DEVELOPMENT OF PLUG-IN HYBRID ELECTRIC MOTORCYCLE POWERTRAIN SYSTEM

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ABSTRACT

Plug-in hybrid electric vehicles are new alternatives that meet the efforts to develop more sustainable means of transportation and reduce fuel consumption. However, this trend could bring some circumstance to Powertrain systems, such as limits space packaging, weight of the Powertrain component, and the capability of plug-in in recharging the battery for Powertrain system. The PHEV design plays a significant role in sizing of the battery pack and cost. To cope with some of those problems, this thesis proposes a development of plug-in hybrid electric motorcycle Powertrain system with the parallel Powertrain system configuration in order to achieve less emission and reduce fuel consumption. A 175 cc ICE motorcycle is selected and converted into a PHEM. A brushless DC (BLDC) motor assembled into working and integrating with ICE to propel the motorcycle. The nominal powers are 13.8 kW and 5 kW for the ICE and BLDC respectively. ADVISOR as a main program to simulate the Powertrain system for PHEM and compared the Powertrain system with the conventional Modenas Jaguh 175cc. From the result the PHEM can reduce fuel consumption while less emission produced by the Powertrain system. The performance for PHEM also can compete with the conventional although the weight for the PHEM is a little bit heavier.

ABSTRAK

Plug-in kenderaan elektrik hibrid adalah alternatif baru yang memenuhi usaha untuk membangunkan cara yang lebih tahan pada pengangkutan dan mengurangkan penggunaan bahan api. Walau bagaimanapun, trend ini boleh membawa beberapa keadaan untuk sistem powertrain, seperti had pembungkusan ruang, berat komponen powertrain, dan keupayaan plug-in dalam pengisian bateri untuk sistem powertrain. Reka PHEV memainkan peranan penting dalam saiz pek bateri dan kos. Untuk menangani beberapa masalah tersebut, tesis ini mencadangkan pembangunan plug-in hibrid motosikal elektrik sistem powertrain dengan menggunakan konfigurasi sistem selari pada powertrain untuk mencapai kurang pelepasan dan mengurangkan penggunaan bahan api. 175 cc motosikal ICE dipilih dan ditukar menjadi PHEM. DC (BLDC) motor digunakan untuk bekerja dan diintegrasikan dengan ICE untuk menggerakkan motosikal. Kuasa nominal masing-masing adalah 13.8 kW dan 5 kW untuk ICE dan BLDC .ADVISOR digunakan sebagai program utama untuk meniru sistem powertrain untuk PHEM dan dibandingkan sistem powertrain dengan konvensional Modenas Jaguh 175cc. Dari hasil PHEM boleh mengurangkan penggunaan bahan api manakala pelepasan kurang dihasilkan oleh sistem powertrain. Prestasi untuk PHEM juga boleh bersaing dengan motorsikal konvensional walaupun berat untuk PHEM adalah sedikit lebih berat.

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LIST OF SYMBOLS

NORMAL SYMBOL

t_a	Acceleration time
F_{aero}	Aerodynamic Resistance
Cd	Aerodynamic drag resistance
C_D	Air drag coefficient
GG Bulk Av Velocity (X)	Average velocity acting on x-axis
GPM_{CS}	Charge-sustaining mode as designated
C_{rr}	Coefficient of rolling resistance
GPM_{CD}	Designates efficiency in charge-depleting mode
Pm	Electric motor power
P_E	Engine maximum power
V_f	Final Speed
GG Force (X)	Force acting on x-axis
A_f	Frontal area
Friction Force (X)	Friction force action on x-axis
F_{grad}	Gradient Resistance
g	Gravitational acceleration
F_{tr}	Tractive Force
M	Mass of the motorcycle
GG Max Velocity (X)	Maximum velocity acting on x-axis
PM	Motor maximum power
F_{roll}	Rolling Resistance
f_r	Rolling resistance coefficient
P_{rot}	Rotational Mechanical Power
V	Speed of motorcycle
M	Torque
PC	Total power demand
A	Vehicle frontal area

m	Vehicle mass

GREEK- SYMBOL

° a	Air density
μ	Angular velocity
¢ CD	Distance in charge depleting mode
η t,m	Efficiency of the electric motor transmission
λ	Equivalent mass factor

LIST OF ABBREVIATIONS

ADVISOR	Advanced Vehicle Simulator
AER	All Electric Range
BLDC	Brushless Direct Current
CFD	Computational Fluid Dynamics
EV	Electric Vehicle
ICE	Internal Combustion Engine
NREL	National Renewable Energy Laboratory
PHE	Plug-in Hybrid Electric
PHEM	Plug-in Hybrid Electric Motorcycle
PHEV	Plug-in Hybrid Electric Vehicle
SOC	State Of Charging

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND STUDY

Nowadays there is a huge attention for low emission and to reduce the fuel energy sources to decrease global warming on the world. 39.2% of total emissions in 2007 is raised for transportation (Chan., 2007). Vehicle manufacturers have started projects about electric vehicles to reduce carbon emission and the dependence to fuel energy. So many development projects about hybrid electric vehicles are promising solutions for the future.

In Asia and South Asia, motorcycles are the major way of transportation (Chia et al., 2007). Initially, there is no compact plug-in hybrid electric vehicle in any form existing in the consumer marketplace. The development of a hybrid electric motorcycle is both good for a healthier environment. Plug-in hybrid electric motorcycle (PHEM) can be taken as an alternative vehicle to achieve minimum emission. At the same time, PHEM can be recharged for being used for the next drive. Thus, the Powertrain system consists of hybrid electric with plug-in as an extra source can be prepared to be utilized by the PHEM.

Powertrain system is one of the important parts in developing PHEM. The function of Powertrain in PHEM is to be given and supply the propulsion power in order to drive the motorcycle (Momoh et al., 2009). The Powertrain system for PHEM consists of main part such as ICE and electric motor by using plug-in type at outsource to recharge the battery to its fully performance.

1.2 PROBLEM STATEMENTS

In hybrid electric Powertrain system, the power source consists of more than one power source. The Powertrain system for PHEM consists of Internal Combustion Engine (ICE) and electric motor with the extension of plug-in capability. To integrate these two components, a good Powertrain system should be studied and developed. To drive the PHEM, the proper configuration of the Powertrain system can produce small space packaging while reduces the mass for overall PHEM and optimize the energy usage.

There is challenging to integrate the Powertrain component of Internal Combustion Engine and electric motor to plug-in capability in PHEM. The plug-in means the extra source of the Powertrain that connect to the battery to fully charge it. The significance of plug-in capability is to study about the charging point of battery and time for the battery capability to recharge.

Therefore the development of PHEM can be very important to study whether the vehicle can be driven efficiently at good performance by reducing fuel consumption and saving in energy usage by reducing using ICE as main propulsion to drive the motorcycle.

1.3 OBJECTIVES

The objectives for this project is as follows

a. To develop plug-in hybrid electric motorcycle Powertrain system.
b. To perform operational analysis of the prototype model.

1.4 SCOPES

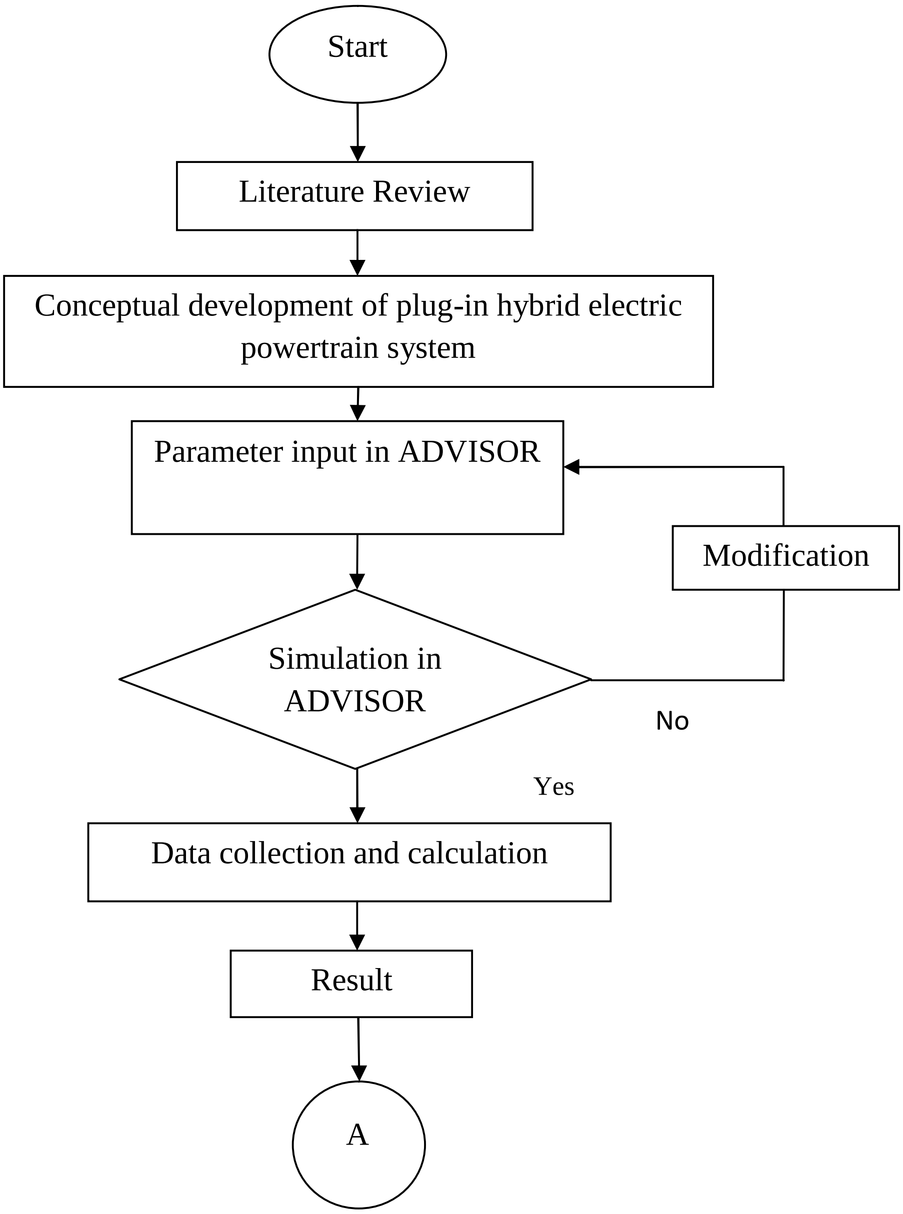
The scopes for this project are as follows:

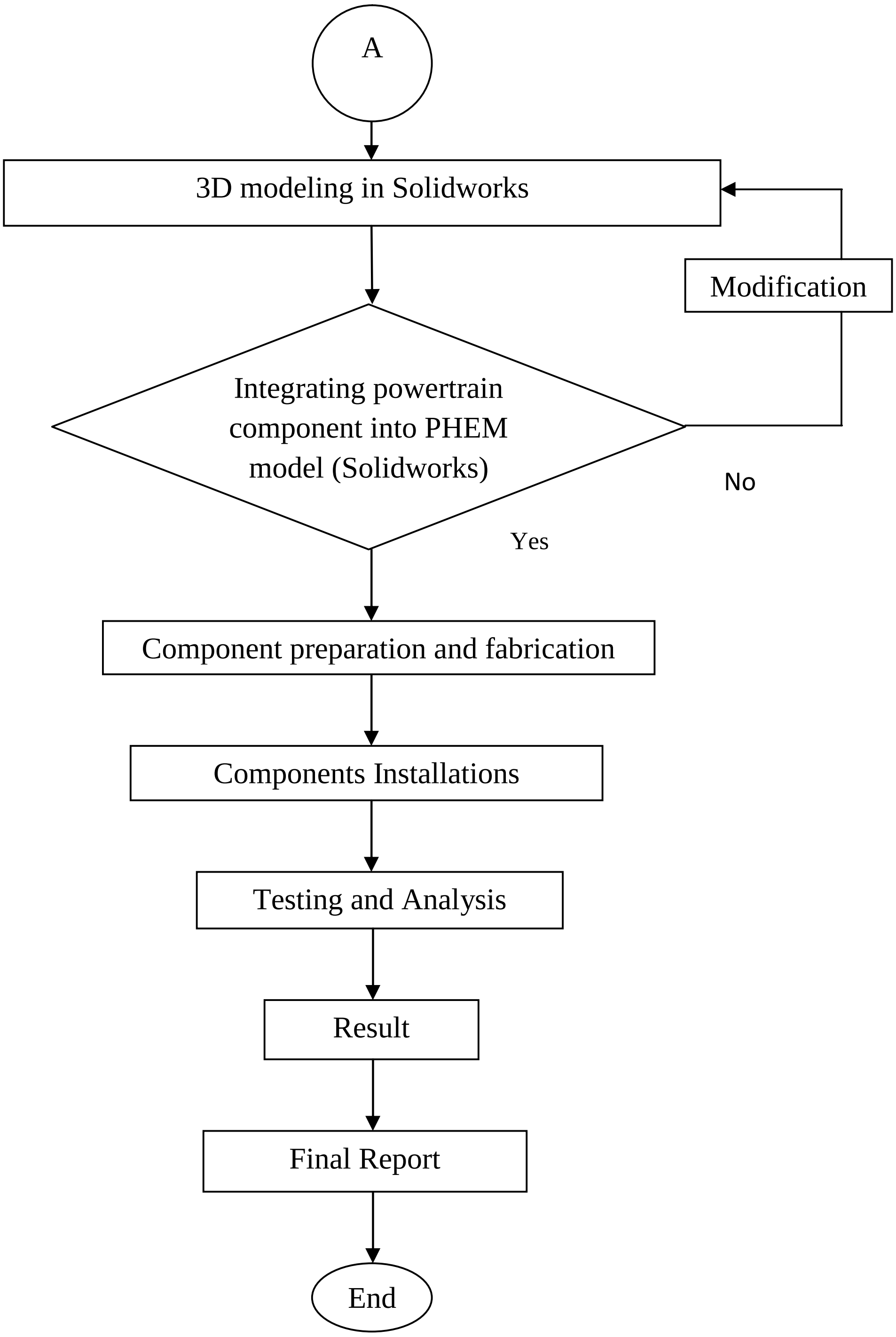
a. Develop the motorcycle Powertrain for plug-in hybrid electric.
b. Installation of measuring devices for data collection.
c. Assemble the parts and components of Powertrain.
d. Working model prototype.
e. Experimentation analysis and data collection.
f. Preparation of final report.

1.5 HYPOTHESIS

Prototype model for the Powertrain system could efficiently deliver the required propulsion power to drive the motorcycle with reducing the fuel consumption and saving energy usage from the IC engine will reduce the emission. The IC engine and electric motor should integrate well to drive the prototype model of PHEM.

1.6 FLOW CHART




A
3D modeling in Solidworks
Modification
Integrating powertrain component into PHEM model (Solidworks)
No
Yes
Component preparation and fabrication
Components Installations
Testing and Analysis
Result
Final Report
End

1.7 GANTT CHART

Refer to APPENDIX A

CHAPTER 2

LITERATURE REVIEW

2.1 DEVELOPMENT OF POWERTRAIN IN AUTOMOTIVE

PHEV is filling in the gap between electric vehicle and gasoline vehicle to consuming less fuel and producing fewer emissions than similar ICE vehicles (Kamil et al., 2010). . The current engine and Powertrain lineup is changing rapidly with introducing to hybridization, electrification, downsizing, down speeding (Kuen et al., 2007). This leads to the development of conventional and new technologies for Powertrain system. The function of Powertrain in PHEV is to give propulsion power to drive the vehicle. PHEV use batteries to power an electric motor and use a fuel, such as gasoline, to power an ICE or other propulsion source.

In general, conventional internal combustion engine driven vehicles are more efficient at relatively higher loads. But, most of the time they are operated at lower engine loads and hence they do not have better overall efficiency (Ehsani et al., 2004). The solution is the use of electric vehicles (EVs), which are more energy efficient and have fewer emissions. However, these vehicles have not been successful because of the high cost, added weight of batteries, reduced load capacity, limited range and lack of recharging infrastructure. Today's hybrid electric vehicles (HEVs) Powertrain offer improved fuel economy, low emissions and take the advantage of existing fuel infrastructure, but, still depend entirely on petroleum to charge the battery pack.

2.2 DEVELOPMENT OF POWERTRAIN IN PLUG-IN HYBRID ELECTRIC MOTORCYCLE (PHEM)

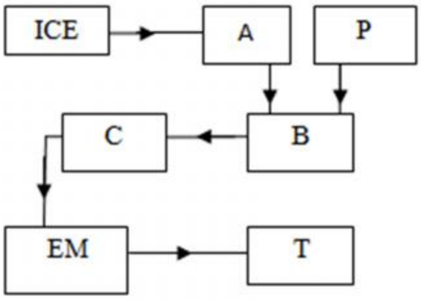
The development of powertrain for PHE for motorcycle is consequently very few because most of the study focusing to develop the PHE car rather than motorcycle. Since motorcycle has little internal space and there is a need for it to inexpensive, it is difficult to install the transmission devices for a hybrid Powertrain system (Kuen et al., 2007). Yamaha has been working on a "High-Performance Hybrid Motorcycle" since 2006. Based on Yamaha's original "Genesis" design ideal, the Gen-RYU combines a lightweight, compact YZF-R6 600cc engine and a high-output, high-efficiency electric motor. It is designed to offer both the joy of handling of a motorcycle and the comfort and carrying capacity of a scooter.

Figure 2.1: Yamaha Gen-RYU

Source: Yamaha (2013)

2.3 CONFIGURATION OF POWERTRAIN IN PHEM

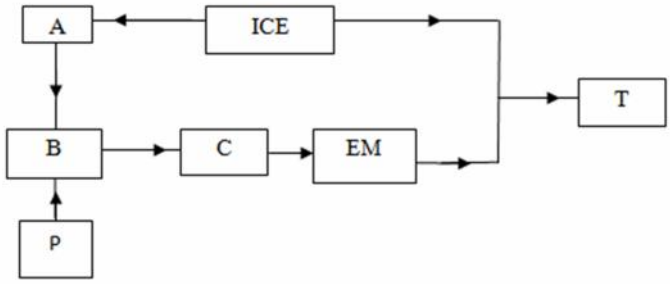
In a current study, thePowertrainn in PHEM can beconfiguredg to basic series configuration and parallel configuration. These configurations have been used to plug-in hybrid electric scooter and plug-in electric motorcycle. However in terms of size packaging and power demand, this configuration logically can be used for PHEM. Figure 2.2 and 2.3 show the possible PHEM Powertrain configuration.



Symbol	A	B	C	EM	P	ICE
Component	Alternator	Battery	Controller	Electric Motor	Plug-in/extra source	Internal Combustion Engine

Figure 2.2: Series PHEM configuration

In series, there is no mechanical connection between ICE and transmission. ICE is turned off when the battery can tolerate the electric motor in urban driving. ICE is turned on when the battery energy low in country driving. As the simplest Powertrain configuration, the mechanical output is converted using the alternator and use to charge the battery or bypass the battery to the electric motor. Therefore the Powertrain can operate at its maximum efficiency to improve on fuel efficiency. This configuration has a space packaging advantage but need multiple energy conversion before it can reach the transmission. The battery can fully recharge using an extra source which is plug-in connected to the battery.



Symbol	A	B	C	EM	P	ICE
Component	Alternator	Battery	Controller	Electric Motor	Plug-in/extra source	Internal Combustion Engine

Figure 2.3: Parallel PHEM configuration

In parallel powertrain configuration for PHEM, both mechanical power output and the electrical power output are connected in parallel to drive the transmission with various control strategies can be use (K.T. Chau et al., 2007). ICE basically always in on mode and operates at almost constant power output and maximum efficiency point while both the ICE and electric motor deliver power to drive transmission. Since the ICE and electric motor generally connected to same propulsion drive, the propulsion power may be provided by the ICE alone, by the electric motor alone or by both. ICE provides both the power to drive the vehicle and to generate the electricity for recharging the battery at the same time.

If the battery terminal voltage is high enough for the operation, engine and electric motor are both activated, thus making a combined torque to turn the drive shaft and move the vehicle forward. The proposed equation below that determine the power contribution from engine and electric motor (B.K. Bose et al., 2007).

$$\text{Power Provided By Motor,} P_{mc} = P_c\left(\frac{P_m}{P_m+P_e}\right) \quad (2.1)$$

$$\text{Power Provided By Engine,} P_{ec} = P_c - P_{mc} \quad (2.2)$$

2.3.1 Energy Storage Devices for PHEM

In the development of PHEM Powertrain system, the biggest concern for plug-in hybrids is the selection of type of battery. Naturally, PHEVs offer greater amounts of on-board energy storage than HEVs by integrating larger batteries. This larger battery size generates the possibility for moving applicable amounts of fuel for the engine with electricity from the electrical power grid.

For, plug-in hybrid electric vehicle designs proposed to have significant all-electric range with the energy storage unit must store sufficient energy to satisfy the driving range requirements (Burke AF., 2007). The electrical energy storage units must be sized so that they store sufficient energy (kWh) and provide enough peak power (kW) for the vehicle to have a required acceleration performance and the capability to meet suitable driving cycles. In addition, the energy storage unit must meet appropriate cycle and calendar life requirements. The batteries in this application are often deep discharged and recharged using grid electricity. Hence, cycle life for deep discharges is a key consideration and it is important that the battery meets a specified minimum requirement. With all battery chemistries, there are tradeoffs between the energy density and useable power density of the battery (Burke AF., 2007).

Lead acid batteries have low energy density normally around 30 Wh/kg whereas nickel-metal hydride (Ni-MH) batteries have an energy density of about 70 Wh/kg. Although Ni-MH batteries have a significant energy density than lead acid batteries, they have lower charging efficiency. Whereas, lithium-ion (Li-ion) batteries have energy density as high as 180 Wh/kg (Hodkinson et al., 2001).

Lithium-ion and lithium polymer batteries represent some of the most promising developments in the area of electric and hybrid vehicles. Figure 2.4 below shows the volumetric energy density (Wh/L) with respect to gravimetric energy density (Wh/kg) for different variety of batteries. New lithium-ion batteries seen from lab tests are able to last 10 years or more. Hence, lithium-ion batteries pack more energy density and specific power into a smaller battery package. The volume and weight savings (about 60%) over a Ni-MH battery means less weight and more space for comfort in the vehicle (Tarascan et al., 2001).

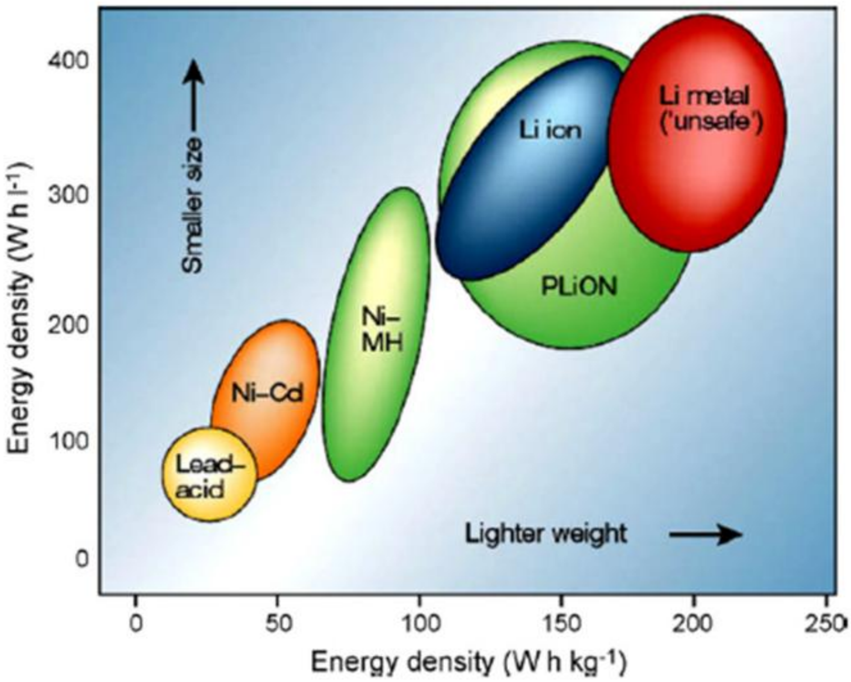


Figure 2.4: Volumetric energy density (Wh/L) with respect to gravimetric energy density (Wh/kg) for different variety of batteries

Source: Shaik Amjad (2010)