**ASSIGNMENT NO: 5**

**ADVANCED PROPULSION OF HYBRID ELECTRIC VEHICLES**

**Technology Assessment and Comparison of Electrified Vehicles to Standard Powertrains**

**GROUP 06.ASSIGNMENT05.MEEM 5295**

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**INTRODUCTION: -**

With the depletion of fuel resources there is a constant need for us to get into alternative fuels or hybrids to maintain our control over the transportation industry. A lot of research, nowadays, concentrates on developing hybrid vehicles or electric vehicles in general, which are a way to spread our horizons to alternate power systems. Gasoline and diesel vehicles have ruled the automotive industry since a long period of time and hence we tend to cling to those when it comes to calculating the cost savings or the cost effectiveness of any new technology that comes in the market.

Due to this large dependence on gasoline and diesel vehicles, the hybrid or electric vehicles are compared with the corresponding gasoline vehicles to calculate the payback period and to compare the two power-trains on various fronts. In this detailed study the vehicle prices, the fuel cost per annum, the vehicle weight, the vehicle specifications etc. are compared with one single baseline car (gasoline) to understand the advantages and disadvantages of these vehicles over the contemporary gasoline vehicles.

**A} VEHICLE CHARACTERISTICS AND POWER TRAIN TECHNOLOGY COMPARISON: -**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| PARAMETER | Chevy Malibu 2013 | VW Jetta TDI 2013 | Tesla Model S 2012 | Chevy Volt 2013 | Ford Fusion 2012 Hybrid | Toyota Prius V 2 2013 |
| Architecture | Gasoline, 4cyl-inline, 6-speed Automatic, FWD | Turbodiesel,2L,4-cyl , 6-speed, FWD | Electric Vehicle, 1-Speed , RWD | eREV, 1-speed Electric Drive | Mixed hybrid, 2.5L, CVT, FWD | PHEV, Mixed Hybrid, 1.8 L 4-cyl |
| Cost | $21995 | $22990 | $59900 | $31645 | $29570 | $26650 |
| Weight (lbs) | 3393 | 3161 | 4648 | 3781 | 3720 | 3274 |
| ICE Power  (hp) | 197 @ 6300 rpm | 140 @ 4000 rpm | - | 74 | 156 @ 6000 rpm | 134 @ 5200 rpm |
| E-Machine Power (hp) | - | - | 235 | 149 | 106 | 80 |
| Torque (lb-ft) | 191 @ 4400 rpm | 236 @ 1750 rpm | 310 | 273 | 136 @ 2250 rpm | 153 |
| Battery type and size | - | - | Li-ion battery, 40 kWh | Li-ion, 16.5 kWh | Li-ion battery,  7.6 kWh | NiMH,  27 kW |
| Power to weight Ratio (hp/lb) | 0.06 | 0.04 | 0.05 | 0.04 | 0.05 | 0.04 |

*Table 1: - Comparison of Vehicle Characteristics for EV’s, HEV’s and Baseline Models*

In Table 1 above we have compared the various EV’s, HEV’s with the two baseline gasoline and diesel models for various parameters like cost, weight, IC Engine Power etc. Some of these points are discussed below:

* Cost: -

We can see that the initial cost of the gasoline or diesel vehicle is comparatively less than those of EV’s and HEV’s. This is because the latter is a recent technology and it will take some time for full market penetration which results in their high initial cost. Once these vehicles are popular in the market this technology will get more affordable due to mass production and more research. Tesla Model S is a performance cum luxury car which gives more initial speed and it is a full electric vehicle, making it more expensive than the others compared. The other prices are comparatively close to those of the baseline models. The cost of the other HEV’s and PHEV’s will reduce with time, if more research is carried out in the hybrid electrical vehicle field. [1], [2]

* Weight: -

The weights of all the cars compared are nearly same except for the Tesla Model S. This car is an all-electric car which employs a high KW-h battery pack in it, which increases its weight as opposed to the others. [1], [2]

* Internal Combustion Engine Power: -

For the baseline models the IC engines is the main source of power and hence having high power output from the engine is mandatory. For HEV’s and PHEV’s the battery (and motor) is another power source which is capable of providing high torque at start-up. This gives us the opportunity to reduce the size of the engine (and hence the power) because engines here are used mainly for cruising or charging the battery in driving mode. Although the battery acts as the main source of power in HEV’s and PHEV’s, Ford Fusion and Toyota Prius employ comparatively high power engines mainly to extend the range of the vehicles and facilitate them for highway driving. Tesla Model S being all electric, there is no engine in this vehicle. [1], [2]

* Torque: -

The highest torque that is obtained is from an electric motor which facilitates its use during start-ups and quick accelerations. Tesla Model S incorporates an electric motor and it is a performance car which gives very high acceleration and attains a top speed within a matter of seconds. Looking at these specifications the torque that is required is more and hence it is the maximum torque provider among all the vehicles discussed above. Same is the case with Volt, it uses an electric motor for start-up purposes and the motor is capable of providing high torque. In a non-hybrid vehicle, diesel engines are the ones that provide more torque than gasoline engines. They run on low RPM’s but have the capacity to provide high torque at the wheels, thus making VW Jetta the third contender in the torque competition. [1], [2]

* Battery: -

Non-hybrid vehicles do not employ a battery pack as a power source to the wheels hence there are no batteries in the baseline models that we have considered. Tesla Model S is a high speed, high performance car and hence it comes with a large battery capacity 40 KW-h (models also come in 60KW-h and 85KW-h battery packs) and hence this is the largest battery capacity of all the vehicles compared. The next battery capacity is of 16.5 KW-h that is being employed in the Volt. [1], [2]

**B} FUEL ECONOMY, FUEL CONSUMPTION AND PBP COMPARISON [3], [4], [5], [6]: -**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| PARAMETER | Chevy Malibu 2013 | VW Jetta TDI 2013 | Tesla Model S 2012 | Chevy Volt 2013 | Ford Fusion 2012 Hybrid | Toyota Prius V 2 2013 |
| Fuel Economy (City) mpg | 22 | 30 | 88 | 35 | 41 | 44 |
| Fuel Economy (Highway) mpg | 34 | 42 | 90 | 40 | 36 | 40 |
| Fuel Consumption(City)  Gallons/100miles | 4.54 | 3.33 | 1.13 | 2.85 | 2.44 | 2.27 |
| Fuel Consumption (Highway)  Gallons/100miles | 2.94 | 2.38 | 1.11 | 2.5 | 2.77 | 2.5 |
| PBP for city | Baseline | 2 years | 25 years | 14 years | 9 years | 5 years |
| Range (city) miles | 347.6 | 435 | 160 | 325.5 | 717.5 | 523.6 |
| Range(Highway) miles | 537.2 | 609 | 160 | 372 | 630 | 476 |

*Table 2: - Comparison of Fuel Consumption, Fuel Economy and PBP for EV’s, HEV’s and Baseline Vehicles[3],[4],[5],[6]*

*Figure 1: Range and Fuel Economy of Various Vehicles [3],[4],[5],[6]*

*Figure 2: Comparison of Costs and Payback Periods of Vehicles [1], [2]*

The above table emphasizes on comparing the fuel economy, the fuel consumption and calculates the PBP for all the vehicles we considered in part A. Some of these points are discussed below.

* Fuel Economy: -

The data from the table shows that the all electrical vehicle Tesla Model S is the more fuel efficient car in the group discussed above. This shows us that electric vehicles can be a good future for the automotive industry where the fuel reserves are depleting by the day. Also the HEV’s and PHEV’s have all appreciable fuel economy ranging from 35 mpg to 44 mpg. Gasoline and diesel cars are not that fuel efficient and hence the mileage is less as seen from the table. All the vehicles give more fuel economy on the highway than in the city except Prius. This is because the more it is in the city the more it brakes and the more it uses the electric motor as a power source. [3], [4], [5], [6]

* Fuel Consumption: -

The fuel consumption is mainly dependant on the fuel efficiency hence the same trend as the fuel economy persists with fuel consumption also. [3], [4], [5], [6]

* Payback Period: -

The payback period is mainly dependant on two factors the fuel prices and the initial cost of the vehicle. The payback period increases as the fuel prices increase and hence these factors play a very important role in the payback period calculation. The cost of electricity does not increase as the price of gasoline (4% increase per year) and the cost of Tesla Model S is the maximum compared to other cars in the list. Hence the payback period of this car is the maximum. If the car uses more fuel then the payback period of that vehicle decreases, hence the gasoline vehicle is considered as the baseline model. Similarly the Volt too uses less fuel per year and its cost is comparatively high, hence the payback period for that is also more. [3], [4], [5], [6]

**C} EXTRA VEHICLE ATTRIBUTES OR PARAMETERS COMPARISONS: -**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| PARAMETER | Chevy Malibu 2013 | VW Jetta TDI 2013 | Tesla Model S 2012 | Chevy Volt 2013 | Ford Fusion 2012 Hybrid | Toyota Prius V 2 2013 |
| Acceleration(0-60mph) | 7.8 | 8.7 | 5.5 | 8.5 | 8.5 | 13 |
| Lateral Acceleration g | 0.75 | 0.82 | 0.86 | 0.78 | 0.79 | 0.82 |
| Braking Distance feet | 130 | 113 | 108 | 124 | 127 | 133 |
| Quarter mile s | 16.8 | 16.2 | 14.7 | 16.8 | 16.7 | 18 |

*Table 3: - Comparison of General Parameters of the vehicles [3], [4], [5], [6]*

The above table compares the vehicles in terms of a few extra vehicle attributes as shown above. It is seen that even in electric vehicles which do not have that high a power density as the gasoline and diesel engine vehicles, in terms of performance there is not much of a difference between the vehicles. Tesla which is a pure electric vehicle has a high acceleration value making it a high performance vehicle and at the same time its braking efficiency is also high as seen by the distance it moves before coming to rest. [3], [4], [5], [6]

**SUMMARY AND CONCLUSIONS: -**

To summarize the entire report, what we did here was compare various parameters of different types of vehicles to get on a conclusion as to which vehicle is better and in what way. The types of vehicles that we chose were gasoline vehicle, diesel vehicle, all electric vehicles and hybrid electrical vehicles. The first chart compared the vehicle characteristics and powertrain technologies in these different vehicles. The second chart focused on the fuel economy, fuel consumptions of all the vehicles and from that the payback period was calculated. The third chart concentrated on comparing some basic parameters of vehicles like top speed, time to reach top speed, accelerations etc. This report was mainly based on comparing the data and mapping the future market penetration of a particular technology.

After comparing all the data we can conclude that the electric vehicles or hybrid electric vehicles are the only future. With fuel prices increasing and fuel reserves decreasing coupled with the emission problems hybrid electric vehicles are the future of the automotive industry but the initial cost tries to pull this technology down in many ways. The high initial cost of the vehicle adds to the major drawback of the technology’s penetration in the market. Due to high initial price and the use of non-conventional fuels makes the payback period for the technology way too much which makes it a bad choice for consumers. The only thing that can make this technology cheaper is more research in this field. If there is more research, we will come up with more solutions to our current problems of hybridization. Once these problems are overcome, we will have mass production of these vehicles and this will make these vehicles cheaper and easy for the consumer to purchase. Also with some attenuation if we could increase the range of the vehicles we could take this technology to a new level.

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5. www.teslamotors.com
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**Evaluation Sheet**

Group Number: 06

Students Names

|  |  |  |
| --- | --- | --- |
| **Last** | **First** | **M Number** |
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|  |  |  |
| --- | --- | --- |
| **Area** | **Points** | **Score** |
| **Report** |  |  |
| Introduction | 20 |  |
| Results and Discussion with tables / Figures | 50 |  |
| Summary and Conclusions | 20 |  |
| References | 10 |  |
| **Presentation** | 40 |  |
| Following format and instructions for report, presentation, and submission | 10 |  |
| **Total =** | **150** |  |