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Review on Electric Vehicles Torque & Efficiency Improvement by used of Transmission System

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Abstract – The development in electric vehicle's market is rapidly growing. This decade will be become revolutionary for automobile industry. Government also focusing towards green energy i.e., electric vehicle in the automotive industry. Worldwide pollution is the major concern, to reduce them internal combustion engine are getting banned in many countries. Current interest in electric vehicle is booming, as manufactures are increasing the production of battery with improved efficiency, zero emission vehicle will be the future.

Electric motor is already the mature technology, instead of IC engine hydrogen fuel cell or lithium-ion battery are used. The effect of the transmission system on the torque and the efficiency by the used of gears is estimated to be a better and effective than a non-transmission electric vehicle. Results presented show a reduction of the overall energy consumption with the use of the 2-speed gearbox, compared to single stage.

Key Words: Transmission, torque, Electric vehicle, Zero emission etc

1. INTRODUCTION

The exceeding necessity to preserve natural resources and environmental issues stimulate interest in the development of electric vehicles. These vehicles offer various advantages compared to internal combustion vehicles. They are more efficient, less noisy and simpler, providing a smooth drive experience. While most of the existing vehicles work under some form of internal combustion engines, electric vehicles invoke the excellent performance specifications of an electric motor, such as high torque at low rotations and constant power during a large speed range.

One of the major differences between ICE vehicle and EV performance is the achieved driving range. Nowadays ICE vehicles have superior range compared to EVs and this is one of the main reasons why popularity of EVs have not raised. Although most of the daily driving is done at urban areas and extensively long driving range is not that essential, driver needs some certainty that car has enough range for whole day needs. Nowadays, many company achieve the mark of high range distance, it would be better for the industry to grow more faster than before.

1.1 GENERAL TREND

One of the biggest original equipment manufacturers have announced the introduction of more than 100 original models powered by an electric motor by 2024, Also the total share of electric vehicles is estimated to reach up to 30–35% in major markets, and 20–25% globally by 2030. EV's market share will be cackled by their capacity to reach higher ranges and their target to increase design efficiency and reduce manufacturing cost to become affordable to more customer segments. Currently, after extended testing in different types of EVs, the average range is more than 300 Km. [1]

The gearbox can be a solution to meet the requirement of high speed, torque & efficiency. When we use two speed transmission the first gear ratio is used to increase the low-speed torque to achieve the high acceleration. Following to that, the second gear is used to reduce the vehicle range.

1.2 METHODOLOGY

The basic concept of EV's is the battery are providing the power to the driving motor. It may be of H_2 fuel cell or lithium-ion battery. It will always come with a power controller which improve to control power or measure the requirement of power to the motor considering the action which will be motor has to done. If the requirement of motor is less the it will decrease the power to the motor and when the requirement is high it will increase the power. For an example when car is claiming so the requirement of power is high. So, the it is a responsibility of power controller to provide exact required amount power to the motor so it can easily claim without any extras load or stress.

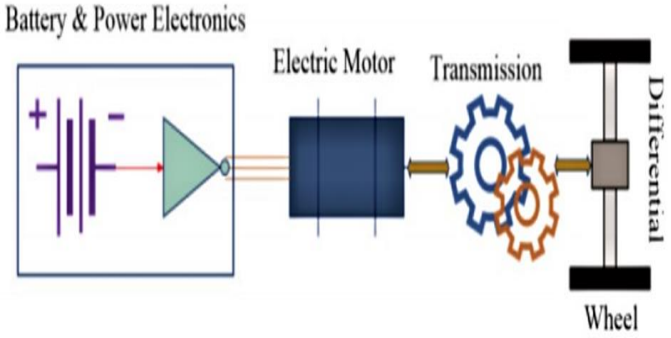

Fig 1.1 EV powertrain layout [2]

After power delivered to the motor. The motor converts electric energy into mechanical energy through rotation of the shaft. Transmission system is mounted on the shaft. so, the energy is transmitting to the wheel using transmission system.

In this paper we will explore different types of multi-speed transmissions in EVs and survey the recent works on addition of the multi-gear transmission system in passenger electric car (E-car) and electric bus (E-bus) segment. Performances of multi-gear system and non-transmission system within EV platform will be compared considering the driving condition, comfort & range. It is conformed that the addition of more than one gear in EV's powertrain will improve the performance. The major factor is the selection of appropriate number of gears in EV's.

2. OBJECTIVES

Multi-speed transmission idea can provide a sensible solution to keep the electric motor efficient during the operation of EVs. IC engine need around 500-700 rpm to remain functional. That is not a case in EV's, due to wide available range of motor rpm up to 30000 rpm it would be vary dangerous to control it without transmission system.

The main objective of this paper is to check a performance of a high-speed gear transmission for a EVs urban passenger vehicle with a city drive, then main focus has been given to battery selection, gear tooth geometry to increase the efficiency & performance of EV's. Compared to IC engine electric vehicle has less noise generation, so maintain this it is important to manufacture perfect gear with standard manufacturing techniques. It will help to reduce the cost & also we are not going to use differential so, weight get reduced & increase the efficiency.

3. LITERATURE REVIEW

1."Experimental Research of Transmissions on Electric Vehicles Energy Consumption"

In this research paper the multiple-speed transmission adopted for an electric drivetrain has energy consumption benefits over a single-speed equivalent. The power source of electronic motor is H_2 fuel cell (1.2KW). The single stage transmission having 10:1 gear ratio and in 2-speed with the 14:1 gear ratio for first gear, 10:1 for second gear. They performed the test on road having 480m length for two laps. They showed efficiency & torque requirements as a result.

2."Electric Vehicle with Multi-Speed Transmission: A Review on Performances and Complexities"

In this research paper they took experiment on the EV's with multi-speed transmission. Which offers improved performance compared to those with a single-speed transmission system. They experimented on passenger car & E-Bus vehicles. Also mentioned effective driving range and energy consumption between single-stage and multi-stage transmission as a result.

Despite the strong increase in electric vehicles (EV) sales, there is still a high price tag associated with them, in particular, due to battery costs and vehicle range, which is still very limited.

The different configurations included a Standard Powertrain setup and Gearbox setup and a prototype 2-speed gearbox. They explored their performance as well as the effect of different gear change at different speeds. Experimental results showed that a 2-speed gearbox can provide lower energy consumption (up to 3.8%) but depends heavily on gear shift strategy.

4. WORKING

In this experiment two different powertrain configurations were tested. a single-stage transmission (Figure 4.1) & another is 2-speed change gearbox (Figure 4.2). In both category the electric motor is given by a hydrogen fuel cell using H_2 at 200 bars. In the first case the transmission system is placed between the motor and the wheel so that it can provide the required torque and rpm, also works as a final transmission with having transmission ratio 10:1. In the second case, with the installation of the system a two-stage transmission system occurs, while the rest of the powertrain remains unchanged. The second stage (final transmission) is kept exactly the same providing a 10:1 ratio. The first stage (gearbox) provides a gear change with ratios 1.4:1 and 1:1 respectively. Thus, the total transmission ratios are 14:1 (1st gear) and 10:1 (2nd gear), which are mostly setup and used as launch and cruise vehicle driving modes. [1]

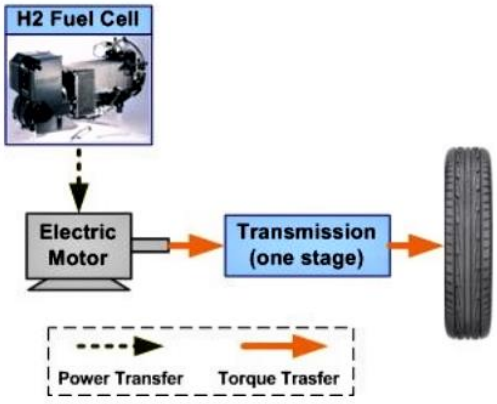

Fig 4.1 Testbed vehicle standard powertrain configuration.[1]

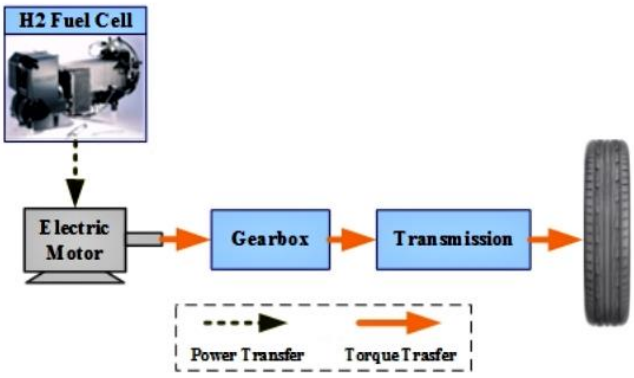

Fig 3.2 Testbed vehicle powertrain configuration with installed gearbox [1]

The use of this gearbox majorly targets lower energy consumption during launch as well as electric motor operation at a higher efficiency region. The construction of the gearbox is based on two gear pairs attached on two parallel axles. The gears are fixed on the first axle (driving axle) and are rotated by the electric motor. On the second axle (driven axle), every gear has a bearing installed that provides a free rotation on the axle. Using the synchronizing mechanism placed between the gears of the second axle, we can change from one gear ratio (1st gear) to another (2nd gear). When no gear is selected, both gears of the second axle can rotate free and thus no power is transferred to the second transmission stage and to the wheel. If the first or second gear is selected by the synchronizing mechanism, then power is transferred to the second stage of the transmission using the corresponding gear ratio. The custom build gearbox is presented as installed on the prototype vehicle. Using the 2-speed change transmission, the different gear change points occur on different vehicle speeds but for the exactly same gear ratios

Below graph shows the efficiency (%) vs motor speed(rpm). As we can see in the result the maximum motor's efficiency is up to 91.3% at the 2500 rpm. The optimal rpm range of motor operation is from 2300 to 2500 rpm.

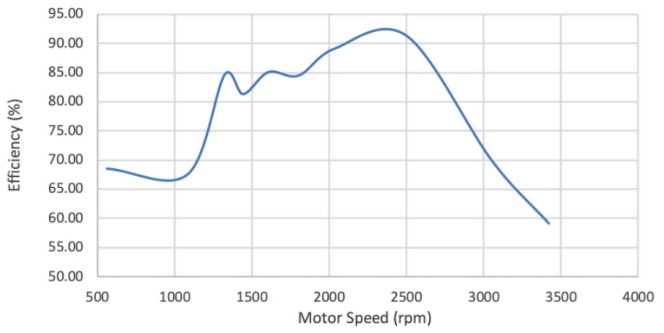

Fig 4.3 Motor's Efficiency vs. motor speed.[1]

5. EXPERIMENTAL SET-UP

Expecting to improve the EV performance, researchers and designers are investing much of their resources to the application of multiple speed transmissions instead of traditional single speed transmissions. The detail advantages of two-speed transmission over single speed are demonstrated and reported work.

The experiments were conducted on TUC's campus, in a track with a total length of 240m & total distance with 2 laps is 480m. Initially they performed experiments with the standard setup and then replicated them using the 2-speed gearbox, in order to compare their respective energy consumption. To perform the aforementioned comparison, in the second case, different gear change speeds were chosen as shift speeds (8, 11, 14, 17 and 20 Km/h), the results are shown in result column.

The Speed limits was set for the car passes from corners 1 and 2, set at 15–17 Km/h. Above 22 km/h the vehicle increased its velocity using full throttle, which results in higher energy consumption, without actual interference from the driver. Total time to complete the two laps is set to a margin of 79–83s with a max speed of 30 Km/h. Driver cannot brake to increase lap time but can stop pushing the throttle while cornering in order to adjust his lap timeframe.[1]

5.1 CHARACTERISTIC

Chassis	Aluminum alloy
Body	Carbon fiber
Motor	Brushless electric motor
Max Motor Torque	4Nm
Max Motor rpm	4000 rpm
Power Source H2 fuel cell	1.2 KW
Dimension	2.5 × 1.25 × 1 m (L × W × H)
Weight	77 Kg/79 Kg (with gearbox)
Max Vehicle Speed	37 Km/h

Fig 4.2 The prototype testbed vehicle ER16. [1]

5.2 E-CAR (PASSENGER) & E-BUS

In E-car & the E-bus worked with a single speed and two-speed transmission model within EV platform. Two-speed transmission system performed well above single speed transmission in terms of top speed and gradeability except the overtaking acceleration mode of 50-80 km/h.

They indicated that the gear change may cause some torque interruption in this acceleration mode. also found two-speed system suffers from lower driving range compared to that with single speed system. In another study, they investigated the economic performance of both small and large passenger EVs, extensively. They found small vehicle with two-speed system achieved 8.5% and 1% more driving range compared to those with single speed and three-speed system, respectively. On the other hand, under large passenger vehicle platform, single speed transmission model achieved the highest driving range of 189 km which is about 4% and 5.5% more compared to those with two-speed and three-speed transmission model, respectively. Another interesting finding of this study is that the three-speed transmission model performs slightly less compared to two-speed system.

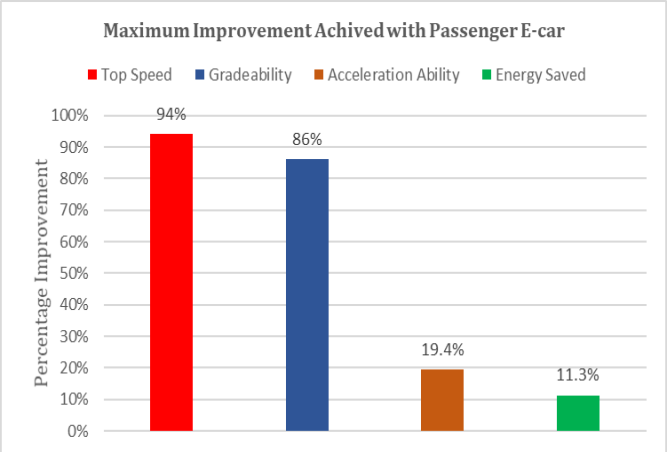

Fig 5.2.1 Maximum performance improvement of passenger E-car with multi-speed transmission system achieved compared to those with single speed system.

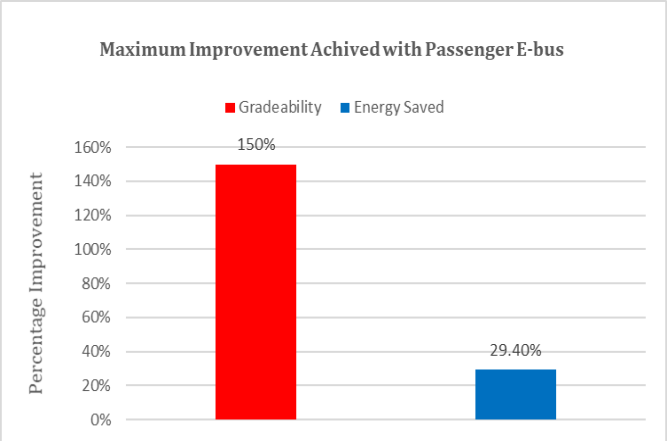

Fig 5.2.2 Maximum performance improvement of public E-bus with multi-speed transmission system achieved compared to those with single speed system.

6. RESULT & DISCUSSION

They took the experiment Based on the setup and procedures, also measured the power demand (Watt) versus sampling time for different scenarios. With that also recorded and calculated the mean power and total hydrogen consumption, which is proportional to power demand.

The 2-stage transmission system is more efficient in factors like time required to achieved torque, more huge acceleration in less time.

Follow with this the Using the gearbox provides higher acceleration which corresponds to less time to reach the first corner (compared to single-stage) and total time in track is found between 80–81sec for both laps. Maximum speed reached was 29.2–30 Km/h. As so, the vehicle's performance

is almost the same in terms of speed inside the track, but it is clear that gearbox use can achieve lower track time. The results are presented in Figures 10–14 whereas the minimum energy consumption is at 11 km/h gear change speed (H2 consumption: 4.28 lt, mean power demand: 205.38 W), followed by 8 km/h gear change as second best (H2 consumption: 4.37 lt, mean power demand: 210.12 W). Above 11 km/h gear shift speed, mean power demand is higher. Compared to single stage transmission results (H2 consumption: 4.43 lt, mean power demand: 213.45 W), correspond to 3.4% H2 consumption reduction and 3.8% lower mean power demand.

Gear Change Speed (Km/h)	Mean Power Demand (W)	H2 (lt)
8	210.12	4.37
11	205.38	4.28
14	221.32	4.49
17	232.09	4.58
20	235.82	4.62

7. CONCLUSIONS

The need of a high-speed gear transmission for a front-wheel drive electric vehicle was performed. The transmission is best suited for passenger vehicles where an urban drive cycle is expected. The electric motors power to the independent transmissions and, since there is no mechanical differential present, an electronic differential is necessary to provide the necessary torque and speed shifts between the output of transmissions when the vehicle is cornering.

The background research was an important step to get a better understanding of the current paradigm of the electric automotive industry. Despite the strong increase in electric vehicles (EV) sales, there is still a high price tag associated with them, in particular, due to battery costs and vehicle range, which is still very limited. The electric motors presently used are already at an advance stage regarding efficiency and the transmission arrangement in the EV industry is conventionally a fixed ratio single speed transmission.

From all the comparisons between single speed transmission and two speed transmission. It can be concluded that two speed transmission is more efficient than single speed transmission. Two speed is an effective solution to improve performance and efficiency. Two speed transmission allows system optimization which reduces the size of electric motor and inverter of the electric vehicle. Two speed transmission allows the various gear ratios and thus maximum speed of vehicle can be achieved. Design of the two-speed transmission is very easy but it has more cost. Though, cost of two speed transmission is high but it can be managed. Now a days two speed transmissions are used most commonly. In coming years, second generation two speed transmissions will be developed in which allow higher torque range for convenient drive of electric vehicles.

The on-road testing of different transmission using a custom electric testbed, powered by hydrogen fuel cell, is presented. The different configurations included a Standard Powertrain setup and Gearbox setup and a prototype 2-speed gearbox. We explored their performance as well as the effect of different gear change at different speeds. Experimental results showed that a 2-speed gearbox can provide lower energy consumption (up to 3.8%) but depends heavily on gear shift strategy. As such, gear change speed is of great importance and should be optimized to reach even higher levels of energy consumption reduction. Experimental results using a prototype electronically controlled CVT were also presented, indicating 4.3% energy reduction compared to single stage results, for just one lap test. All the experimental results presented for different transmissions use are compared to the simulated results found in literature. A good correlation is found regarding the use of single-stage, 2-speed transmissions.[1]

Then discuss the difficulties of adding more gears to the EV transmission system in place of single gear and how these issues can be dealt with. Despite the potential scope of performance improvement, multi-speed transmission system comes with some inherent complexities such as selection of gear ratios and gear shifting techniques, minimizing torque interruption during gear changing, additional transmission loss, etc. A high step ratio (highest gear ratio/lowest gear ratio) can contribute to both dynamic and economic performances of EVs. However, the level of step ratio is constrained by the gearbox mechanical layout. To address this conflicting issue of gear ratio selection, it is necessary to apply optimization techniques.[2]

8. FUTURE SCOPE

This research revealed some topics for future research. One topic could be finding proper gear ratio combination to be used with two-speed gearbox and evaluate the improvement in energy efficiency. Another matter to view could be the effect of gear changing to energy consumption and finding the suitable strategy for it.

This research offer basis for all mentioned topics and the model created in this research can be easily modified for different type of vehicles that use different types of motors.

The electric vehicle transmission design, despite the alleged simplicity compared to internal combustion engine vehicle transmissions, still integrates a vast number of variables which form a network and influence each other. This makes

the design an intricate project, constantly changing. Given that there is still a number of topics that could be considered, some future work which can be developed is like further developments in gears design may be performed considering the defined road profile. This would lead to less oversized gear with respect to the required safeties. Also, the driving range should be higher than the convectional ICE vehicles, due to this it would use as to grab the attention.

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BIOGRAPHIES

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