Dedicate

to

Hybrid Electric Vehicle

Research Team

ACKNOWLEDGEMENT

Is not an easy job to build a vehicle, especially building a vehicle that run on alternative power plant. Enormous of effort and commitment from the research team is not adequate. Consultation from the experts, collaboration with the electrical & electronic engineers and technical team is necessary to succeed the project.

First of all, the battery energy management research group would like to express their gratitude to the consultant of the project, Assoc. Prof. Dr. Rosli Abu Bakar for the ideas and project flow management. Without the support and funding contribution, the project will not able to accomplished within the research period.

HEV is the technology combination between mechanical and electrical engineering. Thereby, the contribution from the E&E engineering support is essential and it is appreciated.

For the detail design, development, fabrication and assembly between the mechanical and electrical system, the technical team from the FKM laboratory had shows their full commitment in the fabrication model, manufacturing process and the utilization of machining tools.

Last but not least, the research team would like to thanks to University Malasyia Pahang for the opportunity to carry out such a meaningful and knowledgeable project.

ABSTRACT

Among all the alternative energy and power plant development, Hybrid Electric Vehicle (HEV) is one of the most applicable systems. Similar to conventional vehicle, it still used internal combustion engine as the power source. Nowadays, the integration between IC engine and electric generation system could be found in various technologies. Several problems with HEV still remain unsolved although many researches had been carried out to build HEV. The research constraints include the size of the battery, charging period and the cost of the technology. In nation car market, some car manufacturers are keen to promote HEV to the nation municipal. Miserably, the price of the HEV is high and the popularity is remained low. To improve environment pollution, A-HEV project was carried out by local university level team to design, construct and develop a simple, attachable and low cost HEV system. Since it was the initial step for the research team move forward HEV technology, series HEV concept was referred. To further reduce the complexity and the attractiveness of the vehicle design, buggy platform was selected in this project. As the HEV technology cost is domain by the battery and electric management system, an alternate capability concept with programmable logic control system were adopted in the A-HEV project as well.

KEYWORD : Chassis, Hybrid system, Electric vehicle, IC engine, electric motor

ABSTRAK

Di antara semua tenaga alternatif dan pembangunan logi tenaga, Kenderaan Elektrik Hibrid (HEV), adalah sistem yang paling dimajukan applikasinya. Seperti kenderaan konvesional, penggunaan enjin pembakaran dalaman, I.C sebagai punca kuasa utama sistem masih digunakan. Kini, integrasi di antara Enjin I. C dan sistem janaan elektrik boleh dijumpai di dalam pelbagai teknologi masa kini. Beberapa masalah di dalam sistem HEV masih lagi tidak dapat diselesaikan walaupun ramai penyelidik telah pun membangunkan sistem HEV. Kekangan penyelidikan termasuklah saiz bateri, tempoh mengecas dan kos teknologi. Di pasaran tempatan, sesetengah pengilang kenderaan berusaha untuk mempromosikan ke peringkat nasional. Malangnya, faktor harga yang sangat tinggi menjadikan teknologi ini kurang popular. Untuk memperbaiki tahap pencemaran, projek A-HEV diketengahkan oleh universiti tempatan di mana penyelidik bermula dari merekabentuk, membina dan membangunkan satu kenderaan yang ringkas, mudah pemasangannya serta kos yang rendah bagi satu sistem HEV. Memandangkan projek ini merupakan langkah pertama untuk kumpulan penyelidik bergerak di dalam teknologi HEV, konsep HEV secara sesiri dirujuk. Untuk mengurangkan kerumitan dan menambah daya penarik kepada rekabentuk kenderaan ini, pelantaran *buggy* dipilih. Disebabkan kos teknologi HEV yang utama adalah bateri dan sistem pengurusan elektrik yang tinggi, konsep alternatif yang berkeupayaan sistem pemprogaman logik terkawal diadaptasi bagi sistem HEV ini.

Kata Kunci: Chasis, Sistem Hibrid, kenderaan elektrik, Enjin I.C , motor elektrik

LIST OF TABLE

LIST OF FIGURE

LIST OF APPENDIX

CONTENT

CHAPTER 1

INTRODUCTION

Over the 100 years of the automobile developments, internal combustion (IC) engine plays an important role to provide propulsion energy to the vehicle. Since then more and more R&D are focuses on the improvement of power, speed, torque, emission, dimension as well as the material used. Although the development of electric vehicle and hybrid electric vehicle had started since the last few decades, limited concentration R&D was achieved. Early electric vehicles were put out of business by the invention of the IC-engine starter motor, ironically another electrical device. **Figure 1** shows a schematic depicting the possible types of energy for driving the automobile. Of the three "large potential" contenders, hydrogen propulsion (probably in a hybrid drive) seems to be the long term future solution. In the meantime, natural gas and battery electric power offer shorter term solutions, each with individual drawbacks, or a hybrid between one of these two could emerge as a short-term quick-fix solution for environmental trouble spots.

In the conventional IC-engine based automobile system, chemical energy is converted into mechanical energy and multiple by the transmission system to the traction wheels. As the global automobile number raise sky-high and petroleum spirits are exhausted, it could worsen the pollution situation by delaying the widespread adoption of electric vehicles.

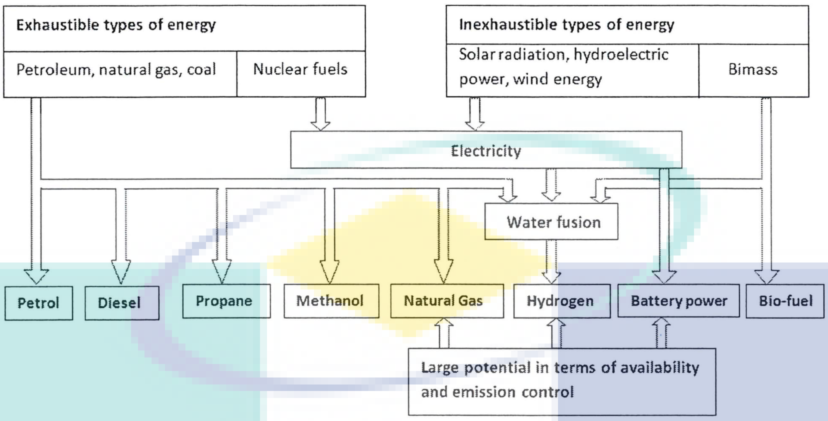


Figure 1.1 : Possible types of energy for driving automobile [3].

1.1 Problem Statement

In general understanding, electric vehicle is the type of automobile that not using IC engine as the main power plant. It store energy in chemical form and convert into electrical energy and drive the motor. Instead of using ECU and throttle opening to control the vehicle speed, EV would use Integrated circuit board (IC) with potential meter to vary the motor speed. A hybrid vehicle is a vehicle that uses two or more distinct power sources to propel the vehicle. Common power sources include on-board rechargeable energy storage system (RESS) and a fueled power source (internal combustion engine or fuel cell), air and internal combustion engines human powered bicycle with electric motor or gas engine assist and human-powered or sail boat with electric power.

The term most commonly refers to Hybrid-electric vehicle (HEV) which includes internal combustion engines and electric motors. Due to the environmental and world fossil fuel issues, HEV show its potential as an alternative power plant which could reduce the fossil fuel consumption or adapt other alternative fuel. In alternative energy research, amount of energy consume and the amount of energy produce by the power plant is normally compare to the fossil fuel system. HEV shows great competitive efficiency, where it prove better performance in fuel consumption and emission control. In the most recent future car development, HEV could be the most adaptable system which will replace the fossil fuel based on-road transportation.

For hybrid electric vehicle system, additional IC engine together with power generator were combined with EV system, whereby it shows enhancement in prolong the operating life and total output traction force on driving wheels. For the future development of EV and HEV system, battery storing system, electric motor system and controller design hold the success key as one of the alternative energy resources.

1.2 Project Objectives

Based on the problem statement, two project objectives were determined :

a. To design and develop a working prototype of hybrid electric vehicle
b. To develop an electric energy management system for the alternate hybrid vehicle system

1.3 Project Scopes

To accomplish the project objectives within the project constraint, the following scopes were made :

a. Literature review
b. Conceptual design
c. Determination of design specification
d. Fabrication model refinement and preparation
e. Design of electrical circuit
f. Manufacturing and assembly
g. Functionality testing

1.4 Flow Chart

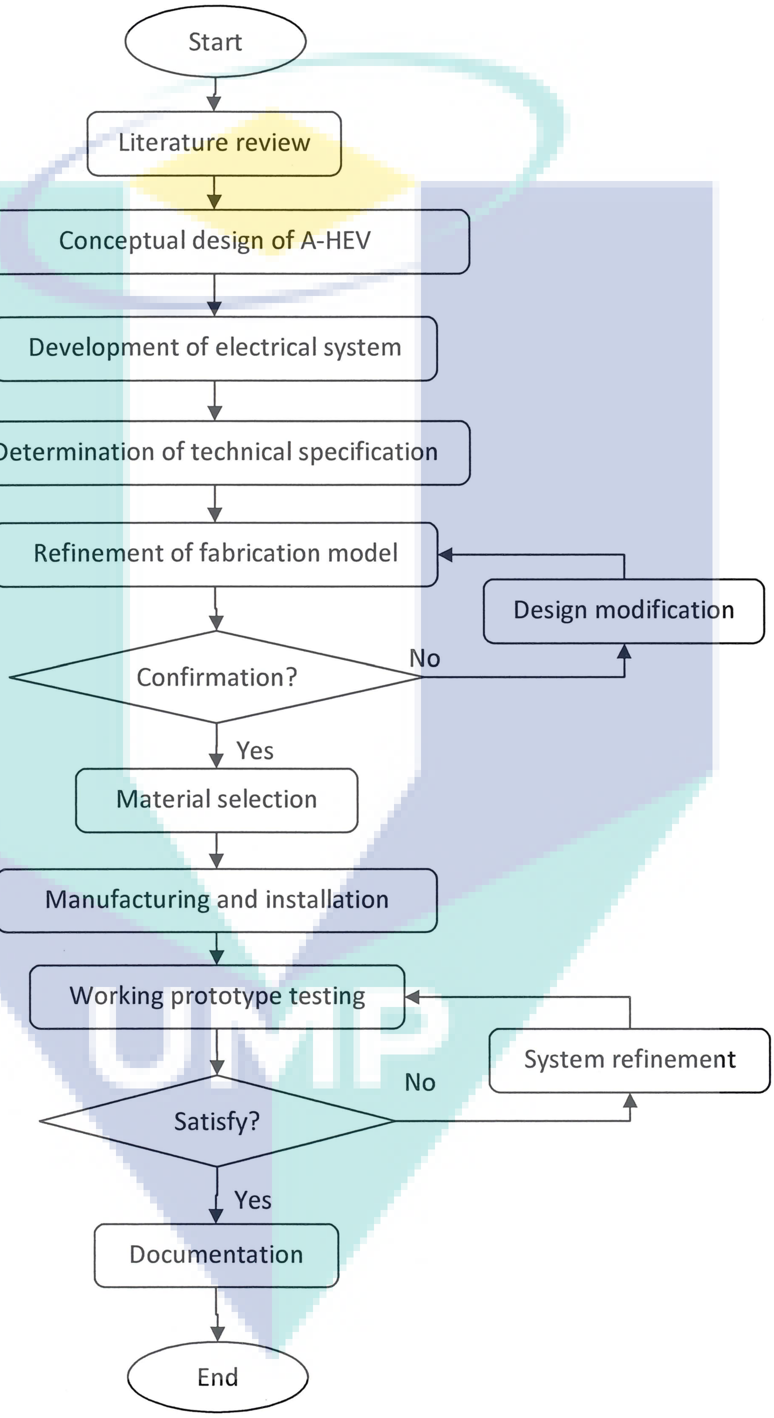


Figure 1.2 : Project flow chart for the development of A-HEV

1.5 Gantt Chart

Soon after the press media had discovered the studying condition of the dwarf child, the research team is given one month due date to design and develop the working prototype of ZUMP. In the time constraint situation, **Table 1.1** proposed the project timeline planning.

Table 1.1 : Project timeline for the development of A-HEV

Event	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
Conceptual design												
Design specification												
Electrical system design												
Material Selection												
Fabrication model refinement												
Manufacturing and installation												
Integration of mechanical and electrical system												
Testing and modification												

CHAPTER 2

LITERATAURE REVIEW

2.1.Fossil Fuel and Alternative Energy

Fossil fuels and their extensive use in various sectors, e.g., transportation, industrial, residential, commercial, etc. have caused some major problems for human health and welfare. To reduce the harmful effects of fossil fuels, some sustainable fuels and solutions need to be increasingly applied. One of the most important properties of sustainable sources is their environmental compatibility. This characteristic leads many to believe that sustainable fuels will become the most attractive energy sources in the short and long-term future and be the most promising from technological and environmental perspectives through the current and future centuries, particularly in the context of sustainable development.

As oil prices increase, the interest in alternative fuels increases. The concern of the air quality in many areas around the world makes finding solutions more urgent. As the price of oil rises, alternate fuels become competitive. Major questions remain to be answered on which fuel or fuels will emerge and to what extent alternative sources will replace gasoline as the main product of crude oil.

Cost differences between gasoline and most alternative fuels present an obstacle to more widespread use of these fuels. While conversion technologies may become more efficient and more cost-competitive over time, as long as gasoline prices remain relatively low, many alternative fuels may both become cost-competitive without government help, in the form of subsidies or tax credits. The cost difference between untaxed renewable fuels and taxed gasoline can be rather small.

If alternative fuels are to be more widely used, changes must take place both in fuel infrastructure, storage and engine technology. Infrastructural changes will improve the availability of alternative fuels. This can be done by modification of existing filling stations and by establishing a distribution system that is as efficient as the current gasoline system.

2.2.Electric Vehicle

An electric vehicle or EV is a vehicle with one or more electric motors for propulsion. This is also referred to as an electric drive vehicle. The motion may be provided either by wheels or propellers driven by rotary motors or in the case of tracked vehicles, by linear motor.

Unlike an internal combustion engine (ICE) that is tuned specifically operate with a particular fuel such as gasoline or diesel, an electric drive vehicle needs electricity which comes from sources such as batteries or a generator. This flexibility allows the drive train of the vehicle to remain the same, while the fuel source can be changed. Electric vehicles can include electric airplanes, electric boats and electric motorcycles and scooters.

Electric motive power started with a small railway operated by a miniature electric motor built by Thomas Davenport in 1835. In 1838, a Scotsman named Robert Davidson built an electric locomotive that attained a speed of four miles an hour. In England, a patent was granted in 1840 for the use of rails as conductors of electric current and similar American patents were issued to Lilley and Colten in

1847. Between 1832 and `839 (the exact year is uncertain), Robert Anderson of Scotland invented the first crude electric carriage, powered by non-rechargeable primary cells.

By the 20th century, electric cars and rail transport were commonplace, with commercial electric automobiles having the majority of the market. Over time their general purpose commercial use reduced to specialists roles as platform trucks, forklift trucks, tow tractors and urban delivery vehicles, such as the iconic British milk float, for most of the 20th century, the UK was the world's largest user of electric road vehicles.

Electric vehicles were among the earliest automobiles and before the preeminence of light, powerful internal combustion engines, electric automobiles held many vehicle land speed and distance records in the early 1990s. they produced by Baker Electric, Columbia Electric, Detroit Electric and others and at one point in history out sold gasoline powered vehicle. Currently, only a few electric cars are commercially available, including:

- The REVA, manufactured in India since 2001 for the India market, then also commercialized in the UK (since 2003) and several other European countries (including Cyprus and Greece, Belgium, Germany, Spain, Norway and Iceland)
- The Tesla Roadster, commercialized in the USA
- Several smaller electric vehicles, most of which are only commercialized locally in USA.

The power of a vehicle electric motor, as in other vehicles, is measured in kW. 100kW is roughly equivalent to 134 horsepower, although most electric motors deliver full torque over a wide RPM range, so the performance is not equivalent, and far exceeds a 134 horsepower fuel powered motor, which has a limited torque curve. For the operation of the electric vehicle, D.C. motors are used. Usually DC electricity is fed into a DC/AC inverter where it is converted to AC electricity and this AC electricity is connected to a 3-phase AC motor.

Some bicycles have been converted to electric power with a small battery and a small electric motor, some even have solar panels that are folded out when the vehicle is at rest. Small scale electric vehicles include electric cars, light trucks, neighborhood electric vehicles, motorcycles, motorized bicycles, electric scooters, golf carts, milk floats, forklifts and similar vehicles.

Although electric vehicles have few direct emissions, all rely on energy created through electricity generation which will emit pollution and generate waste, unless it is generated by renewable source power plants. Even with power plants emitting CO_2, the overall levels would be reduced because the entire process of moving a car is more efficient using electricity than producing gasoline and burning it in a car's engine. Since electric vehicles use whatever electricity is delivered by their electrical utility/grid operator, it is effortless to make vast amounts of electric vehicles more efficient or reduce/eliminate pollution by modify their generation stations that are the electrical source for them.

Electric vehicles are better suited for everyday driving than gasoline vehicles. They are simpler to manufacture, use less fuel, more efficient, more reliable, require less maintenance, quieter and produce less heat and air pollution. There are no fumes to inhale when sitting at a stoplight or when driving in a line of traffic. It often achieve 90% energy conversion efficiency over the full range of speeds and power output and can be precisely controlled, they can also combined with regenerative braking systems that have the ability to convert movement energy back into stored electricity. This can be used to reduce the wear on brake systems (and consequent brake pad dust) and reduce the total energy consumption of a trip especially effective for start-and-stop city use.

Electric motors can be finely controlled and provide high torque rest, unlike internal combustion engines, and do not need multiple gears to match power curves. This removes the need for gearboxes and torque converters. It develops most of their torque immediately when started allowing electric cars to accelerate faster and more efficiently than equivalent powered gasoline cars. Electric cars do not have a transmission, fuel tank, gasoline line, fuel pump, lubricating system or exhaust system. Oil changes are not necessary. Other advantages are not readily apparent. The air conditioning compressor is run by an electric motor, not a belt off of the gasoline engine. The air conditioning system is just as efficient as a stop light, as when the car is moving.

Electric systems, including batteries, ultra capacitors and controllers are developing rapidly. The subsystems of electric vehicles such as electric power steering, hear pumps and instruments are already being developed for hybrid vehicles. Development of all electric vehicle can have all of the safety systems now present, including air bags, stability control and antilock brakes. Another advantage is that electric vehicles typically have less vibration and noise pollution than a vehicle powered by an internal combustion engine, whether it is at rest or in motion.

2.3.Hybrid Electric Vehicle

In 1901, while employed at Lohner Coach Factory, Ferdinand Porsche designed the "*Mixte*", a series-hybrid vehicle based on his earlier "*System Lohner-Porsche*" electric carriage. The Mixte broke several Austrian speed records, and also won the Exelberg Rally in 1901 with Porsche himself driving. The Mixte used a gasoline engine powering a generator, which in turn powered electric hub motors, with a small battery pack for reliability. It had a range of 50 km, a top speed of 50 km/h and a power of 5.22 kW during 20 minutes.

A more recent working prototype of the HEV was built by Victor Wouk (one of the scientists involved with the Henney Kilowatt, the first transistor-based electric car). Wouk's work with HEVs in the 1960s and 1970s earned him the title as the "Godfather of the Hybrid". Wouk installed a prototype hybrid drivetrain (with a 16 kW electric motor) into a 1972 Buick Skylark provided by GM for the 1970 Federal Clean Car Incentive Program

For Parallel hybrid; electric & petroleum engine drive system, an electric motor and internal combustion engine are installed so that they can both individually or together power the vehicle. Typical passenger car installations such as those from Toyota and Lexus use electric power for reversing and low speed low throttle opening work, typical in urban and suburban environments. As the vehicle speed increases or the higher acceleration demand, the internal combustion engine starts and both power units work together in parallel (hence the name). The installed electric motors and battery capacity may offer a range of 3-5km in pure electric mode, at speeds of up to 40km/hr. Beyond this, the internal combustion engine is needed to either provide increased power or to recharge the batteries. The Toyota Prius and the Ford Escape Hybrid are examples of vehicles falling into this category.

On the open road, the primary power source is the internal combustion engine (partly to maximize the life of the batteries), but when maximum power is required, for example to overtake, the electric motor is used to maximize the available power for a short time, giving the effect of having a larger engine than that actually installed.

The fuel consumption benefits of a hybrid electric vehicle against an internal combustion vehicle of similar performance come through the recovery of braking energy, stored in the battery by the motor/generator for use at the next start which in a conventional vehicle would have been dissipated as heat from the brakes. The capability to shut-off the engine while maintain the operation of electric motor could further improve fuel consumption. The larger the motor and the battery, the more braking energy it can recover before conventional brakes are necessary to achieve the required retardation. However, a weight/space compromise determines the limit of energy recovery possible in a given installation.

Mild hybrid, Electric assist is the second type of hybrid system, where it uses the electric motor only to assist the gasoline engine when it needs extra boost, again during brisk acceleration or when going up a hill. The Honda Civic Hybrid and Honda Insight fall into the second category. The main improvement in fuel consumption over a conventional vehicle with the same performance is possible by the installation of a smaller internal combustion engine, with smaller internal losses and lower weight. There are also savings through energy recovery through the motor/generator on the overrun and while decelerating.

When a car like the Honda Insight and Civic Hybrid, the electric motor assists the gas engine only when driving conditions demand more power, such as during hard acceleration from a stop, while climbing a hill or passing other vehicles. As with normal, gas-powered cars, these hybrids get better fuel economy while cruising on the highway, as that is when the gas engine is least taxed. The Smart Hybrid is a recently introduced mild-hybrid.

An addition to the hybrid market is the Plug-in Hybrid Electric Vehicle (PHEV). The PHEV usually consists of a gasoline-electric hybrid with increased energy storage capacity (usually Li-ion batteries). It may be connected to mains electricity supply at the end of the journey to avoid charging using the on-board internal combustion engine. This concept is attractive to those seeking to minimize on-road emissions by avoiding - or at least minimizing - the use of ICE during daily driving. As with pure electric vehicles, the total emissions improvement is dependent upon the energy source of the electricity generating company.

For some users, this type of vehicle may also be financially attractive so long as the electrical energy being used is cheaper than the petrol/diesel that they would have otherwise used. Current tax régimes in many European countries use mineral oil taxation as a major income source. This is generally not the case for electricity, which is taxed uniformly for the domestic customer; however he/she uses it. Some electricity suppliers also offer price benefits for off-peak night users, which may further increase the attractiveness of the plug-in option for commuters and urban motorists. There are currently no series production plug-in hybrids, but GM, for example, with the Chevrolet Volt is pushing forward towards a series product introduction in 2-3 years

Automotive hybrid technology became successful in the 1990s when the Honda Insight and Toyota Prius became available. These vehicles have a direct linkage from the ICE to the driven wheels, so the engine can provide acceleration power. The Prius has been in high demand since 2004. Newer designs have more conventional appearance and are less expensive, often appearing and performing identically to their non-hybrid counterparts while delivering 40% better fuel efficiency.

Current HEVs reduce petroleum consumption under certain circumstances, compared to otherwise similar conventional vehicles, primarily by using three mechanisms.

- Reducing wasted energy during idle/low output, generally by turning the ICE off
- Recapturing waste energy (i.e. regenerative braking)
- Reducing the size and power of the ICE, and hence inefficiencies from under-utilization, by using the added power from the electric motor to compensate for the loss in peak power output from the smaller ICE.

Any combination of these three primary hybrid advantages may be used in different vehicles to realize different fuel usage, power, emissions, weight and cost profiles. The ICE in an HEV can be smaller, lighter, and more efficient than the one in a conventional vehicle, because the combustion engine can be sized for slightly above *average* power demand rather than *peak* power demand. The drive system in a vehicle is required to operate over a range of speed and power, but an ICE's highest efficiency is in a narrow range of operation, making conventional vehicles inefficient. In contrast, in most HEV designs, the ICE operates closer to its range of highest efficiency more frequently. The power curve of electric motors is better suited to variable speeds and can provide substantially greater torque at low speeds compared with internal-combustion engines. The greater fuel economy of HEVs has implication for reduced petroleum consumption and vehicle air pollution emissions worldwide

Instead of fuel consumption, lower noise emissions is obtained resulting from substantial use of the electric motor at idling and low speeds. Reduced noise may not be considered an advantage by some; for example, some people who are blind or visually-impaired consider the noise of combustion engines a helpful aid while crossing streets and feel quiet hybrids could pose an unexpected hazard.

Due to lower fuel consumption, HEV lead improved human health with regard to respiratory problems and other illnesses. Pollution reduction in urban environments may be particularly significant due to elimination of idle-at-rest.

2.4.Energy Storing, Conversion and Control Unit

On an energy basis, the price of electricity to run an EV is a small fraction of the cost of liquid fuel needed to produce an equivalent amount of energy. Issues related to batteries, however, can add to the operating costs.

Lead-acid batteries in EV applications end up being a significant (25-50%) portion of the final vehicle mass. Like all batteries, they have significantly lower energy density than petroleum fuels – in the case, 30-40Wh/kg. while the difference isn't as extreme as it first appears due to the lighter drive-train in an EV, even the best batteries tend to lead to higher masses when applied to vehicles with a normal range. The efficiency and storage capacity of the current generation of common deep cycle lead acid batteries decrease with lower temperature, and diverting power to run a heating coil reduces efficiency and range by up to 40%. Recent advances in battery efficiency, capacity, materials, safety, toxicity and durability are likely to allow these superior characteristics to be applied in car sized EVs.

Charging and operation of batteries typically results in the emission of hydrogen, oxygen and sulfur, which are naturally occurring and normally harmless if properly vented. Early City-car owners discovered that, if not vented properly, unpleasant sulfur smells would leak into the cabin immediately after charging. Lad acid batteries have been re-engineered by Firefly Energy, increasing longevity, slightly increasing energy density and significantly increasing power density. Firefly is expected market lightweight vehicle batteries, either directly or through manufacturing partners in 2008.

Nickel-metal hydride batteries are now considered a relatively mature technology. While less efficient in charging and discharging than even lead-acid, they boast an energy density of 30-80 Wh/kg, far higher than lead acid. When used properly, nickel-metal hydride batteries can have exceptionally long lives, as has been demonstrated in their use in hybrid cars and surviving NiMH RAV4EVs that still operate well after 100,000 miles and over a decade of service. Downsides include the poor efficiency, high-self-discharge, very finicky charge cycles and poor performance in cold weather.

The sodium or "zebra" battery used a molten chloro-aluminate ($NaAlCl_4$) salt as the electrolyte. Also a relatively mature technology, the Zebra battery boasts a good energy density of 90Wh/kg and near lossless charge/discharge cycles. Since the battery must be heated for use, cold weather doesn't strongly affect its operation excepted for in increasing heating costs. It has been used in several EVs. The downsides to the Zebra battery include poor power density and the requirement of having to heat the electrolyte, which wastes energy and presents difficulties in long-term storage of charge. Zebras can last for a few thousand charge cycles and are nontoxic.

Lithium-ion (and similar lithium polymer) batteries, widely known through their use in laptops and consumer electronics, dominate the most recent group of EVs on development. The traditional lithium-ion chemistry involves a lithium cobalt oxide cathode and a graphite anode. This yields cells with an impressive 160Wh/kg energy density and good power density, and near lossless charge/discharge cycles. The downsides of traditional lithium-ion batteries include short cycle life (hundreds to a few thousand charge cycles) and significant degradation with age. The cathode is also somewhat toxic. Also, traditional lithium-ion batteries can pose a fire safety risk if punctured or charged improperly. The maturity of this technology is moderate. The Tesla Roaster uses "blades" of traditional lithium-ion "laptop battery" cells that can be replaced individually as needed.

Most other EVs are utilizing new variations on lithium-ion chemistry that sacrifice energy density (often resulting in batteries with 100Wh/kg or less) to provide extreme power density, fire resistance, environmental friendliness, very rapid charges (as low as a few minutes) and very long lifespan.

Assuming a 50 kilowatt-hour battery pack and ideal charging efficiency, a ten minute quick charge from 10% to 80% capacity would require a power draw of 210 kilowatts from the electric grid. At 240 volts, this means a current draw 0f 875 Amperes from the outlet. In practice, the energy efficiency of quick charging is likely to be somewhat lowered due to the ohmic losses caused by the required high current. The lost energy is converted directly to heat, which causes wear to the battery pack and other electronics involved. Increasing the capacity of the battery pack increases the required power, current and heat loss linearly which is why quick charging may become impractical or impossible as vehicles with increased range are developed.

The high peak power requirement of quick charging also puts additional stress to the local power grid and many put it to a risk of failure during periods of peak demand. The most obvious solution is to use another battery to act as a buffer between the charging station and the power grid. The battery as a buffer however, suffers a similar efficiency drops the car itself, thus lowering the overall efficiency of the system. Another possibility is on-site, on-demand electricity generation.

Battery replacement is also proposed as an alternative. While it suffers from some problems (weight, standardization, etc), project Better Place has already raised several hundred million dollars to build networks of charging and battery replacement stations. One type of battery "replacement" proposed is much simpler while the latest generation of vanadium redox battery only has an energy density similar to lead acid, the charge is stored solely in a vanadium based electrolyte, which can be pumped out and replaced with charged fluid.

There have been several developments which could bring electric vehicles outside their current fields of application, as scooters, golf cars, neighborhood vehicles, in industrial operational yards and indoor operation. First, advances in lithium-based battery technology, in large part driven by the consumer electronics industry, allow full-sized, highway-capable electric vehicles to be propelled as far on a single charge as conventional cars go on a single tank of gasoline. Lithium batteries have been made safe, can be recharged in minutes instead of hours, and now last longer than the typical vehicle. The production cost of these lighter, higher-capacity lithium batteries is gradually decreasing as the technology matures and production volumes increase.

Another improvement is to decouple the electric motor from the battery through electronic control, employing ultra-capacitors to buffer large but short power demands and regenerative braking energy. The development of new cell types combined with intelligent cell management improved both weak points mentioned above. The cell management involves not only monitoring the health of the cells but also a redundant cell configuration (one more cell than needed). With sophisticated switched wiring it is possible to condition one cell while the rest are on duty.

2.5.Chassis and Body Design

A frame is the main structure of an automobile chassis. All other components fasten to it. While appearing at first glance as a simple hunk of metal, frames encounter great amounts of stress and are built accordingly. They first issue addressed is beam height, or the height of the vertical side of a frame. The taller the frame, the better it's able to resist vertical flex when force is applied to the top of the frame. This is the reason semi-trucks have taller frame rails than other vehicles instead of just being thicker.

Another factor considered when engineering a frame is torsional resistance, or the ability to resist twisting. This, and diamonding (one rail moving backwards or forwards in relation to the other rail), are countered by cross-members. While hat-shaped cross-members are the norm, these forces are best countered with "K" or "X"-shaped cross-members.

The use of monocoque extended into the realm of automobiles as unibody construction (body is integrated into a single unit with the chassis) starting in 1923 with the Lancia Lambda, but it didn't really take off until Nash Motors released their 600 in 1941. Because the body was constructed as a single unit, Nash produced a vehicle that was not only stronger, but about 500 pounds lighter than a traditional body-on-frame automobile. Today, monocoque or unibody construction is so sophisticated in automobile manufacturing that the windshields often make a significant contribution to the structural strength of the vehicle.

Body-on-frame is an automobile construction technology. Mounting a separate body to a rigid frame which supports the drivetrain was the original method of building automobiles, and its use continues to this day. The original frames were made of wood (commonly ash), but steel ladder frames became common in the 1930s.

In the frequent changes in automobile design made it necessary to use a ladder frame rather than monocoque to make it possible to change the design without having to change the chassis, allowing frequent changes and improvements to the car's bodywork and interior (where they were most noticeable to customers) while leaving the chassis and driveline unchanged, and thus keeping cost down and design time short. It was also easy to use the same chassis and driveline for several very different cars. Especially in the days before computer-aided design, this was a big advantage.

Most small passenger vehicles switched to Body Frame Integral construction in the 1960s, leaving just trucks, some bus manufacturers and large cars using conventional frames. The switch continued for several decades - even small SUVs typically use unibody construction today. Body-on-frame remains the preferred construction method for heavy-duty commercial vehicles, especially those which are intended to carry and pull heavy loads, such as trucks. Some pros and cons of the body-on-frame over unibody design are listed in **Table 2.1**.

Table 2.1 : Pros and cons of body-on-frame over unibody design

Pros	Cons
Easier to design, build and modify (less of an issue now that CAD is commonplace, but still an advantage for coach-built vehicles).	Heavier than unibody - lower performance and/or higher fuel consumption.
More suited for heavy duty usage and can be more durable.	Less resistant to torsion (flexing of the whole car in corners) - compromising handling and road grip.
Easier to repair after accidents.	No crumple zone - higher rate of death and serious injury
Overall better ride quality [2] for SUVs.	Higher production costs
	Center of gravity is usually higher - compromising stability and handling.

Backbone chassis is a type of an automobile construction chassis that is similar to the body-on-frame design. Instead of a two-dimensional ladder type structure, it consists of a strong tubular backbone (usually rectangular in cross section) that connects the front and rear suspension attachment areas. A body is then placed on this structure. It is almost a trademark design feature of Czech (oslovak) Tatra heavy trucks (cross-country, military etc.), but this type of chassis is also often found on small sports cars. It also does not provide protection against side collisions, and has to be combined with a body that would compensate for this shortcoming.

A sub-frame is a structural component of a vehicle, such as an automobile or an aircraft, that uses a discrete, separate structure within a larger body-on-frame or unit body to carry certain components, such as the engine, drivetrain, or suspension. The sub-frame is bolted and/or welded to the vehicle. When bolted, it is sometimes equipped with rubber bushings or springs to dampen vibration.

The principal purpose of using a sub-frame is to isolate vibration and harshness from the rest of the body. When the powertrain contained in a sub-frame, forces generated by the engine and transmission can be damped enough that they will not disturb passengers. As a natural development from a car with a full chassis, separate front and rear sub-frames are used in modern vehicles to reduce the overall weight and cost. In addition a sub-frame yields benefits to production in that subassemblies can be made which can be introduced to the main body-shell when required on an automated line. There are generally two basic forms of the sub-frame:

a. A simple "axle" type which usually carries the lower control arms and steering rack.
b. A perimeter frame which carries the above components but in addition supports the engine.

A space frame or space structure is a truss-like, lightweight rigid structure constructed from interlocking struts in a geometric pattern. Space frames usually utilize a multidirectional span, and are often used to accomplish long spans with few supports. They derive their strength from the inherent rigidity of the triangular frame; flexing loads (bending moments) are transmitted as tension and compression loads along the length of each strut.

Most often their geometry is based on platonic solids. The simplest form is a horizontal slab of interlocking square pyramids built from aluminum or steel tubular struts. In many ways this looks like the horizontal jib of a tower crane repeated many times to make it wider. A stronger purer form is composed of interlocking tetrahedral pyramids in which all the struts have unit length. More technically this is referred to as an isotropic vector matrix or in a single unit width an octet truss. More complex variations change the lengths of the struts to curve the overall structure or may incorporate other geometrical shapes.

Space frames were independently developed by Alexander Graham Bell around 1900 and Buckminster Fuller in the 1950s. Bell's interest was primarily in using them to make rigid frames for nautical and aeronautical engineering although few if any were realized. Buckminster Fuller's focus was architectural structures and has had more lasting influence. It is an increasingly common architectural technique especially for large roof spans in modernist commercial and industrial buildings.

Tubular space frames are also widely used in the production of modern motorcycles and automobiles (and NASCAR race cars are exclusively built from space frame construction), but monocoque car bodies have been more common since the 1950s. Space frames have also been used in the latest incarnations of the unorthodox bicycles designed by Alex Moulton.

Instead of referring to types of vehicle body design as the general guideline, the development of the electric vehicle or hybrid electric vehicle also has to consider the following factors:

a. Weight : a big issue with an EV and HEV because it will affects performance. Acceleration, hill climbing ability, and rolling resistance all get worse as the car gets heavier.
b. Aerodynamics : Aerodynamic drag goes up with the square of speed, so doubling the speed will quadruple the aerodynamic drag
c. Precedent
d. Conversion Issues
e. Parts availability
f. Cost

CHAPTER 3

METHODOLOGY

Among the operating environments which have attracted commercial/ industrial EVs are early-morning urban milk delivery, in-factory materials handling and airport cargo/baggage handling – and aircraft ground-towing. Future possibilities lay in noise and exhaust-fume sensitive city goods deliveries and public passenger-transport – also the possibility of individual passenger transport in future new town residential and/or industrial areas incorporating suitable purpose-built carriageways. The remove of individual transport from congested city centre could be rescinded in favor of sympathetic route planning and vehicle development which would enhance prospects for special purpose electric cars. For passenger cars, electric vehicle technology seems always to be waiting for that 'breakthrough around the corner' in battery development; however, for industrial vehicles, many operating environments rule that EV technology is the only solution.

BUGGY – a kind of short distance transportation for multipurpose application. The general utilization including golf field, recreational place, large factory area, beach side and some other off-road condition. The design of the buddy might be vary due to different application. For off-road buggy, high torque with high travel distance suspension system is suitable since the traveling area is not even. For recreational purpose, low speed and comfortable buggy design will be the main selection. For the leisure outdoor activities and time saving walking distance purpose, electric buggy had become the public choice. Its zero emission and low noise operation give comfort ride without creating any unnecessary disturbance to the environment. As an alternative power plant for future automotive development, electric buggy would serve as a simple research platform rather than on-road fully electronic control vehicle. Compare to engine powered buggy, popularity of the electric buggy still require improvement especially in battery power management, battery charging system and electric motor output control.

A-HEV – Since the chassis design is much simpler and the vehicle dynamics of the buggy is similar with the commercial vehicle, an inspiration has drives the HEV research team in University Malaysia Pahang (UMP) to develop local HEV. Although the HEV is well developed in other countries like Japan and America, this research is still necessary for Malaysian to prove its independent technology enhancement in the world spectacle. In this content, electric buggy system would be the unlikely the reference model for the initial UMP-HEV development.

The term **ALTERNATE** in the project means the modular capability of the HEV unit in the UMP buggy. Limitations in the general electric buggy give negative impression to the public user. Some of it including short travel distance due to low battery power and specific external charging system which require household electricity. In addition, the battery unit for the general electric vehicle is built in and battery charging time usually takes plenty of time where the buggy must remain rest during charging period. Therefore, the innovations of the A-HEV project is to develop a simple and detachable modular battery unit and portable power charging source which allow the buggy to switch between full electric mode and hybrid mode depending on situation. The development of the alternate power plant switching module could benefits the power refueling period, maintenance time, emission and noise as well as the driving pleasure experience.

3.1. Project Consideration

As the initial project to develop A-HEV, some basic consideration had been list out and amount of literature study and brainstorming help to improve the quality of the design.

It is clear that the target of the projects is to design and develop a buggy type hybrid electric system. Based on the project objectives, following is a list of important features to be considered for the whole project:

a. Battery storing system
b. Electric energy management system
c. Alternate hybrid system
d. Ride and handling
e. Prototyping construction (rapid and working) which including
    i. Chassis design
    ii. Autobody design
    iii. Material and manufacturing selection

3.2.Conceptual Design Creation

In the design and development project, ideas with technical explanation/ support would be a very promoting step. Based on the general adult height dimensions which published by Pat Papp Enterprises, a basic 3D human model is necessary as the reference. After the forming of technical team, brainstorming session is required to generate ideas and design sketches. At first, very basic free hand sketch will dominant the project progress and it would be a fast and straight forward method to collect information. For detail conceptualization, 3D graphic based modeling technique provides better idea visualization.

Without any pre-requisites, conceptual design might come with enormous of nonsense and ridiculous design, where it could direct the research group to other field. In this manner, a specific theme is required as the ignition key to spark up the project. It could inspire and at the same time restraint the ideas generating within the scopes.

There are variety of car category based on the application, functionality and configuration. Refer to the project theme and basic dimensions, requirements (end-user, material, production technology, cost, size and etc), it serve a simple and useful guideline for brainstorming session. In addition, not all logical conceptual ideas will be accept. A filtering session could be benefit to short list the most realistic design to be proposed for detail discussion.

3.3. Design Specification and Physical Dimensions Measurement

After accomplish the conceptual design, the next research progress is on the development of rapid prototype and refinement of the fabrication model with detail dimensions, components, mechanical linkage and electrical system as well. Although there is a basic human model which help to smoothen the conceptualization, detail physical dimensions measurement is still very important so that the final product suite the end-user utilization. Refer to **Figure 3.1**, the proper modeling of human dummy is govern by the dimensions listed from A to Z. Based on moderate adult human physical dimensions, the conceptual model will be refined few times according to main theme, esthetic, compactness, rapid modeling and fabrication stage.

The design detail for the A-HEV could be sub-divided into few groups. First of all, the research team has to consider the passenger cabin or safety cage design. Since the objectives of the design are for low speed, confine area application, lower level of safety features is considered. In case of accident such as roll-over or crashed by other vehicles, the passenger cabin must serve two purposes – instant escape and full protection from harmful attack. For modern vehicle design, technical functionality must come with esthetic look and comfort issue. All this factors must be considered during the design and development of the passenger design.

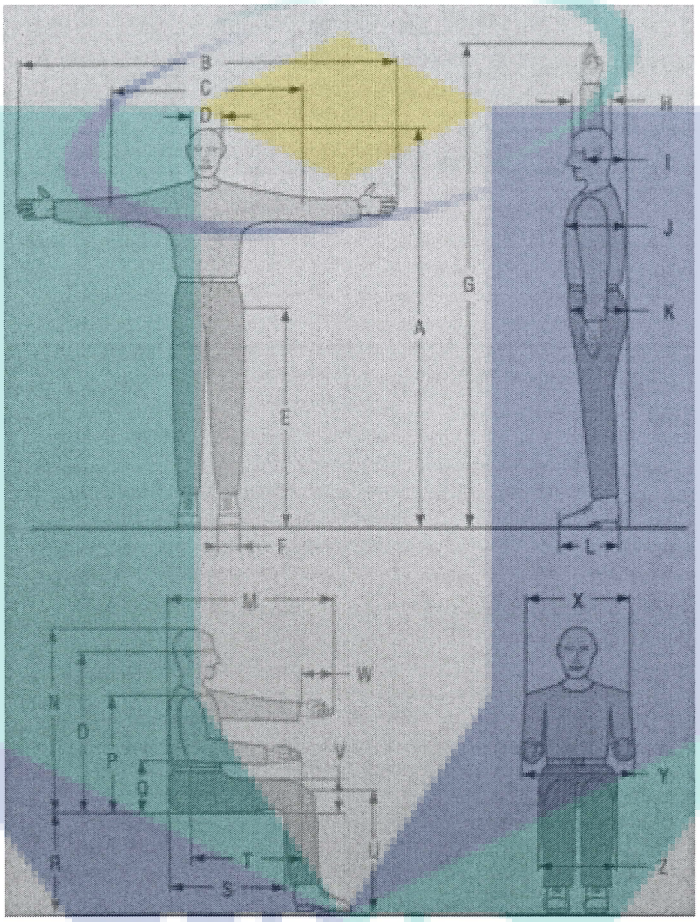


Figure 3.1: Physical dimensions reference for human dummy design

Secondly – front cabin or the storage compartment. In general perception, vehicle front cabin could be use as engine plus other auxiliary system installation or luggage compartment depend on the vehicle configuration. Newer development of the alternative vehicle, powering system is located beneath the car and this could eliminate the front compartment to gain spacious passenger cabin. For buggy design, alternate concept allows fast battery exchange. In order to realize this concept, front cabin could be use as the battery storing unit. During the exchange process, the battery should not be removed unit by unit. It means that specific battery chassis is required. For the battery chassis design, the research group should consider the strength, size, mounting, balancing and interface with the passenger cabin. For mass saving purpose, the battery frame could serve as load carrier for the suspension strut tower and front weight support.

Thirdly – rear trailing chassis design. Similar to the front cabin design, the vehicle rear chassis could be constructed with either drive or driven system depends on the vehicle configuration. If the front cabin for the proposed buggy design had been used for battery storing purpose, it is totally agree that rear cabin should design for driving purpose. For either electric vehicles or series hybrid electric vehicle design, electric motor is the last contact with the driving wheels via some form of coupling unit. Compare to IC engine powered vehicle, EV or HEV has the advantage in noise reduction. Therefore, the selection of the coupling unit between driving motor and the driving wheel must meet this requirement.

Fourthly – Rear cabin design. This unit show is general and simple, where it should provide adequate space for portable charging unit (in HEV mode) and rooms to transport low to medium weighted stock.

3.4.Development of Rapid Prototype

As the full preparation on the conceptual design stage, a rapid prototyping model will be made. Compared to computer 3D model, rapid prototype allows designers to have detail analysis on the structure and system integration between mechanical and electrical system.

Rapid prototyping could be either full scale, scaled down or scaled up depends on the requirements. For hand held components such as piston and connecting rod, full scale rapid prototype is sufficient. For micro components such as electronic chips, the model should be scaled up for detail inspection. For vehicle size or enormous design, the rapid prototype could be either scaled down or full sized. The main factors which influence the process is the cost and necessity. If the prototype will be use for working model development as well, full scale rapid prototype is preferred. For design inspection purpose, scaled down model is most cost effective.

In A-HEV model development, the 3D printing technology was adapted in the project. The basic concept for this technology is simple. The original idea comes from the Japanese Origami, which is a kind of paper art work. When the designer wants to build a 3D or actual solid model, they split the model into layer by layer. Then the cross sectional areas for each layer are cut and then join together by glue. Based on this art work, the 3D printing technology was created. Using a scrapper, a specific powder is spread in printing margin (0.1mm thickness). The cross section graphic is printed using general print head. After that, second layer of powder is spread on the previous layer and follow by second printing. The process is continuous from the initial layer to the last layer. After heat treatment and curing, the rapid prototype will be ready for visual inspection, functional testing and visual display. Although the technology promising a cost effective model, recycle capability and environmental friendly, this material is brittle and the curing process is difficult to handle.

From the initial concept design, the proposed model is modified and scaled down for modeling purpose. In the model modification, all components must be union in a specific solid model and the minimum thickness is within 3mm so that the finish product could be use for curing process. Following the process restriction, overall design must go through full modification (especially the chassis, spring and component simplification).

There is one important reason why the 3D printing technology is adapted in this project – capability of 24 bits full color printing. For other rapid prototyping technology, only few selected colors is available. But for the 3D printing technology, it allows the designer to color the end product as proposed.

3.5.Fabrication Model Refinement

For the development of fabrication model, there are two methods. First of all, the researcher could determine the dimensions of the A-HEV and then search for the auxiliary components (mechanical and electrical) which suitable for project utilization. Second, researcher could gather all necessary components, transform it into 3D graphical model and fit with the main system before the manufacturing process.

Both methods show it potential solutions in providing alternative way for a research project. First method could speed up the manufacturing and development time but it only suitable for development of single and non-interrelated system design. Comparatively, second method will confirm that no additional modification work on the complex system design but it might drag the development time especially for vehicle development Due to limited budget, the research will have to precede the refinement of the project according to second method.

Back to the project progress, refinement of the concept design to rapid prototype and into fabrication model is an important step. A single wrong decision might cause the malfunction of other system and need rework modification and finally delay the project schedule. **Table 3.1** listed out some of the important features need fine inspection and serious decision making.

Table 3.1 : Consideration factors for refinement process

No.	Features	Detail Description
1	Overall dimension	Ensure comfort and safety design with the consider of driver and passenger dimensions and ergonomic features Adequate rooms for batteries, motor, drive system, steering system, control unit and etc. Strong and stiff structure with sufficient mounting point for mechanical and electrical system.

		Transmission mechanism must suite the application (forward, reverse, acceleration and braking)
2	Stability	High clearance distance with stable structure (low c.g.) Triangle steel structure for minimal deformation and load distraction
3	Integration	Sufficient tolerance and rooms between passenger cabin, front cabin, rear cabin and trailing structure Space for hidden cable (safety)
4	Safety	Leisure and safe driving condition Not reachable to electrical and hearing system No disturbance in control units Low operating noise between Easy to disassembly and assembly Total short circuit possibility free Easy and fool proof operation mode Emergency stopping features.
5.	Mechanical	Selection of driving mechanism, transmission system Material and sizing Manufacturing method : lathe, mill, bending, welding and etc. Mounting and joining method : bolt and nut, rivets, epoxy, latches
6.	Electrical	Adequate power size rating motor with suitable controller Design of the control unit (hardware and software) Linkage between DC and AC power supply Air ventilation

Although **Table 3.1** could provide basic guidance for the researchers to refine concept model into fabrication model, experience and general knowledge on industry and creativity is still valuable for the development project

3.6.Material Selection and Manufacturing Process

Although high strength and light material is the alternative and superior option for the A-HEV, tight budget has brought down the ambitious of the research team. For the structural design, A-HEV will only utilize general industry grade material. First of all, various steel structure. It serves a very good feature for the researcher to expand their creativity to cut and join the simple rectangle steel structure into desired shape. Secondly, the Aluminum alloys ASTM 6160. Due to its light in weight and easy to shape, it is very suitable for the manufacturing hubs and other low load components. For better surface quality, sand blasting technology could be implied for surface treatment.

For other metal components, conventional lathe machine, milling machine, CNC lathe, CNC mill, ART welding, MIG welding would easy the manufacturing process. For the overall development, research team would like to prove the capability of technical skill in prototyping a vehicle. Hence, the jig design, 3D chassis construction, grinding, welding, drilling, machining and etc is fully conduct by the research team. For the quality control and inspection, all joining parts are given certain amount of tolerance.

3.7.Electrical and Electronic System

120% of care and focus is the success key for the electrical and electronic system development. When dealing with sensitive electronic system such as speed controller, few important rules must be obey. First of all, no wiring starts when there are no complete circuit diagrams. For the design of the circuit diagrams, the designer must read through the detail descriptions for each electric and electronic device. All the voltage and current supply for each wire must within the operating range.

Secondly, conduct individual testing on each sub-system before the final confirmation. For example, the potential meter for the controller and the existing potential meter might be varies. Voltage regulator might require in overcoming the situation. Before the final testing on the integrated motor-controller system, a small test on regulator and potential meter is preferred. For the AC-DC external charging system, plenty of solid state relays and automotive relays are required to transform the voltage from 12V to 48V (series) and 48V to 12V (parallel). High voltage also means high risk. Pre-test is also required before the real testing.

Thirdly, the wiring process for the overall system must not connect to the power source. During installing the wiring system, all components and wires could be confusing. Therefore, the possibility of short circuiting might happen. If it happens to the sensitive device, it could worsen the project budget. If it happens on the research members, it could threaten life.

For the proposed electrical and electronic system, the hybrid system and the full electric system must be able to switch easily. Meanwhile, the circuit design also has to consider the external charging requirement plus other auxiliary components such as head lamp, rear lamp, signal light, dim light, alarm bacon and etc.

3.8.Model Assembly and System Integration

As the finish of the refinement process and the technical drawings had been sent for the manufacturing purpose, the development task will not end. Assembly and system integration require the expertise from both mechanical and electrical engineers. Mechanical engineer has to design and plan how the components are installed according to sequence and the electrical engineers will do the wiring and testing on the electrical system. Once the manufacturing process has complete, 60 percentages of the mechanical parts need to be install first. Then the tested electrical system will integrate into the A-HEV chassis design and follow by another 40 percentages of mechanical parts installation.

Continues inspection and dimension checking is very important in this stage. Although the assembly simulation had been conducted in 3D modeling software, it doesn't mean that no other mistake occur in real application. For smooth installation purpose, lubricating oil, sand papers, filing tools, power tools such as drilling & grinding, various hammer size, allen keys, screw driver, bolting tools are very essential.

3.9. Tuning, Testing and Modification

Once the mechanical and electrical system had integrated, tuning is necessary to produce a fine working prototype. In assembly stage, installation of the systems will be constraint by the mechanical components due to dimension errors. In tuning stage, the performance and the workability is restraint by the electrical system. Consequently, the research team has to ensure the functionality, smoothness, noise, ride and comfort, handling and safety issues as well during the tuning and testing stage.

Next, the exterior design for the A-HEV also plays an important role. Since most of the engineering material explore to certain kind of corrosion, protection is a must to avoid end-use and other children in the classroom from any form of destructive condition. Instead of that the exterior design must consider good ventilation for the batteries cage because flammable gases are release when the batteries in use or in charging condition.

For the actual testing, the research team will prefer to use UMP's road as the testing area. The actual test for the A-HEV has including the full load test, straight road acceleration, braking, cornering, on-road and off-road, up-hill and down-hill condition. Due to limited testing equipments, no specific data will be collect. Conventional test driver driving experience is the main reference for the entire test.

CHAPTER 4

RESULT AND DISCUSSION

4.1.Energy Storing System

In the design of storing system, precise selection of storing method is govern by the type of motor used, controller design, consistency of supply, consume durability, as well as size and cost. The comparison of different types of electric storing cell is engaging most EV designers who seek maximum energy density with minimum cost and weight as well as quick charging and long life characteristics. The lead acid battery is still very much a serious contender and is attractive for its comparatively low cost and an existing infrastructure for charging, servicing and recyclable disposal. A director of battery makers Varta, Dr. Reinhard Gereth maintains that "*those who want to wait for some miracle battery will only delay the introduction of the electric car instead of promoting it*". He recommends that what is now feasible should be implemented [3].

Literature study shows that there are some EV designers use either AC or DC drive electric motor according to different purposes. According to EV motor makers Nelco, requirements for traction motors can be summarized as light weight, wide speed range, high efficiency, maximum torque and long life [3]. DC drive permanent magnet wound series electric motor was chosen as the driving device. For a 48V 10hp DC drive electric motor, 4 units of 12V N200 batteries are essential to be connect in series in order to obtain 48V DC supply. As one of the advantages of the EV is the capability to recharge the energy storing system via household electrical supply, 12V charging system is the safest, cheapest and most common device. Therefore, the battery system should be placed in parallel system. Switching between series and parallel mode could cause spark occur and consequently high current solid state relay and general 12V automotive relays are combined as described in **Figure 4.1**. The design and working prototype of the external switching and charging box is shown in **Figure 4.2**.

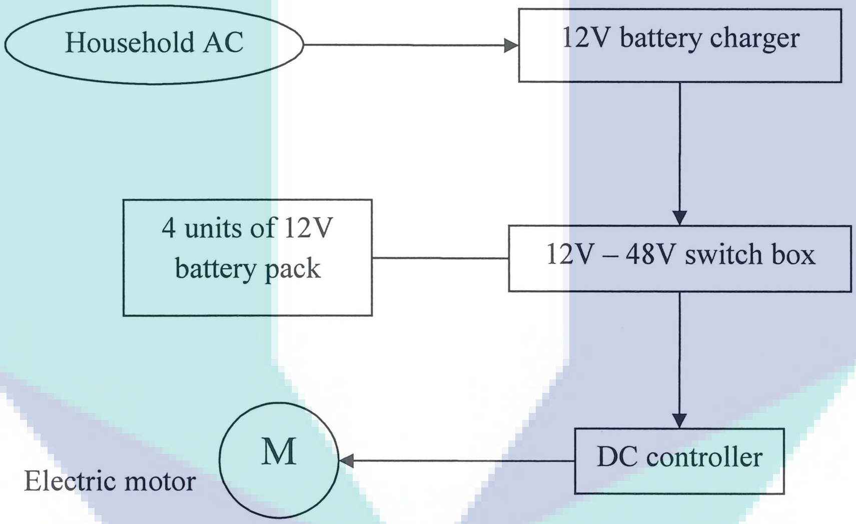


Figure 4.1 : Schematic diagram of voltage control unit : 12V - 48V switch box

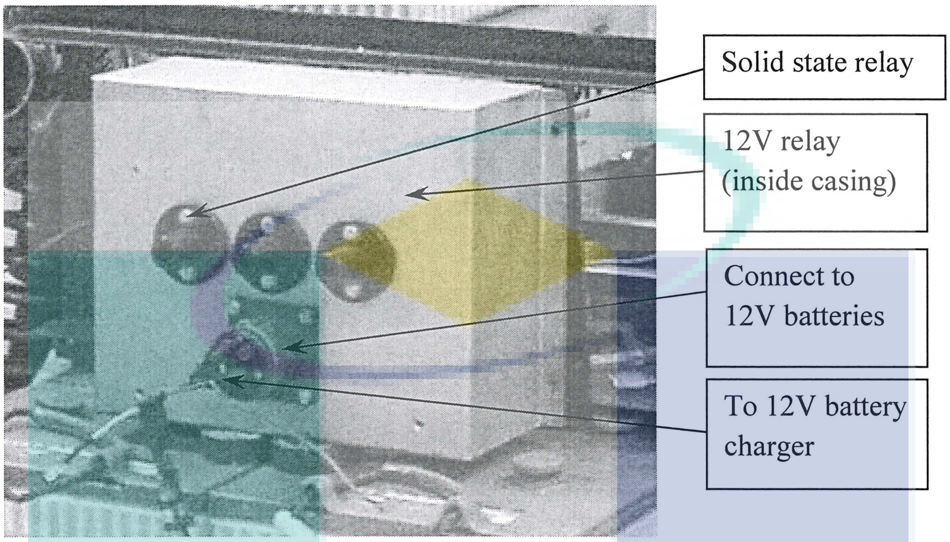


Figure 4.2 : Working prototype for high low voltage switching device for household charging

4.2 A-HEV Electric Energy Management System

Hybrid drives is seen by many as the most realistic contender when various battery-electric technologies competing for commercial exploitation in vehicles. While the IC engine is currently superior in terms of available performance and range, it has disadvantages such as drop in efficiency under conditions of part load operation, and increasing emissions prior to optimum speed operation, which have led to the design of vehicles in which the IC engine is specified only for optimum-power operation.

Controller development Motorola researchers point out that DC series wound motor controllers require few control elements. Motor speed is normally regulated by alternating the average voltage to the motor by PWM, relaying on the motor's inductance to iron out pulse peaks. The increasing popularity of AC induction motor EV drives is leading to more complex control system involving more costly electronics [2]. The motor's attributes of low cost, rugged design, high justifiable and use of digital electronics allows some of the complexity to be transferred to the software. The software controls conversion of DC to AC and monitoring the amplitude and frequency of AC signals.

For A-HEV system, the electrical system could be divided into EV and HEV portion. According to the chosen electric motor, full electrical circuit is designed. After the conversion from 12V to 48V voltage supply, the output source will transfer to the 48V DC motor controller. Since the rotation direction for the series wound DC motor cannot be reverse via the controller unit, two units of NO and two units of NC high voltage contactors are connect between the motor and the controller. Forward and reverse of the vehicle will be shift via external knob. The regulation of the motor speed could be done by using simple voltage potential meter. 0 – 5V DC voltage signal is alter externally via throttle pedal and motor controller will vary the electric motor speed from 0 – 48V DC.

The adaption of hybrid system into the EV could be done by portable charging system is proposed. A voltage sensing device which is attaches to the 48V battery pack will allow the IC engine to operate precisely when it required. As the battery pack voltage drop to certain value, voltage sensing unit will generate output signal to main controller. The main controller will activate the engine chock valve and electric starter. Cranking will initial to start the IC engine. As the IC engine running smoothly, chock valve and starter motor will stop. AC generator will drive by the IC engine and generate 230V AC voltage. Since the 48V battery pack cannot accept the AC voltage directly, a transformer and battery charger is use to rectifier the 230V AC to 60V DC. In the voltage transforming stage, two important factors are considered. First, the charging voltage must higher than the battery pack, which is 48V DC.

Secondly, the peak charging voltage must not exceed the motor controller acceptable voltage. During charging process, output voltage from the battery charger will fluctuate according to the condition of the battery pack. Therefore, the main controller must monitor the charging process all the time. In order to minimize the fuel consumption and emission while maintain it efficiency, IC engine is tuned to operate at one constant speed. The overall electrical circuit diagram is summarized in **Figure** 4.3.

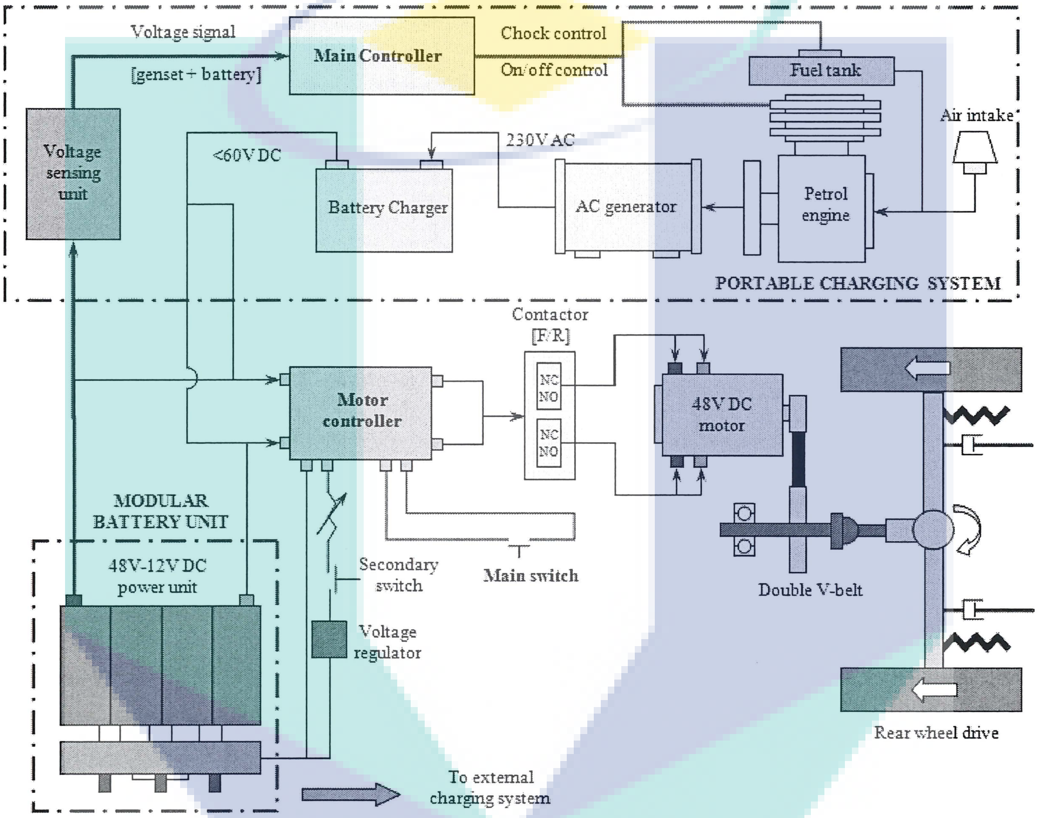


Figure 4.3 : Electrical circuit for A-HEV design

4.3 Ride and Handling

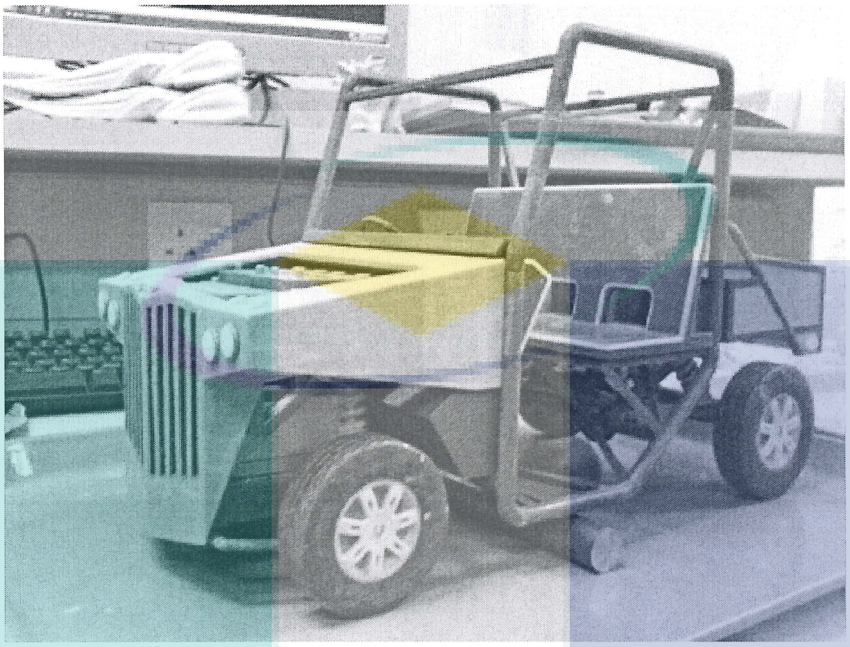
In the development of an automobile, driving comfort and good handling is essential for straight road, off-road and cornering performance. Isolation between road roughing amplitude to the buggy chassis is simple and straight forward. To reduce the prototyping cost, Front and rear suspension could use the MacPherson Strut independent suspension. Due to the limitation in the rear assembly, combination between MacPherson Strut, trailing arm and solid axle suspension is introduced.

The elimination of large size IC engine and transmission unit in the front compartment also further reduce the required steering force. In this aspect, manual rack and pinion steering system could satisfy the project objective. For the assembly of the front and rear suspension unit as well as the steering linkage, camber, castor and toe angle must be take into consideration in order to ensure cornering stability, straight line maneuver and the centering of the steering wheel. From the actual measurement on the Perodua Kancil 660cc vehicle model, the castor angle is within 5^{o}, while the camber angle for the A-HEV is present to 1^{o}. Since the A-HEV buggy model will use the Perodua Kancil steering and suspension reference dimensions, specific measurement and dimension transfer could assist the prototyping process.

4.4 Prototype Construction

Prototyping uses models and sample components to verify the theoretical constructs of the design engineer and technical production planning on the basis of practical tests. Defects can be identified by evaluating individual components and by studying the interplay between different components – generally at different points in the development cycle. These flaws can then be eliminated by making changes to the design or by starting again from scratch with a completely new design. The function of individual components is not of major significance here. The main emphasis is on manufacture and successful integration in the complete model.

In the development project, 3D graphic modeling using CAD package could assist the process but rapid prototyping is an effective tool to analyze the design of the proposed model. In Universiti Malaysia Pahang, the production of actual rapid prototype is made using 24 bits full color 3D printing technology. The finalized A-HEV buggy model was sent for rapid prototyping process. After 48 hours printing progress, the result is shown in **Figure 4.4a** and **Figure 4.4b**.



a. Front isometric view

b. Rear isometric view

Figure 4.4 : Rapid prototype for finalized A-HEV buggy

4.5 Chassis Design

Before the project could reach the rapid prototyping model, a series of conceptual and design refinement process is necessary. As the beginning of the chassis design, a human dimension reference could be very useful as the initial guideline. Therefore, 50th percentile adult male dimensions were referred, where the data compiled from ISO 3411:1999 human physical dimensions of operators [4]. **Figure 3.1** illustrate the general human reference dimension and **Table 4.1** indicates the 50th percentile adult male dimensions refer to 20-65 years range.

Table 4.1 : Adult physical dimensions for medium 50th percentile operator (20 – 65 years range) [4]

Symbol	50th Percentile Weight : 76.5kg (In mm)	Symbol	50th Percentile Weight : 76.5kg (In mm)
A	1715	N	880
B	1750	O	765
C	950	P	590
D	152	Q	235
E	927	R	445
F	105	S	470
G	2100	T	460
H	188	U	560
I	188	V	145
J	245	W	188
K	255	X	440
L	285	Y	450
M	825	Z	365

A number of different principles have been applied to vehicle body and chassis design since the start of automobile construction more than 100 years ago. Once a basic concept has become established, many different models and variants are developed and built over the years.

Generally, the vehicle body design could be categorized into self supporting body and skeleton construction. In this project, the buggy chassis is design based on the skeleton construction in addition to the shell construction. Here, a steel skeleton forms the carcass to give the basic strength of the car. The secondary and tertiary parts of the body such as fenders, panel and etc are then welded, bolted, riveted or bonded to the skeleton. This structure is slightly heavier than the unitary design but has the advantage that the fabrication has more flexibility in the external design. Designs based on this principle make it much cheaper for fabrication because it required less technology. This is why the skeleton construction has been particularly popular for small to medium volume production especially with sport cars and hand-built models.

As the brainstorming stage (Refer to **Figure 4.5**), a rigid occupant cage is designed as a survival box for the inhabitants in the event of an accident and it serve as the basic requirement for the safety design of the A-HEV. In this concept, side frame is strengthen by cross hollow tube and extruded hollow bar is reserved at the front (after the firewall) to locate the steering linkage and the rear frame to locate portable charging unit. Based on the human reference dimension, the basic dimension of the occupant cage was determined. With the consideration of the esthetic outlook while ensure all mechanical and electrical system could assembly into the buggy chassis, the initial concept model is further refined into rapid prototyping model. Instead of utilize 3D human model to develop the buggy chassis, initial exterior design also proposed in this stage.

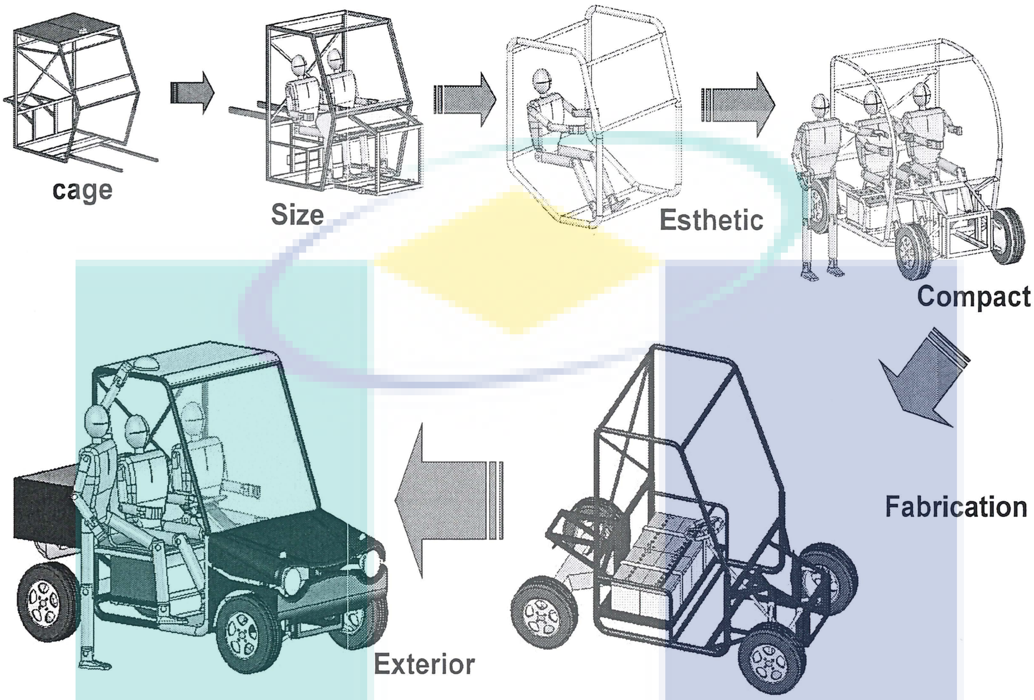
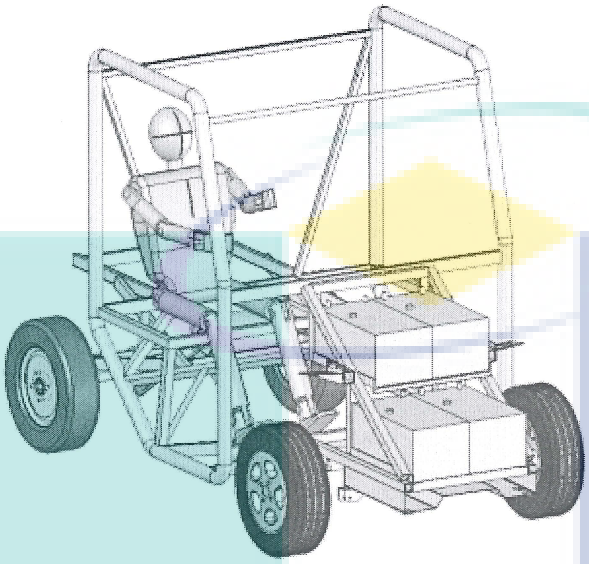


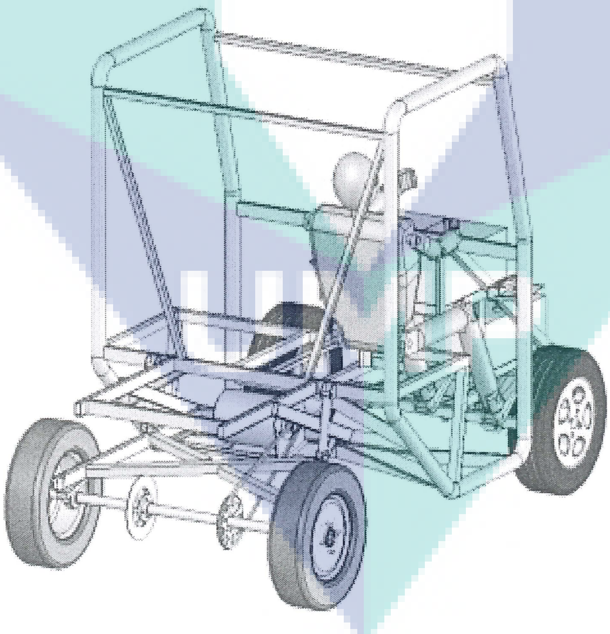
Figure 4.5 : Development process of A-HEV buggy chassis

In the refinement of the conceptual design into the fabrication model, material availability, fabrication method and capability of the R&D group is considered. First of all, the occupant cage side frame is made of from 60mm diameter hollow bar. It provides the safety feature as well as protruding the buggy design. To allow comfort seating position, wide internal compartment is proposed. Since the A-HEV concept is on the portable charging system and the detachable battery pack, a specific battery frame is design (Refer to **Figure 4.6a**).

When the battery frame is attached to the front firewall, it could strengthen the suspension strut tower and lower frame instead of store batteries. When the battery frame detach from the main chassis, the front MacPherson strut suspension will only support by 3 hollow bars. The attach/detach process is guided by rigid rail way so that the assembly is consistent every time changing new battery pack. In the rear frame design (Refer to **Figure 4.6b**), a swing sub-frame is attached to the occupant cage via heavy duty hinge. The sub-frame is use to locate the electric motor, drive/driven sprockets, solid drive shaft, brake system and the suspension units.



a. Front view of fabrication model



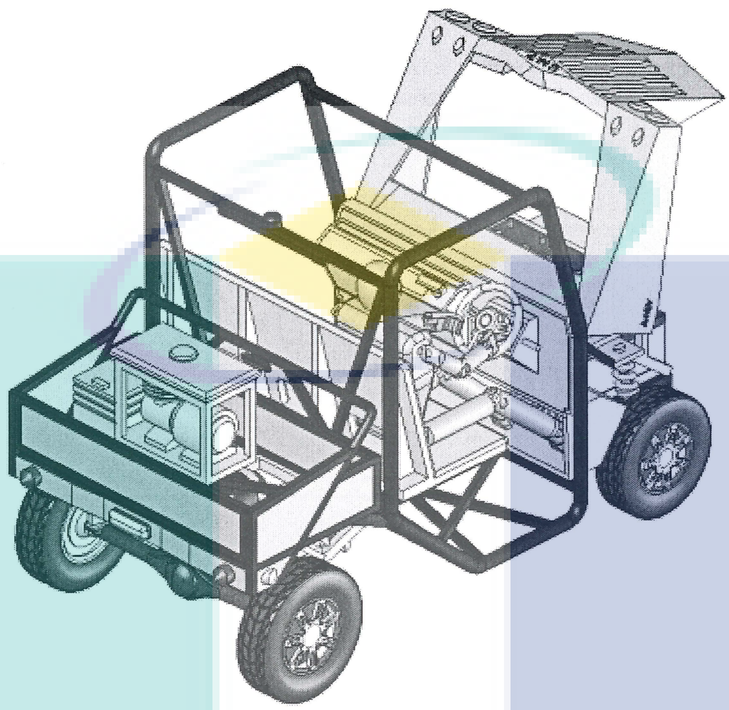
b. Rear view of fabrication model

Figure 4.6 : Development of A-HEV fabrication model

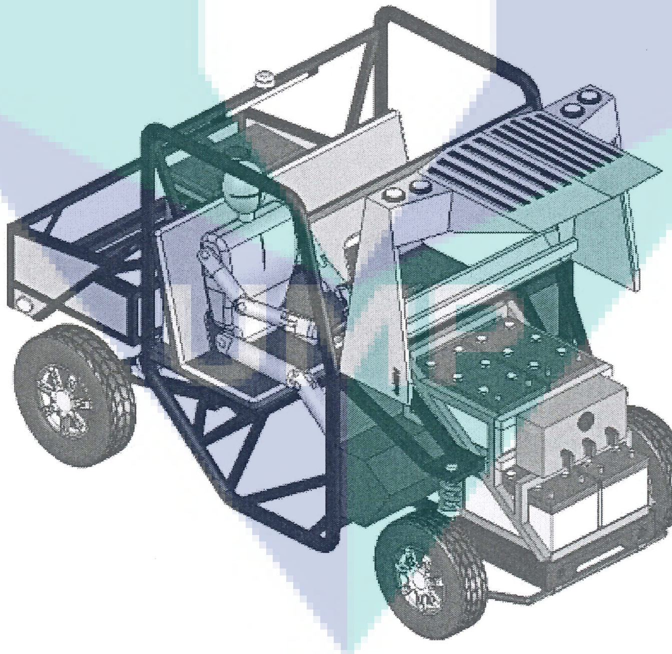
4.6 Basic Test Drive and Refinement of Autobody Design

Before the autobody design, the fabrication model had been produced and some simple test drive had been conducted. From the initial finding, it found that sprocket system with 1:6 gear ratio cause overload on the DC motor and over voltage on the DC controller. Meanwhile, it had spoiled the 4 units of N200 lead-acid battery as well. The failure of the test drive also inspires the designer to make two modifications. First of all, solid drive shaft is replaced with differential drive (with final drive ratio) rear axle to reduce rolling resistant. Secondly, the sprocket system is replaced by 2 V-belt pulleys to reduce the noise, vibration and improve the driving torque (Refer to **Figure 4.7a**).

Refinement from fabrication model to autobody design model includes the rear compartment design, driver panel design, passenger seat design and front bonnet design. In EV mode, the portable charging unit will only add on the parasitic load to the electric motor. Therefore, a rear compartment is fabricated so that the buggy could switch between EV and HEV easily. For the front bonnet design, it must protect the battery pack from rain, dust and seal all the high voltage cables. Since the buggy is run by electric energy, reinforced fiber glass is proposed and fabricated 100% in UMP FKM laboratory (Refer to **Figure 4.7a** and **4.7b**).



a. Modified model after test drive



b. Assembly of the high-low switch box

Figure 4.7 : Autobody design of A-HEV buggy prototype

4.7 Material and Manufacturing Selection

Up to date, one of the factors which has limit the R&D in EV and HEV is the weight issue. Comparatively, although aluminum is the better material choice to built A-HEV (density is one-third of steel but the strength is much lower than steel), steel structure is still the predominant material used for manufacture and the generally high ratings levels shown the "ease of manufacturing" column reflect the provision already made by the industry for compatible facilities [1].

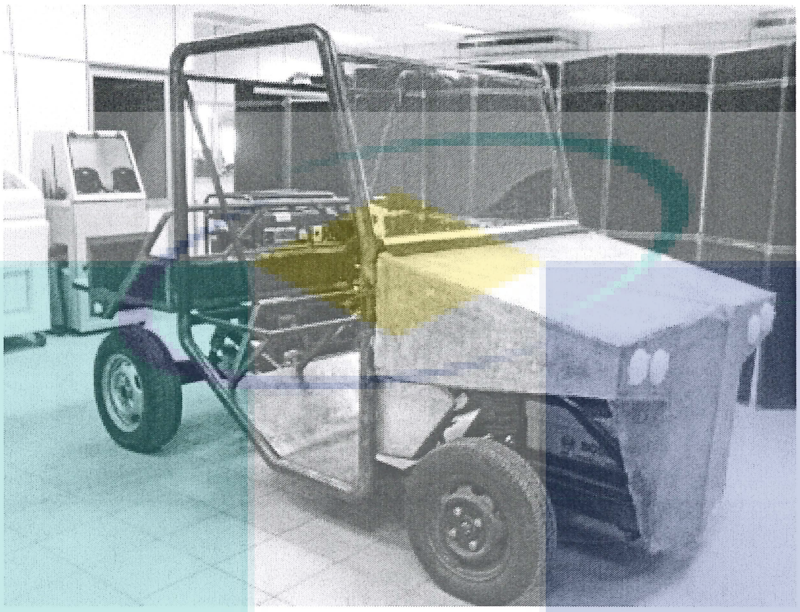
Put it simply, advantages of steel as an autobody material include low cost, ease of forming, corrosion resistance with zinc coatings, ease of joining, recyclable and good crash energy absorption. During the working prototype development, few manufacturing methods were implied. First of all, arc welding and MIG welding is used to join the steel structures, mechanical fastening such as bolt and nuts, hinge, latch, self tapping screw and rivet tool were used to join components, aluminum to steel parts and etc.

CHAPTER 5

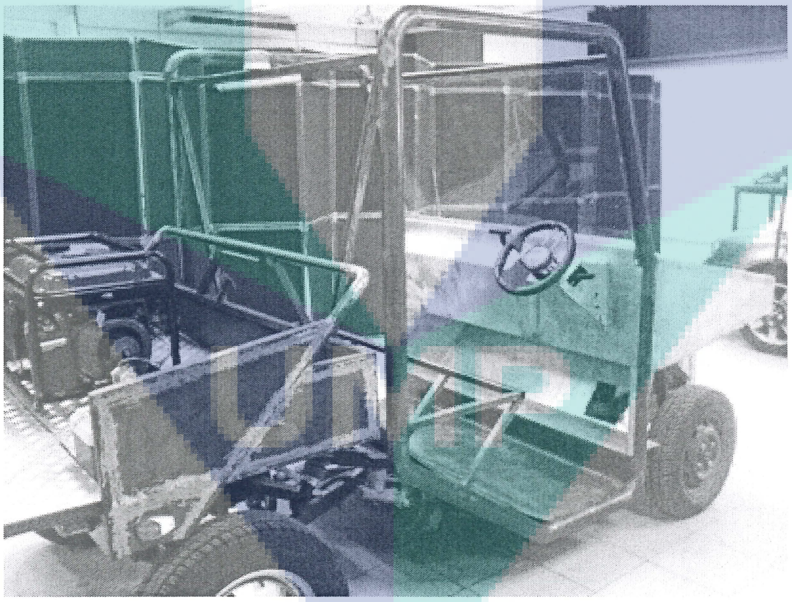
CONCLUSION AND RECOMMENDATION

After the wide range of R&D in the mechanical and electrical system for A-HEV buggy, complete working prototype had been produced (Refer **Figure 5.1**) and tested by the FKM automotive research group. Although the buggy only run in low speed mode, moderate vibration and long period charging time, it still serve as a superior research path toward high efficiency and low cost HEV.

Further improvement is necessary to refine the chassis design with mass reduction. It could be done by utilize CAE software. Meanwhile, the electric and electronic system also needs improvement in term of charging period and energy utilization.



a. Front view for A-HEV working prototype



b. Rear view for A-HEV working prototype

Figure 5.1 : A-HEV buggy working prototype

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2. J.C. Brown at el, 2002 *"Motor vehicle structures : concepts and fundamentals"*, Butterworth-Heinemann, Burlington

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APPENDIX

International Conference on Science &
Technology: Applications in Industry
& Education (2008)

DEVELOPMENT OF ALTERNATE HYBRID ELECTRIC VEHICLE (A-HEV) : MAIN CHASSIS CONSTRUCTION AND BODY DESIGN

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Abstract. Among all the alternative energy and power plant development, Hybrid Electric Vehicle is one of the most applicable systems. Similar to conventional vehicle, it still used internal combustion engine as the power source. Nowadays, the integration between IC engine and electric generation system could be found in various technologies. Several problems with HEV still remain unsolved although many researches had been carried out to build HEV. The research constraints include the size of the battery, charging period and the cost of the technology. In nation car market, some car manufacturers are keen to promote HEV to the nation municipal. Miserably, the price of the HEV is high and the popularity is remained low. To improve environment pollution, A-HEV project was carried out by local university level team to design, construct and develop a simple, attachable and low cost HEV system. Since it was the initial step for the research team move forward HEV technology, series HEV concept was referred. To further reduce the complexity and the attractiveness of the vehicle design, buggy platform was selected in this project. As the HEV technology cost is domain by the battery and electric management system, an alternate capability concept with programmable logic control system were adopted in the A-HEV project as well.

KEYWORD : Chassis, Hybrid system, Electric vehicle, IC engine, electric motor

Introduction

Over the 100 years of the automobile developments, internal combustion (IC) engine plays an important role to provide propulsion energy to the vehicle. Since then more and more R&D are focuses on the improvement of power, speed, torque, emission, dimension as well as the material used. Although the development of electric vehicle and hybrid electric vehicle had started since the last few decades, limited concentration R&D was achieved. Early electric vehicles were put out of business by the invention of the IC-engine starter motor, ironically another electrical device. **Figure 1** shows a schematic depicting the possible types of energy for driving the automobile. Of the three "large potential" contenders, hydrogen propulsion (probably in a hybrid drive) seems to be the long term future solution. In the meantime, natural gas and battery electric power offer shorter term solutions, each with individual drawbacks, or a hybrid between one of these two could emerge as a short-term quick-fix solution for environmental trouble spots.

In the conventional IC-engine based automobile system, chemical energy is converted into mechanical energy and multiple by the transmission system to the traction wheels. As the global automobile number raise sky-high and petroleum spirits are exhausted, it could worsen the pollution situation by delaying the widespread adoption of electric vehicles.

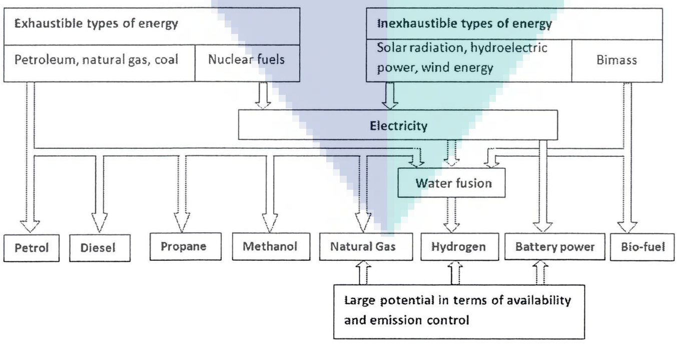


Figure 1 : Possible types of energy for driving automobile [3].

Development of A-HEV

In general understanding, electric vehicle is the type of automobile that not using IC engine as the main power plant. It store energy in chemical form and convert into electrical energy and drive the motor. Instead of using ECU and throttle opening to control the vehicle speed, EV would use Integrated circuit board (IC) with potential meter to vary the motor speed. A hybrid vehicle is a vehicle that uses two or more distinct power sources to propel the vehicle. Common power sources include on-board rechargeable energy storage system (RESS) and a fueled power source (internal combustion engine or fuel cell), air and internal combustion engines human powered bicycle with electric motor or gas engine assist and human-powered or sail boat with electric power.

The term most commonly refers to Hybrid-electric vehicle (HEV) which includes internal combustion engines and electric motors. Due to the environmental and world fossil fuel issues, HEV show its potential as an alternative power plant which could reduce the fossil fuel consumption or adapt other alternative fuel. In alternative energy research, amount of energy consume and the amount of energy produce by the power plant is normally compare to the fossil fuel system. HEV shows great competitive efficiency, where it prove better performance in fuel consumption and emission control. In the most recent future car development, HEV could be the most adaptable system which will replace the fossil fuel based on-road transportation. For hybrid electric vehicle system, additional IC engine together with power generator were combined with EV system, whereby it shows enhancement in prolong the operating life and total output traction force on driving wheels. For the future development of EV and HEV system, battery storing system, electric motor system and controller design hold the success key as one of the alternative energy resources.

Project Goal

Among the operating environments which have attracted commercial/industrial EVs are early-morning urban milk delivery, in-factory materials handling and airport cargo/baggage handling – and aircraft ground-towing. Future possibilities lay in noise and exhaust-fume sensitive city goods deliveries and public passenger-transport – also the possibility of individual passenger transport in future new town residential and/or industrial areas incorporating suitable purpose-built carriageways. The remove of individual transport from congested city centre could be rescinded in favor of sympathetic route planning and vehicle development which would enhance prospects for special purpose electric cars. For passenger cars, electric vehicle technology seems always to be awaiting for that 'breakthrough around the corner' in battery development; however, for industrial vehicles, many operating environments rule that EV technology is the only solution.

BUGGY – a kind of short distance transportation for multipurpose application. The general utilization including golf field, recreational place, large factory area, beach side and some other off-road condition. The design of the buddy might be vary due to different application. For off-road buggy, high torque with high travel distance suspension system is suitable since the traveling area is not even. For recreational purpose, low speed and comfortable buggy design will be the main selection. For the leisure outdoor activities and time saving walking distance purpose, electric buggy had become the public choice. Its zero emission and low noise operation give comfort ride without creating any unnecessary disturbance to the environment. As an alternative power plant for future automotive development, electric buggy would serve as a simple research platform rather than on-road fully electronic control vehicle. Compare to engine powered buggy, popularity of the electric buggy still require improvement especially in battery power management, battery charging system and electric motor output control.

A-HEV – Since the chassis design is much simpler and the vehicle dynamics of the buggy is similar with the commercial vehicle, an inspiration has drives the HEV research team in University Malaysia Pahang (UMP) to develop local HEV. Although the HEV is well developed in other countries like Japan and America, this research is still necessary for Malaysian to prove its independent technology enhancement in the world spectacle. In this content, electric buggy system would be the unlikely the reference model for the initial UMP-HEV development.

The term **ALTERNATE** in the project means the modular capability of the HEV unit in the UMP buggy. Limitations in the general electric buggy give negative impression to the public user. Some of it including short travel distance due to low battery power and specific external charging system which require household electricity. In addition, the battery unit for the general electric vehicle is built in and battery charging time usually takes plenty of time where the buggy must remain rest during charging period. Therefore, the innovations of the A-HEV project is to develop a simple and detachable modular battery unit and portable power charging source which allow the buggy to switch between full electric mode and hybrid mode depending on situation. The development of the alternate power plant switching module could benefits the power refueling period, maintenance time, emission and noise as well as the driving pleasure experience.

DESIGN CONSIDERATION

As the initial project to develop A-HEV, some basic consideration had been list out and amount of literature study and brainstorming help to improve the quality of the design.

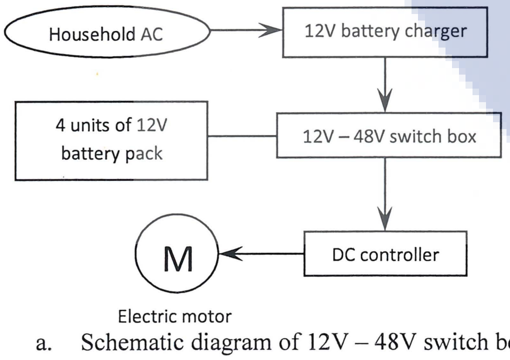
a. Battery storing system
b. Electric energy management system
c. Alternate hybrid system
d. Ride and handling
e. Prototyping construction which including
   i. Chassis design
   ii. Autobody design
   iii. Material and manufacturing selection

As the full preparation on the conceptual design stage, a rapid prototyping model will be made. Compared to computer 3D model, rapid prototype allows designers to have detail analysis on the structure and system integration between mechanical and electrical system.

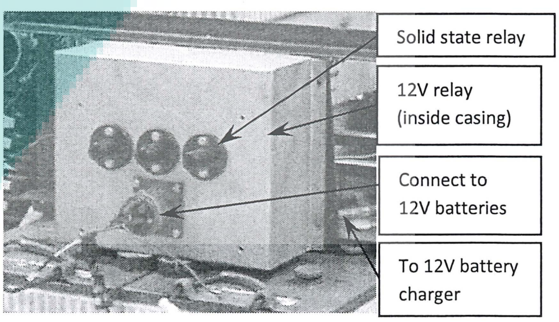
a. Energy storing system

In the design of storing system, precise selection of storing method is govern by the type of motor used, controller design, consistency of supply, consume durability, as well as size and cost. The comparison of different types of electric storing cell is engaging most EV designers who seek maximum energy density with minimum cost and weight as well as quick charging and long life characteristics. The lead acid battery is still very much a serious contender and is attractive for its comparatively low cost and an existing infrastructure for charging, servicing and recyclable disposal. A director of battery makers Varta, Dr. Reinhard Gereth maintains that "*those who want to wait for some miracle battery will only delay the introduction of the electric car instead of promoting it*". He recommends that what is now feasible should be implemented [3].

Literature study shows that there are some EV designers use either AC or DC drive electric motor according to different purposes. According to EV motor makers Nelco, requirements for traction motors can be summarized as light weight, wide speed range, high efficiency, maximum torque and long life [3]. DC drive permanent magnet wound series electric motor was chosen as the driving device. For a 48V 10hp DC drive electric motor, 4 units of 12V N200 batteries are essential to be connect in series in order to obtain 48V DC supply. As one of the advantages of the EV is the capability to recharge the energy storing system via household electrical supply, 12V charging system is the safest, cheapest and most common device. Therefore, the battery system should be placed in parallel system. Switching between series and parallel mode could cause spark occur and consequently high current solid state relay and general 12V automotive relays are combined as described in **Figure 2a**. The design and working prototype of the external switching and charging box is shown in **Figure 2b**.



a. Schematic diagram of 12V – 48V switch box



b. Working prototype for high low voltage switching device

Figure 2 : Design and development voltage control unit working prototype for household charging

b. A-HEV electric energy management system

Hybrid drives is seen by many as the most realistic contender when various battery-electric technologies competing for commercial exploitation in vehicles. While the IC engine is currently superior in terms of available performance and range, it has disadvantages such as drop in efficiency under conditions of part load operation, and increasing emissions prior to optimum speed operation, which have led to the design of vehicles in which the IC engine is specified only for optimum-power operation.

Controller development Motorola researchers point out that DC series wound motor controllers require few control elements. Motor speed is normally regulated by alternating the average voltage to the motor by PWM, relaying on the motor's inductance to iron out pulse peaks. The increasing popularity of AC induction motor EV drives is leading to more complex control system involving more costly electronics [2]. The motor's attributes of low cost, rugged design, high justifiable and use of digital electronics allows some of the complexity to be transferred to the software. The software controls conversion of DC to AC and monitoring the amplitude and frequency of AC signals.

For A-HEV system, the electrical system could be divided into EV and HEV portion. According to the chosen electric motor, full electrical circuit is designed. After the conversion from 12V to 48V voltage supply, the output source will transfer to the 48V DC motor controller. Since the rotation direction for the series wound DC motor cannot be reverse via the controller unit, two units of NO and two units of NC high voltage contactors are connect between the motor and the controller. Forward and reverse of the vehicle will be shift via external knob. The regulation of the motor speed could be done by using simple voltage potential meter. 0 – 5V DC voltage signal is alter externally via throttle pedal and motor controller will vary the electric motor speed from 0 – 48V DC.

The adaption of hybrid system into the EV could be done by portable charging system is proposed. A voltage sensing device which is attaches to the 48V battery pack will allow the IC engine to operate precisely when it required. As the battery pack voltage drop to certain value, voltage sensing unit will generate output signal to main controller. The main controller will activate the engine chock valve and electric starter. Cranking will initial to start the IC engine. As the IC engine running smoothly, chock valve and starter motor will stop. AC generator will drive by the IC engine and generate 230V AC voltage. Since the 48V battery pack cannot accept the AC voltage directly, a transformer and battery charger is use to rectifier the 230V AC to 60V DC. In the voltage transforming stage, two important factors are considered. First, the charging voltage must higher than the battery pack, which is 48V DC.

Secondly, the peak charging voltage must not exceed the motor controller acceptable voltage. During charging process, output voltage from the battery charger will fluctuate according to the condition of the battery pack. Therefore, the main controller must monitor the charging process all the time. In order to minimize the fuel consumption and emission while maintain it efficiency, IC engine is tuned to operate at one constant speed. The overall electrical circuit diagram is summarized in **Figure 3**.

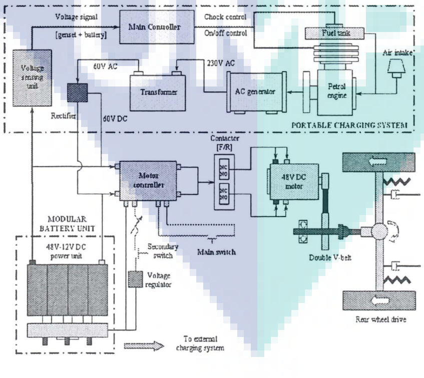


Figure 3 : Electrical circuit for A-HEV design

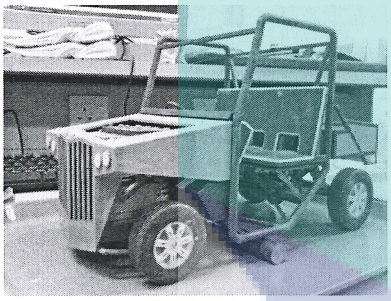
c. Ride and handling

In the development of an automobile, driving comfort and good handling is essential for straight road, off-road and cornering performance. Isolation between road roughing amplitude to the buggy chassis is simple and straight forward. To reduce the prototyping cost, Front and rear suspension could use the MacPherson Strut independent suspension. Due to the limitation in the rear assembly, combination between MacPherson Strut, trailing arm and solid axle suspension is introduced.

The elimination of large size IC engine and transmission unit in the front compartment also further reduce the required steering force. In this aspect, manual rack and pinion steering system could satisfy the project objective. For the assembly of the front and rear suspension unit as well as the steering linkage, camber, castor and toe angle must be take into consideration in order to ensure cornering stability, straight line maneuver and the centering of the steering wheel. From the actual measurement on the Perodua Kancil 660cc vehicle model, the castor angle is within 5°, while the camber angle for the A-HEV is present to 1°.
Since the A-HEV buggy model will use the Perodua Kancil steering and suspension reference dimensions, specific measurement and dimension transfer could assist the prototyping process.

d. Prototype Construction

Prototyping uses models and sample components to verify the theoretical constructs of the design engineer and technical production planning on the basis of practical tests. Defects can be identified by evaluating individual components and by studying the interplay between different components – generally at different points in the development cycle. These flaws can then be eliminated by making changes to the design or by starting again from scratch with a completely new design. The function of individual components is not of major significance here. The main emphasis is on manufacture and successful integration in the complete model. In the development project, 3D graphic modeling using CAD package could assist the process but rapid prototyping is an effective tool to analyze the design of the proposed model. In Universiti Malaysia Pahang, the production of actual rapid prototype is made using 24 bits full color 3D printing technology. The finalized A-HEV buggy model was sent for rapid prototyping process. After 48 hours printing progress, the result is shown in **Figure 4a** and **Figure 4b**.



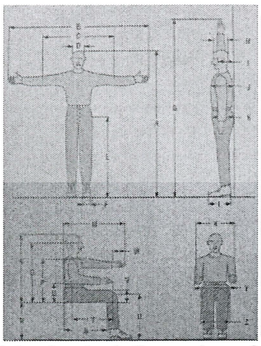
a. Front isometric view

b. Rear isometric view

Figure 4 : Rapid prototype for finalized A-HEV buggy

Chassis design

Before the project could reach the rapid prototyping model, a series of conceptual and design refinement process is necessary. As the beginning of the chassis design, a human dimension reference could be very useful as the initial guideline. Therefore, 50th percentile adult male dimensions were referred, where the data compiled from ISO 3411:1999 human physical dimensions of operators [4]. **Figure 5** illustrate the general human reference dimension and **Figure 5** indicates the 50th percentile adult male dimensions refer to 20-65 years range.



Symbol	50th Percentile Weight : 76.5kg (In mm)	Symbol	50th Percentile Weight : 76.5kg (In mm)
A	1715	N	880
B	1750	O	765
C	950	P	590
D	152	Q	235
E	927	R	445
F	105	S	470
G	2100	T	460
H	188	U	560
I	188	V	145
J	245	W	188
K	255	X	440
L	285	Y	450
M	825	Z	365

Figure 5 : Adult physical dimensions for medium 50th percentile operator (20 – 65 years range) [4]

A number of different principles have been applied to vehicle body and chassis design since the start of automobile construction more than 100 years ago. Once a basic concept has become established, many different models and variants are developed and built over the years. Generally, the vehicle body design could be categorized into self supporting body and skeleton construction. In this project, the buggy chassis is design based on the skeleton construction in addition to the shell construction. Here, a steel skeleton forms the carcass to give the basic strength of the car. The secondary and tertiary parts of the body such as fenders, panel and etc are then welded, bolted, riveted or bonded to the skeleton. This structure is slightly heavier than the unitary design but has the advantage that the fabrication has more flexibility in the external design. Designs based on this principle make it much cheaper for fabrication because it required less technology. This is why the skeleton construction has been particularly popular for small to medium volume production especially with sport cars and hand-built models.

As the brainstorming stage (Refer to **Figure 6**), a rigid occupant cage is designed as a survival box for the inhabitants in the event of an accident and it serve as the basic requirement for the safety design of the A-HEV. In this concept, side frame is strengthen by cross hollow tube and extruded hollow bar is reserved at the front (after the firewall) to locate the steering linkage and the rear frame to locate portable charging unit. Based on the human reference dimension, the basic dimension of the occupant cage was determined. With the consideration of the esthetic outlook while ensure all mechanical and electrical system could assembly into the buggy chassis, the initial concept model is further refined into rapid prototyping model. Instead of utilize 3D human model to develop the buggy chassis, initial exterior design also proposed in this stage.

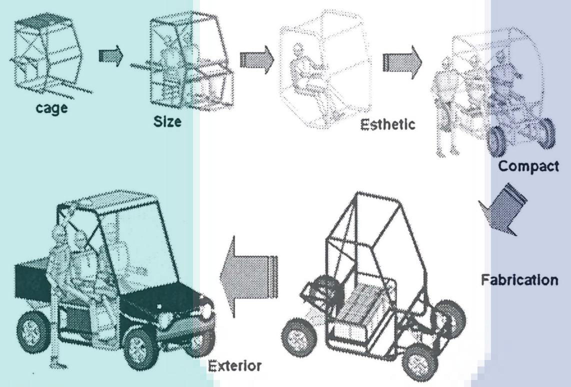


Figure 6 : Development process of A-HEV buggy chassis

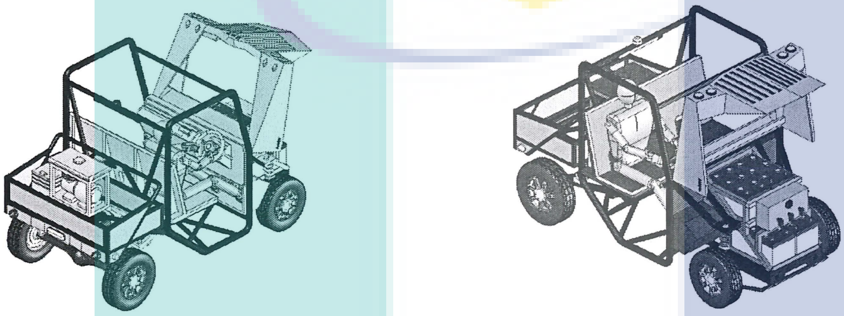
In the refinement of the conceptual design into the fabrication model, material availability, fabrication method and capability of the R&D group is considered. First of all, the occupant cage side frame is made of from 60mm diameter hollow bar. It provides the safety feature as well as protruding the buggy design. To allow comfort seating position, wide internal compartment is proposed. Since the A-HEV concept is on the portable charging system and the detachable battery pack, a specific battery frame is design (Refer to **Figure 7a**). When the battery frame is attached to the front firewall, it could strengthen the suspension strut tower and lower frame instead of store batteries. When the battery frame detach from the main chassis, the front MacPherson strut suspension will only support by 3 hollow bars. The attach/detach process is guided by rigid rail way so that the assembly is consistent every time changing new battery pack. In the rear frame design (Refer to **Figure 7b**), a swing sub-frame is attached to the occupant cage via heavy duty hinge. The sub-frame is use to locate the electric motor, drive/driven sprockets, solid drive shaft, brake system and the suspension units.

a. Front view of fabrication model b. Rear view of fabrication model

Figure 7 : Development of A-HEV fabrication model

Basic test drive and refinement of Autobody design

Before the autobody design, the fabrication model had been produced and some simple test drive had been conducted. From the initial finding, it found that sprocket system with 1:6 gear ratio cause overload on the DC motor and over voltage on the DC controller. Meanwhile, it had spoiled the 4 units of N200 lead-acid battery as well. The failure of the test drive also inspires the designer to make two modifications. First of all, solid drive shaft is replaced with differential drive (with final drive ratio) rear axle to reduce rolling resistant. Secondly, the sprocket system is replaced by 2 V-belt pulleys to reduce the noise, vibration and improve the driving torque (Refer to **Figure 8a**). Refinement from fabrication model to autobody design model includes the rear compartment design, driver panel design, passenger seat design and front bonnet design. In EV mode, the portable charging unit will only add on the parasitic load to the electric motor. Therefore, a rear compartment is fabricated so that the buggy could switch between EV and HEV easily. For the front bonnet design, it must protect the battery pack from rain, dust and seal all the high voltage cables. Since the buggy is run by electric energy, reinforced fiber glass is proposed and fabricated 100% in UMP FKM laboratory (Refer to **Figure 8a** and **7b**).



a. Modified model after test drive b. Assembly of the high-low switch box

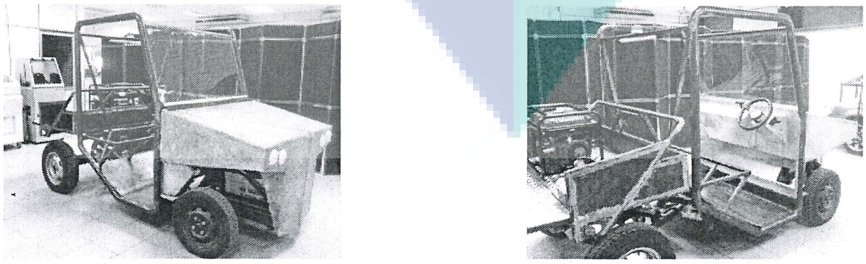
Figure 8 : Autobody design of A-HEV buggy prototype

Material and manufacturing selection

Up to date, one of the factors which has limit the R&D in EV and HEV is the weight issue. Comparatively, although aluminum is the better material choice to built A-HEV (density is one-third of steel but the strength is much lower than steel), steel structure is still the predominant material used for manufacture and the generally high ratings levels shown the "ease of manufacturing" column reflect the provision already made by the industry for compatible facilities [1]. Put simply, advantages of steel as an autobody material include low cost, ease of forming, corrosion resistance with zinc coatings, ease of joining, recyclable and good crash energy absorption. During the working prototype development, few manufacturing methods were implied. First of all, arc welding and MIG welding is used to join the steel structures, mechanical fastening such as bolt and nuts, hinge, latch, self tapping screw and rivet tool were used to join components, aluminum to steel parts and etc.

CONCLUSION

After the wide range of R&D in the mechanical and electrical system for A-HEV buggy, complete working prototype had been produced (Refer **Figure 9**) and tested by the FKM automotive research group. Although the buggy only run in low speed mode, moderate vibration and long period charging time, it still serve as a superior research path toward high efficiency and low cost HEV.



a. Front view for A-HEV working prototype b. Rear view for A-HEV working prototype

Figure 9 : A-HEV buggy working prototype

RECOMMENDATION

Further improvement is necessary to refine the chassis design with mass reduction. It could be done by utilize CAE software. Meanwhile, the electric and electronic system also needs improvement in term of charging period and energy utilization.

REFERENCE

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