an alternative to conventional vehicles to mitigate GHG emissions from transport. PHEVs shift a part of the emission burden of transport from fossil fuel combustion to electricity. The effect of this shift on the overall CO_2 emissions from PHEVs depends on the overall efficiency of the IC Engine and on the amount of the electricity utilized from power stations.It has been found that PHEVs have a high CO_2 emission mitigation potential and would lead to clean transporting future.

Comparison of PHEV and Conventional Gasoline (CV) vehicles:

The comparison here considers parallel PHEV as it has following advantages:

1.Relative low cost

2.High total power output as both engine and electric motor can be used simultaneously.

3.It can function as a conventional vehicle.

With reference to the study carried out by ICCT(International Council on Clean Transportation)

The following charts provide evidence to the claim that PHEVs are a lot cleaner than gasoline engines.Ref:ICCT

VW Golf (gasoline)	0 km e-range 121 g/km	**VW Golf GTE (PHEV)**	50 km e-range 36 g/km
Porsche Panamera (gasoline)	0 km e-range 177 g/km	**Porsche Panamera (PHEV)**	51 km e-range 56 g/km
Mitsubishi Outlander (gasoline)	0 km e-range 149 g/km	**Mitsubishi Outlander (PHEV)**	54 km e-range 41 g/km

As seen from the above table the PHEV vehicles are a lot cleaner as compared to their gasoline counterparts. The CO_2 emissions are about 75% less than the gasoline variants.

The table below shows us the relationship between CO_2 emissions and electric range.

At 0 km electric range i.e. pure gasoline run, the emissions are found to be the highest. As the vehicle is run more and more on electric drive the emissions are following a downward trend. At 75 km electric range CO_2 emissions are quite low.

Electric range	0 km	25 km	50 km	75 km
Weighted CO_2	200 g/km	100 g/km	67 g/km	50 g/km

The table below provides a clear comparison of diesel and gasoline vehicles' emission and corresponding diesel and gasoline PHEVs. For Diesel PHEV, the CO_2 emissions are about 10% less than conventional Diesels. While for gasoline, the reduction in CO_2 emission is a staggering 21%.The following data has been obtained by tests conducted by ICCT (International Council on Clean Transportation)

Fuel	kWh/100km	CO_2e g/km
Diesel	65	174
Diesel, hybrid	57	155
Gasoline	81	204
Gasoline, hybrid	63	161

Conclusion:

This article presents an overview of the study of emissions of PHEV and conventional gasoline vehicles and a comparative study of these two class of vehicles. The emissions of PHEVs have been found to be quite less compared to the conventional vehicles. The main reason for this is the hybrid power train. Alternate power source eliminates the dependence on gasoline and reduces emissions as electricity is cleaner compared to gasoline combustion. Use of PHEV will surely reduce the emissions of GHGs, CO_2, SO_2 and particulate matter.

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