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DESIGN AND DEVELOPMENT OF AN ELECTRIC HYBRID RICKSHAW

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ABSTRACT

Most of the transport vehicles prevailing in the cities of developing countries are accountable for noise and air pollution, with the exception of human powered vehicles (HPV). However the human powered vehicles running commercially need a lot of physical effort to drive. A motor assisted battery driven Hybrid rickshaw can provide a relatively comfortable non-polluting and a silent transport system for urban and rural areas of Bangladesh. The primary focus of this research was to develop an Electric Hybrid Rickshaw without requiring significant changes to the structure of widely popular existing rickshaws. In fact it is a combination of a battery operated motor driving system with the existing pedal arrangement. This would allow the use of relatively smaller motor and storage batteries for automation as well as reducing human effort, while keeping the option of full human power drive readily possible. The performance test revealed that the hybrid vehicle provides satisfactory speed, easier motion control and good scope of manipulating the shares of human effort and motor power. Besides reducing air and sound pollution, such rickshaws –demanding less physical effort, may provide large scale employment in urban and rural areas of Bangladesh.

Keywords: HPV, Rickshaw, Hybrid Rickshaw, Hybrid Drive, Electric Motor, Battery.

1. INTRODUCTION

Rickshaws are small three wheeled vehicles which are used extensively in many Asian countries for transportation of people and goods. These vehicles are small and narrow allowing easy maneuverability in congested Asian metropolises. Bangladesh is home of more than a millions of rickshaws[1,2].

Day by day pollution is overwhelming all major cities of our country. The main reasons are the air and noise pollution caused by transport vehicles and a significant part comes from petrol and diesel-powered motorbikes and three-wheelers. In Bangladesh, there are presently nearly half a millions of petrol-powered motorbikes and thousands of petrol or diesel-powered three wheelers[3]. A limited number of three wheelers are operated with CNG. Pollution from these vehicles is growing at a significant rate. Besides these vehicles recently electric rickshaws are being tried out which do not contains any pedal arrangement. So its driving speed is totally dependent on the charge of battery which diminishes gradually on use[4]. When the batteries don't have enough charges these become inoperable. As a result these require high motor and battery capacities that make them expensive.

The concept of an electric hybrid rickshaw combines the advantages of the pedal and electric auto rickshaws in a single arrangement. This was tried out without changing the main structure of existing rickshaw

significantly, allowing cost effective conversions of existing rickshaws.

To fulfill this objective this experimental research work involved the following processes:

- Study the structure and driving features of the existing conventional rickshaws and electric auto-rickshaws.
- To find a cost effective, feasible design and fabrication of parts for transforming conventional rickshaw to a hybrid one.
- Performance test of the hybrid vehicle to evaluate its feasibility and effectiveness compared to conventional and electric motor assisted rickshaws.

2. ESOCIO-ECONOMIC BARRIERS ON THE IMPROVEMENT OF RICKSHAW

Although a number of research works have been carried out and many recommendations were proposed for improvement of rickshaw yet no remarkable change has been implemented in this vehicle in our country [2,4,5]. The major reasons behind this situation is related to some prevailing socio-economic barriers.

- The rickshaw owners enjoy substantial incomes from the prevailing vehicles and hence are reluctant to invest any further for purchasing improved rickshaws as well as to modify their own rickshaws. They are well organized in their activity and have a reasonably powerful influence on the government and relevant decision making parts of the society.
- Since the rickshaw pullers are available abundance in number, they are not organized and hence can not press for better driving machines.
- No financers are coming forward to invest money for mass production of improved rickshaws as it seems risky to motivate the buyers for new ones.
- There is no strict Government legislation to maintain a standard specification on which rickshaws should be produced.

As a result, no significant change in the existing rickshaw-design has been carried out up to road level in the last few decades.

3. EXPERIMENTAL SETUP

In order to facilitate gathering performance data of the rickshaw in running condition, a roller dynamometer arrangement was used to simulate the road condition. The setup comprised of a friction-roller arrangement and the test vehicle (rickshaw) run on it.

Fig 1. Experimental Setup

3.1 Mechanical Equipments

To house and couple the motor in the existing rickshaw some extra mechanical equipment needed to be used. These included - i) Angle Bars ii) Additional Chain-Sprocket iii) Mechanical Bush. The conventional bush is a mechanical fixing between two, possibly moving, parts, or a strengthened fixing point where one mechanical assembly is attached to another. The outer and inner diameters are 38 mm and 25 mm respectively. The length of bushes is 50 mm. They are fixed with the axle by means of four bolts.

An additional chain and sprocket arrangement was used to transmit the motor power to the axles. As a result the axle contains two sprockets unlike conventional rickshaws. For motor power transmission we used gear ratio 1:1. so that the conventional sprocket of rickshaws could be used with the motor's shaft. The pitch circle diameter of sprockets is 81 mm, contain 22 teeth and they are designed to fit at a shaft of 25 mm in diameter.

Two angle bars of mild steel were used to house the motor. They were attached to the rickshaw chassis by nut and bolts. Angle bars were used instead of flat bar as it provided better support. The bars were 31 inches long, 50mm in breadth and 5mm in thickness. For ease and reliability of correct chain movement, one groove was cut in each of the bars.

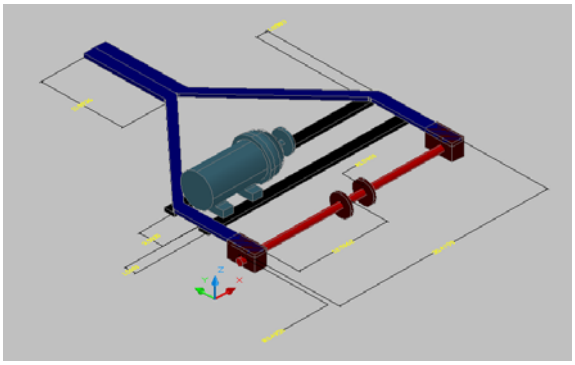

Fig 2. AUTOCAD design for the fabrication of Mechanical equipments

3.2 Electrical Equipments

To facilitate the electric driving system and its safe controlling some electrical components are used. These include - i) Electric Motor ii) DC Battery iii) Electric Relay iv) Push switch v) Ampere meter vi) Multi-meter vii) Fuse. Table-1 shows the specifications of different electrical equipments.

Table 1: Different electrical equipments and their specifications

Equipment	Specifications
Electrical Motor	Brush Type DC motor Weight =16kg, 500W, 36V, Rated shaft rpm=360
Battery	Model NS40ZL, VOLVO, 12V, 11 Plates, 35AH
Relay	Model SLD-12VDC-1C, NO-40 A, NC-30A, 14VDC
Ampere Meter	Model SF-80, 30A
Fuse	20A, 500V

3.2.1 Selection of Prime mover

Apparently it seems that if a motor run by battery is attached with the existing axle drive system a hybrid rickshaw can be achieved. But the real scenario is not so simple. There are four types of motions that need to be accommodated by a hybrid drive assembly. The drive may transmit from the prime mover ie. motor/pedal to the wheel, alternatively the motor/pedal may be idle and the road inclination, inertia or a physical push may move the vehicle and transmit the drive from the tyre to the motor/pedal[6,7]. These motions can be categorized as:

1. Motor forward motion with the pedal fixed.

2. Motor forward motion with pedal forward.
3. Motor fixed and vehicle in forward motion.
4. Motor fixed and vehicle in reverse motion.

A proper selection of prime mover (motor) as well as an appropriate drive mechanism is necessary to achieve the hybrid solution. The power output, which is a function of speed and torque is a major factor to be considered. The motor needs to be capable of providing sufficient torque at starting and at running condition. Again the motor speed is also an important factor which can neither be too high that is uncontrollable or requires a large speed reduction. The motor needs to be stable in its performance for a sufficiently long time. The availability and cost of the motor is also a fact due to economic and market demand aspect. A motor that has the provision for repairing later (ie. not a one-time use design) is also a desirable quality, to sustain the use of the prime mover in Bangladesh.

At first automotive windshield wiper motors were considered as the prime mover. The built-in gear arrangement, making torque amplification with such motors made them a possible candidate. However after assembling and performance trial the motor was found to provide insufficient torque to bring the rickshaw up to the desired speed. Due to the high gear ratio the vehicle could not be pushed to reverse direction, which added complexity in the drive mechanism.

As a second choice starter motors with automotive engines were considered. The power of such motors was found to be adequate, but the speed was high requiring multistage gear-ratios to bring it to a level suitable for a rickshaw drive. Large gear reductions restricted the manually operated motion in reverse direction. The motor was also found to be designed to operate for bursts of short periods and body temperature increased as it was run for more than 15 minutes at a time.

Fig 3. Electric Motor from BDP

Finally a suitable electric motor could be identified at BDP (Bangladesh Diesel Plant).The motor was a Brush Type DC motor, 500watt, 36 volt. It weighs 16 kg and its rated shaft speed is 360 rpm. BDP had imported this type of motors from China. The motor was found to be of adequate capacity and suitable speed to be used as a prime mover for a hybrid electric drive.

3.2.2 Electrical circuitry

The electrical components are connected by means of wire to run and control the motor driving system. The motor got the power from the battery via a relay. The relay separates the switching circuit from the motor powering circuit. It prevents the switches from overheating. An ampere meter and a fuse were connected in series along the motor powering line. A multi-meter is connected in parallel across the battery to measure the battery voltages. The switching circuit is comprised of two switches. One of them is a push switch. When the main switch is turned on, the motor is only in action while the push switch is being pressed. The push switch facilitates the easy controlling of motor switching and its safer operation.

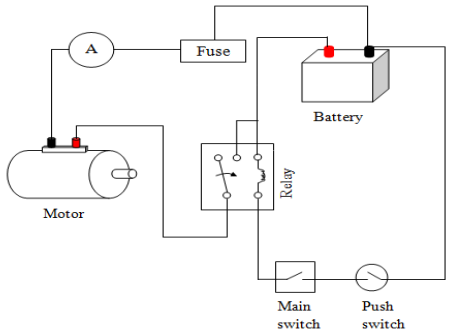

Fig 4. Electrical Block Diagram of Hybrid Rickshaw

4. SEQUENCES OF OPERATION

- First the main switch should be turned on.
- Small paddle assistance is desirable at starting for smooth and reliable starting of the hybrid system.
- Next the push switch is pressed. As current passes from battery through the switching line the relay activates the motor circuit line.
- Motor draws current from the battery according to load applied in its shaft. Once moving pedal assistance is optional. The push switch should remain turned on as long as motor assistance is required.
- The rickshaw could be pedaled along with motor assistance to get hybrid action as well as to get increased speed with lower human effort and longer service time from battery.
- For safer braking the push switch is released and then the manual brake needs to by applied.

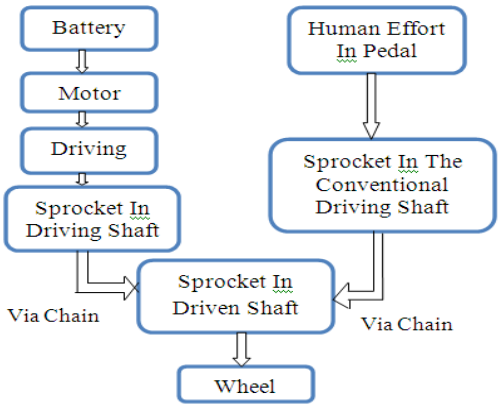

Fig 5. Flow chart of power transmission

5. RESULTS AND DISCUSSIONS

Performance tests were carried out on the chassis roller dynamometer shown in section-3 with constant torque. From the performance tests the following results are worth mentioning :

- **Comparative study with one 35AH battery:**

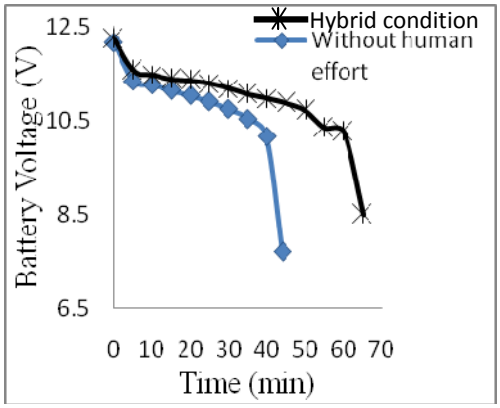

Fig 6. Battery voltage vs time curve for one 35 AH battery

Fig-6 illustrates the variation of battery voltage with respect to time for one 12 volt 35 Ampere-Hour battery. From this figure it is evident that as the human effort is added with the electric drive battery service time increases to a great extent. The test showed 1.5 times increase of service time from 40 minutes to about an hour. Battery voltage up to 10 volts gave satisfactory drive.

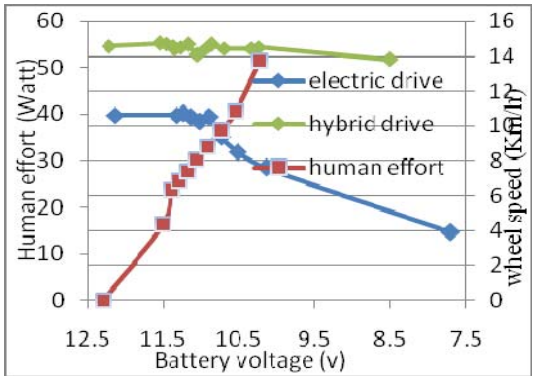

Fig 7. Human effort and wheel speed vs Battery voltage

Fig-7 illustrates the variation of wheel speed with respect to battery voltage as well as increase in human effort with respect to decrease in battery voltage for one 35AH battery, maintaining a resultant vehicle speed of about 14 km/h. Figure shows that as the battery voltage decreases, wheel speed drops at relatively lower rate in case of hybrid drive than that of electric drive. Initially very small amount of human effort is required to maintain a desired speed but as the battery voltage decreases, the human effort needs to be increased. However it is still much less (only up to 25%) compared to human effort needed to run the vehicle manually.

- **Comparative study with 2×35AH battery (12V each):**

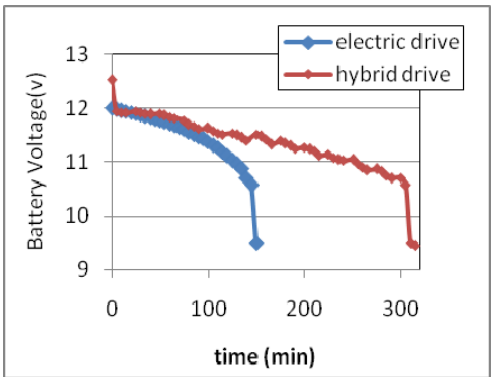

Fig 8. Battery voltage vs time curve for both electric and hybrid drive respectively

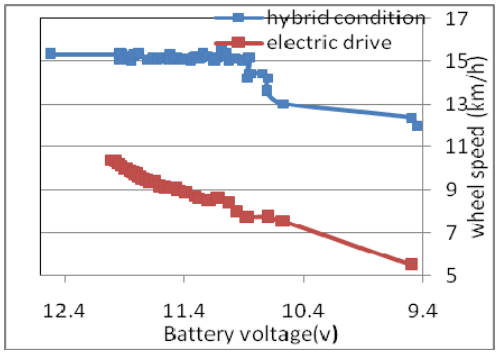

Fig 9. Wheel speed vs battery voltage for both hybrid and electric drive respectively

Fig-8 depicts the variation of battery voltage with respect to time for two 12 volt 35 Ampere-Hour battery in parallel connection. From this graph it is shown that with two batteries in parallel, the hybrid system increases the battery service time almost to a double (150 to 300 minutes) compared to that of only electric drive condition. The service time was found to be almost three times compared to a single battery operation. On the other hand figure-9 shows the variation of wheel speed with respect to battery voltage for the same battery stated above. This graph shows similarity (about 15 km/h) in wheel speed achieved for hybrid condition as compared to single battery drive condition. The greater battery weight slows down the maximum speed with electric battery operation only, compared to the single battery case.

➢ **Study with 2×35AH battery (24V in series)**

During these tests two 12 volt 35 Ampere-hour batteries were connected in series and the electric motor was driven at 24 volts. The two figures 10-11 below show the variation of battery voltage with respect to time and wheel speed with respect to battery voltage respectively. From these figures it can be seen that initially wheel speed is at comperatively high level but as the battery voltage drops down wheel speed also drops. So initially hybrid drive is only necessary for attaining higher speeds for example to driving a long distance, free of much traffic. However it was not found to be comfortable as the feet had to be pedalled very rapidly, to synchronize with the high vehicle speed. Rather on driving when the voltage drops to a certain lower level, wheel speed reduces to around 15-16 km/h, at such condition the hybrid drive can comfortably be applied to get a satisfactory speed as well as a longer battery service time.

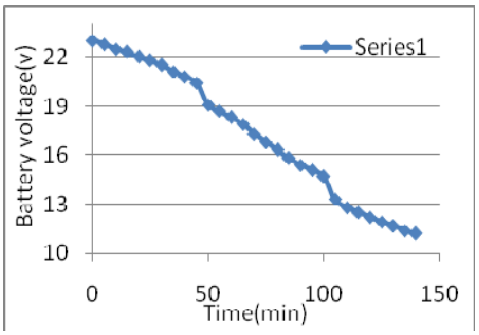

Fig 10. Battery voltage vs time curve for two 35AH batteries in series

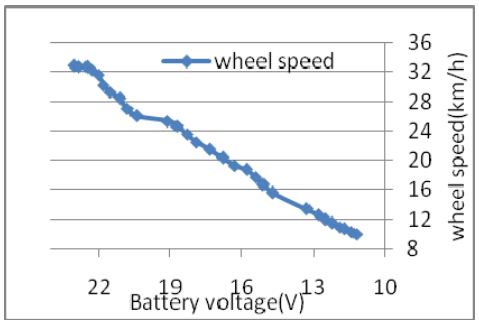

Fig 11. Wheel speed vs battery voltage for two 35AH batteries in series

6. ADVANTAGES AND LIMITATIONS OF HYBRID RICKSHAW DRIVE

6.1 Advantages

- First of all using hybrid system it is possible to manipulate the use of motor assistance and human effort. As less physical power is associated in driving it facilitates proper driving in long distances or severe weather condition. Even a less stronger person or aged people could run it.
- For hybrid system, during starting, addition of human power reduces the load on motor. So motor of smaller capacity can be used and its longevity will be higher compared to conventional electrically driven three wheelers.
- The hybrid drive is fitted in the existing manually driven rickshaw, needing only some extra components. No extra vehicle space is required to incorporate the hybrid drive. Motor is placed at the free space found under the seat. Hence parking and moving parameters will not be changed. Sometimes volume is a factor for shipment or parking charge, in this case it will be same as the conventional three wheeler run by human power.
- Except Battery and Motor all equipments are cheap enough. All the materials are purchased from local market. All joints of the structure are nut-bolt joints providing ease of dismantling if needed.
- It can easily go uphill. In case of manual rickshaw the puller faces difficulty because it causes significantly more human effort to go uphill. Motor torque assisted by little human power can make easy uphill climbing.
- No additional speed regulator is required as the speed delivered by motor is at the speed range of conventional rickshaw. Hence control is easier.
- Presence of electric battery will open the option of better lighting and traffic signal indicators in a rickshaw, making it safer to drive.
- Relatively lower conversion cost. A conventional rickshaw costs around BDT 15,000. The hybrid drive system (including DC motor and one 35 Ah battery) costs about BDT 12,000. Hence hybrid rickshaw costs BDT 27,000 for single piece production. Mass conversion cost is expected to be around BDT 8,000 which is far more economically

viable than buying a new electrically driven three wheeler.

6.2 Limitations

- The batteries would need recharging, increasing the load on mains electricity during charging. Charging at off-peak hour or using solar power may be effective. Improper disposal of Pb-acid batteries may cause environmental hazard in future.
- The reverse motion could only be accomplished by human push, as in the case of manually operated rickshaws. Hybrid system is not applicable for a reverse drive.
- The assembly weight including weight of battery is about 28% (26 kg of 92 kg) of total vehicle load. Vehicle weight is increased by about 18% compared to manual rickshaw weight. However redesigning of some existing vehicle components may offset the increase in weight.
- Less suitable to run in flooded roads. If not properly insulated, the wiring may be cause electrical problem.

7. CONCLUSIONS

The hybrid system was found to work satisfactorily. The system could be fitted in the existing conventional rickshaw, at a small conversion cost. It allowed reduction of human effort as well as use of relatively small capacity motor and battery. Required human efforts varied from 0% to 25% as compared to a conventional manually operated human power vehicle. The hybrid system improves battery operation time by 50% for a single 12V 35AH battery, 100% for two 12V 35AH batteries in parallel. The maximum vehicle speed using hybrid drive could be achieved with two 12V 35AH batteries in series. Switching between two batteries in parallel and series connections also could be done according to the driving requirements.

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