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VARIATION OF PERFORMANCE PARAMETER OF LEAD ACID BATTERY POWERED ELECTRIC SCOOTER WITH REDUCTION IN REMAINING CHARGE

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ABSTRACT:

Lead Acid Batteries are traditionally used in low powered electric scooters, cars etc. from centuries. The advancement and reliability of gasoline powered vehicles surpassed Lead Acid Battery technology but advancement in electronics and battery technology revived the electric powered vehicles in recent decades. The pollution concern and price of gasoline emerged as a big problem lately. So, the e-scooters again becoming popular choice. The cheaper option of electric two-wheeler is Lead acid battery powered scooters. The model name of scooter which was checked was LY1200DQT-16F. The machine used to check performance parameters namely power, torque, RPM and speed was Two Wheelers Chassis Dynamometer. The chassis dynamometer is a machine which is used to measure the power, torque, acceleration etc. of a vehicle. The electric scooter has been fully (100%) charged and then checked the performance parameters namely the motor power, wheel power, wheel torque, RPM and speed in every 5% decrease in remaining charge percentage. The Motor Power, wheel power, maximum torque, maximum RPM and maximum speed have been decreased up to 71%, 79%, 48%, 45% and 46% respectively till lowest charge condition i.e., at 5%.

Keywords: Motor Power, Wheel Power, Maximum Torque, Lead Acid Battery, Electric Scooter, Chassis Dynamometer.

1.0 INTRODUCTION:

Lead acid batteries are one of the most extensively used battery in many scientific areas from centuries such as in low powered locomotives, solar battery backup, automobile lighting and ignition power etc. The initial form of Lead Acid battery was invented by Gaston Plante in 1860 and after series of development in its design until most popular construction red lead (Pb_3O_4) as an active material in positive plate and litharge (PbO) in negative plate, its use have even widened (Kripal Singh, 2000). Lead acid battery contain many cells inside the container where each individual cell has cell voltage of 2.12 V at 100% charge state (Giri, 2008), so can be used with variation as per requirement. From the invention of lead acid battery, these were extensively used in initial form of automobiles before the invention of petroleum and advancement of Internal Combustion Engines. But nowadays e-scooters are again gaining popularity for example during 2016 only China produced 34 million e-bikes contributing to the already 200 million in circulation (Garche and Mosley, 2017). Moreover, the trend of population growth and migration requires fast and sustainable urban solutions and an efficient transport system. According to one estimate, by 2050 as much as 68% of the world's population will be concentrated in urban areas (UNDESA report, 2018) and car is not efficient means of transport for short distances which depicts the future of e-scooters. So, literatures state that new modes of transport such as e-scooters integrated with public transport have the potential to significantly reduce the use of car and provide a sustainable transport system (Galvic et. al., 2021). From the initial use in automobiles the reliability of power, torque and driving range produced is always in question while using the lead acid battery powered vehicles. The test of scooters with lead acid battery, in chassis dynamometer clearly depicts the availability of power and torque on scooter wheel at different charge level remaining in the battery. Power, torque, RPM and speed produced in automobile by using lead acid battery is generally not clarified in many literatures.

Power output refers to an amount of energy delivered within a given timeframe. Applied to the electric vehicle, it means the amount of mechanical energy output generated by the motor, again within a given timeframe. It has an impact on the scooter acceleration, traction capacity (the weight that it is able to move) and its ability to climb uphill. Whether it be a combustion engine or electric motor, mechanical energy power output refers to the product of rotation speed (measured in revolutions per minute) and torque. Expressed in Newton meters (Nm), torque describes the motor's pulling power. In electric motors, maximum torque is produced from the get-go. As a current flows through the electric motor, a related electrical charge causes an armature to rotate. These rotations within an internal magnetic field causes something called a back-EMF (electromotive force) which opposes the supply voltage. Imagine back-EMF to be the equivalent of a natural braking force, much like in IC engines. The net overall force being applied to the wheels is therefore the difference between the supply voltage and the EMF. The back-EMF is proportional to speed, therefore the higher the speed, the smaller the net overall force is. This explains why the torque curve begins to diminish on an EV dyno graph as the scooter's electric motors are pushed into the upper ranges of their performance limits. To turn that on its head, if speed is very small (or zero from a standing start), there is little to no back-EMF, meaning that the supply voltage is immediately equated to a torque output. So if you floor the throttle, maximum voltage is suddenly applied therefore maximum torque is immediately available (Ehsani et. al., 2005). This test has been done in chassis dynamometer, which is a mechanical machine used to measure power, torque, acceleration, rpm etc. of a vehicle in simulation of real road condition. An eddy current dynamometer consists of a metal disc or wheel that is rotated in the flux of a magnetic field. The field is produced by field elements or coils excited by an external source and attached to the dynamometer housing which is mounted in trunnion bearings. As the disc turns, eddy currents are generated, and the reaction with the magnetic field tends to rotate the complete housing in the trunnion bearings (Bechwith et al., 2000). Two Wheelers Chassis Dynamometer needs to be well calibrated. The chassis dynamometer simulates real road condition. The speed, slope, air resistance and other relevant parameters are programmed to represent the real road condition.

In recent years use of EV has been increased. Among them electric scooters are highly preferred in urban areas. Mostly in the market two types of electric scooters are most common. One is E-scooter with Lithium-ion Battery and another with Lead Acid battery. In spite of many technical shortcomings Lead Acid E-scooters are still very common due to its cheaper price and cheap in battery replacement. In one study, the battery cost ($/kWhr) of Lithium ion battery is 568.39 US dollar while lead acid battery is 113.68 US dollar (Allcell technologies, 2012). Many people still hesitate to use E- Scooter because of lack of sufficient data regarding torque, power, speed etc. of scooter in different charge conditions. This research is carried out to show the torque and power of electric scooter at different charge condition of battery.

2.0 METHODS AND MATERIALS:

Two wheelers are one of the primary commuting means in developing countries. Electric scooters are gaining more popularity because many government agencies are providing better subsidy. Besides, the hiking fuel price is also one of the reasons of its more importance in coming days. Among many types of electric scooters, Lithium-ion battery powered and Lead acid battery powered scooters are most common. Lead Acid battery powered scooters are cheaper option so they are still using in short distance commuting. The performance of electric scooter with Lead Acid battery, at declining battery charges are not well documented so some people still hesitate to use it. This experiment has tried to solve this problem by finding the performance parameters at various charge condition.

The experiment has conducted in two-wheeler chassis dynamometer. The provided chassis dynamometer was capable of testing power up to 350 kilowatts. The basic technical specification of chassis dynamometer has shown in Table 1.

Equipment Name- Chassis Dynamometer for two wheelers (MSR 400)

Equipment Manufacturer- MAHA, Germany

Roller Set Technical Specifications

Table 1 Technical specification of chassis dynamometer

Axle load	1000 kg
Weight	270 kg
Roller set rotating mass	approx. 150 kg
Roller diameter	400 mm
Roller set dimensions (L x W x H)	546 x 770 x 456 mm
Measurement principle	Flywheel test stand
Max. air pressure	7 bar
Max. test speed	320 km/h
Wheel power (dynamic) peak	> 350 kW
Max. tractive force	6.5 kN
Measurement accuracy	
Wheel power measurement	+/- 2% from measured value

Similarly, the lead acid powered electric scooter has used to conduct the research. The e-scooter was already used in urban area having odometer reading of around 2800 km.

Vehicle Name- Electric Scooter

Vehicle Model- LY1200 DQT-16F

Vehicle Manufacturer- M/s Zhejiang Luyuan Electrical Vehicle Co. Ltd., China

Table 2 Technical specification of electric scooter

S.No.	Technical Parameters	Technical Values	Remarks
1	Battery Voltage	72 V	
2	Battery Current	30 Ah	
3	Battery Type	Lead Acid Battery	
4	Front Brake Type	Disc	
5	Rear Brake Type	Luyuan Ceramic Drum Brake	
6	Battery Life	300-400 Charge/Discharge Cycle	
7	Maximum Range	85 km	
8	Ground Clearance	155 mm	
9	Charging Time	3.5 hours	
10	Wheel Size	10*2.15 inch	
11	Front Suspension type	AL oil Hydraulic fork	
12	Rear Suspension type	Single spring oil hydraulic	

The Lead Acid Battery used is selected as per its rating. Battery rating is ampere-hour capacity which is amount of current that a battery can deliver for 20 hours without the temperature corrected cell voltages dropping below 1.75 volts per cell (Crouse et. al., 2007)

The e-scooter has fully charged up to 100 %. Then the torque and power at that condition was checked. After brief running the charge percentage lowers and again was checked while at 95% remaining charge level. By this way, the electric scooter was checked in the charge decline rate of 5% till it comes down to 5%. The acquired power, torque, rpm and speed at different charge levels have analyzed and conclusions are made.

3.0 RESULTS AND DISCUSSION:

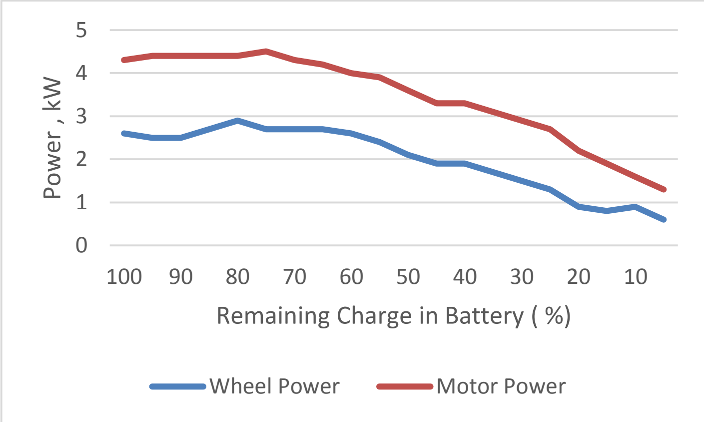
The various parameters namely Wheel Power, Motor Power, Maximum Torque Produced, RPM of wheel, maximum attained speed with remaining charge from 100% to 5% are tabulated and analyzed in Table 3.

Table 3 Performance parameters readings of scooter from chassis dynamometer

S. No.	Remaining Charge, %	Wheel Power (P_{wheel}), kW	Motor Power (P_{motor}), kW	Torque Produced, Nm	RPM of wheel while maximum torque production	Maximum attained speed, km/hr	Remarks
1.	100	2.6	4.3	13.5	3015	34.4	
2.	95	2.5	4.4	14	3010	34.3	
3.	90	2.5	4.4	13.9	3020	34.4	
4.	85	2.7	4.4	13.9	3005	34.2	
5.	80	2.9	4.4	13.9	2995	34.1	
6.	75	2.7	4.5	14.1	3015	34.4	
7.	70	2.7	4.3	13.2	3010	34.3	
8.	65	2.7	4.2	13.3	3005	34.2	
9.	60	2.6	4.0	12.8	2985	34.0	
10.	55	2.4	3.9	12.3	3035	34.6	
11.	50	2.1	3.6	11.2	3040	34.6	
12.	45	1.9	3.3	10.3	3040	34.6	
13.	40	1.9	3.3	10.5	3035	34.6	
14.	35	1.7	3.1	11.0	3030	34.6	
15.	30	1.5	2.9	11.6	2225	25.4	
16.	25	1.3	2.7	13.3	1630	18.6	
17.	20	0.9	2.2	12.0	1650	18.8	
18.	15	0.8	1.9	10.9	1665	19	
19.	10	0.9	1.6	9.3	1660	18.9	
20.	5	0.6	1.3	7.3	1655	18.9	

3.1 Power vs Remaining Charge in Battery Curve:

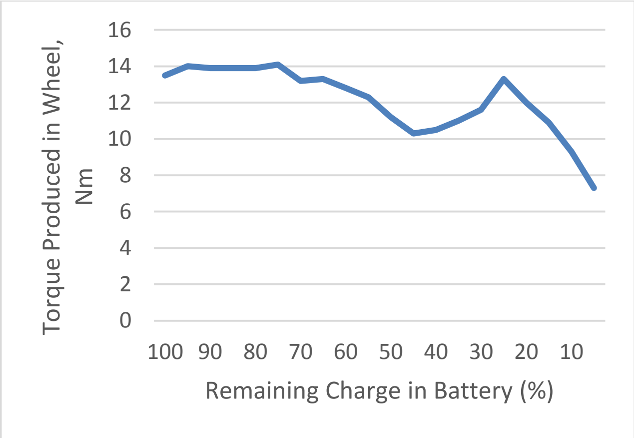
This curve has plotted between the Motor Power (in kW) and Wheel Power (in kW) shown by chassis dynamometer at various charge state of battery from 100% charge to 5% charge condition at the declining of 5% interval. From the result it has noticed that the motor power and wheel power are constant around 4.5kW and 2.5 kW until 75% charge remaining. After that, the net power value has decreased rapidly in linear basis of around 45 degrees and has become minimum at minimum charge condition. The difference between motor power and wheel power is a loss due to drag as well as drivetrain. The loss is about 2 kW until 75% charge condition and then becomes lesser and lesser and around 0.7 kW at minimum charge condition (5% charge remaining). The Motor Power and wheel power have decreased up to 71% and 79% till lowest charge condition i.e. at 5%. This condition may be due to reduction in maximum speed of the scooter since the drag force is dependent on the speed of vehicle.



Graph 1 Motor/Wheel Power vs Battery Charge Curve

3.2 Maximum Torque vs Remaining Charge in Battery Curve:

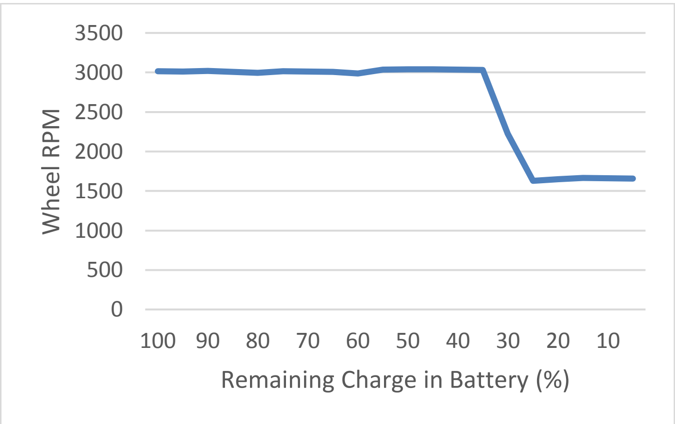
Maximum torque produced on scooter wheel at various state of charge condition has measured in different charge condition from 100% to 5% charge remaining at the interval of 5%. The torque values (in Nm) obtained has plotted against remaining battery charge, the graphical analysis shows the variable torque production characteristics. Wheel torque value has remained constant of around 14 Nm till the 75% of battery charge and then started to decrease from 14 Nm to 10 Nm up to 50% charge state. From 50% charge condition, the torque was around 10Nm again increased to 13Nm till 25% charge remaining in the battery and then declined to minimum value of 7 Nm at minimum charge condition (5%) of the battery. Maximum torque has decreased to 48% of initial value till lowest charge condition i.e. at 5%.



Graph 2 Torque production in wheel vs battery charge

3.3 Wheel RPM vs Remaining Charge in Battery Curve:

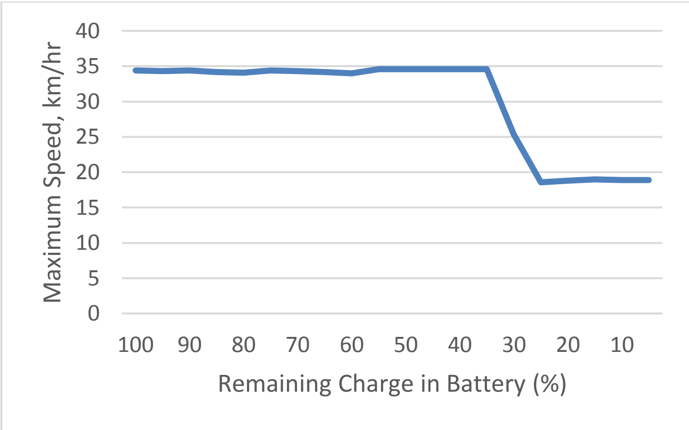
Regarding the RPM of wheel, the wheel RPM has plotted against remaining charge in battery. From the graph, the wheel RPM has exactly constant value of 3000 RPM from 100% charge condition to 35% charge condition. Again from 35% battery charge remaining to 25% battery charge the RPM value sharply decreased from 3000RPM to 1630 RPM. Then, the wheel RPM value has remained constant at 1630 RPM from 25% charge state to 5% charge state. maximum wheel RPM has decreased to 45% of initial value till lowest charge condition i.e. at 5%.



Graph 3 Wheel RPM vs Battery charge curve

3.4 Maximum Speed Vs Remaining Charge in Battery Curve:

Regarding the maximum speed of the scooter, the graphical analysis has become similar with Wheel RPM because both parameters are directly proportional. Maximum speed has plotted against remaining charge in battery. From the graph, the maximum speed has constant value of about 34 km/hr 100% charge condition to 35% charge condition. Again from 35% battery charge remaining to 25% battery charge the maximum speed value sharply decreases from around 34 km/hr to 18 km/hr. Then, the maximum speed value again remains constant at around 18 km/hr from 25% charge state to 5% charge state. Maximum speed has decreased to 46% of initial value till lowest charge condition i.e. at 5%.



Graph 4 Maximum speed vs battery charge curve

CONCLUSION

i.) If higher power of scooter is needed it should be operated in maximum charge condition i.e. up to until 70% charge remaining the scooter remains in high power delivery condition.

ii.) Generally, in a high torque requiring condition such as in steep road, the scooter has rode easily until about 70% charge remaining condition after that the traction power of the scooter has decreased.

iii.) If higher speed is needed, the scooter should run until 35% charge remaining condition, after that the speed decreases rapidly and reaches about 55% speed of higher charge speed.

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Annex: