# Design of Electric Drive for One-Wheeled Motorcycle

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***Abstract* — This paper describes process, planning and designing of electric drive for one-wheeled motorcycle, providing details and challenges for selection and implementation of components. The components that are proposed for electric drive are selected using the reference of models available in the market having advantage of smaller size, low maintenance and less vibrations. The present mechanism design ties up mechanical system with the electric drive and electro-control system to power one-wheeled motorcycle effectively. Closed loop control system is proposed to be designed to assist effective transmission and balancing of one-wheeled motorcycle.**

***Index terms – Electric Drive, self-balancing vehicle, controller, gyroscope, one-wheeled motorcycle.***

## I. INTRODUCTION

Electrical vehicles can become a key to personal transportation in the environment where atmospheric pollution must be restricted, traffic conjunction is a severe issue and parking space is big concern especially in urban areas. Considering all these issues there is immense necessity of developing the transportation system that will be able to solve these problems. Developing a one-wheeled electric motorcycle which has features that can over-come all the problems mentioned above since it has small longitudinal length and low carbon footprint. Moreover, they are suitable for all age groups; use of helmet is not compulsory and does not require any registration, taxes and licensing. To develop one wheeled motorcycle for efficient working it is necessary to design electric drive carefully such that it is be able to meet the desired results. Electric drive components selected ought to be small in size so that actuating mechanism should be fitted inside the wheel.

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The Automotive Research Association of India (ARAI) [1] has declared the standards for the measurement and minimum requirement of starting gradeability for all types of vehicles, where norms are regulated for the vehicle design, test conditions, test procedures and requirements. Texas Instruments application report [2] specified the different design factors that must be taken into consideration while designing electric bicycle using BLDC motors. Mushin abdul-rehaman et.al.[3]- have presented the process planning and designing of hybrid bike with two stage transmission system to transmit desired speed to wheel with using relatively small size components in their design project. They designed an electro-mechanical system, with several non-human inputs and feedback channels thereby developing a hybrid electric bike that could be used for safe and easy to use. Mohamad Nasser hashmenia and Behzad Asaei [4] have carried out the study of different motors used in electric bikes and compared them under different cycles to determine the best suited motor for electric vehicle applications. They compared five main electric motor types viz. DC, permanent magnet synchronous, induction, switched reluctance and brushless DC motors and after extensive research on them they concluded that brushless DC motors are best suited for Electric Vehicle applications over other motors due to their advantages such as less pollution, less fuel (electric power) consumption and more power to volume ratio. Dein Shaw and S. H. Chan [5] proposed study of doubled-wheeled self-balanced unicycle with small longitudinal length with two axial wheel and pedal by human with electric control system to balance the unicycle. G.Veerapathiran et.al [6] presented the comparison of chain drive and belt drive for motor bikes using the factors such as noise, vibrations, friction, performance, transmission speed and displayed the advantages of belt drive over the chain drive for power transmission. Zidong Zhang et.al [7] presented the study of designing the brushless dc motor controller strategy applied to electric bike to have over-current and under-voltage protection. They carried out experiments to show that the controller has better dynamic stability and ran steadily for 36V and 250W brushless DC Motor. Yangsheng Xu et.al [8] present the concept of Dynamic mobility through the use of gyroscope that is used to balance the single wheel robot. The balancing of single wheel can be triggered by drive motor and wheel bearing where spinning flywheel acts as gyroscope. V.Thiyagarajan and V. Sekar [9] described the design of electronic control for brushless dc motor in an electric cum human powered bicycle characterized by new solutions for the control method with 8-bit microcontroller system. Michael Baloh and Michael Parent [10] have presented a mathematical model of vehicle dynamics for B2 model and have used open loop and closed loop experiments for the verification purposes.

## II. ELECTRIC DRIVE SYSTEM

As shown in Fig.1 an electric drive system consists of four main components:

1. Motor
2. A Transmission system
3. A control system and
4. A battery pack

The selection of battery pack and motor are the main aspects to be focused on while designing an electrical drive system for one-wheeled motorcycle. For efficient working of the system i.e. to avoid undesired acceleration and to increase the battery range, closed loop control system to control the output power is studied and implemented. Such solutions are not available commercially so they have to be designed as per the desired requirements. Position sensors detect the motion of the motorcycle and the controller controls the motion, to keep the motorcycle balanced. Criteria's such as speed, efficiency, weight and available space are to be defined properly before design and implementation of components for electric drive system of one-wheeled motorcycle. Design and selection of components is to be done by taking into consideration the available space as all the actuating mechanism is fitted inside the wheel space. Motor speed is reduced through reduction stages in transmission system to obtain desired speed at the wheel. The electrical drive system for one wheeled drive is designed in such a way that it produces enough starting torque and speed to propel bike and rider comfortably.

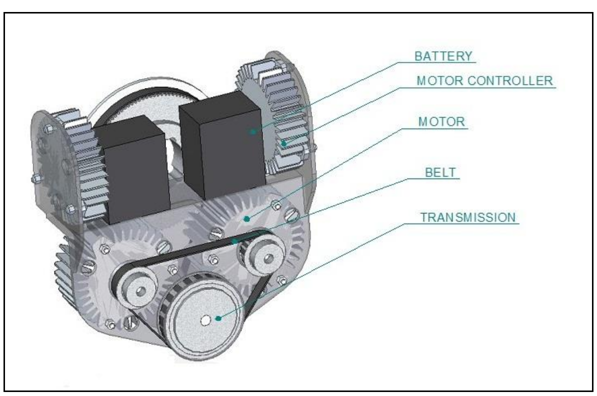


Fig. 1- Electric Drive System

While designing electric drive of one-wheeled motorcycle some of basic calculations are carried before selection of components such as power required.

Calculation for power required by motorcycle to develop necessary torque for the indicated travel condition is done as per ARAI standards-As per which bikes up to 85cc are required to be designed with road gradient of 3.81°[1]

From fig. 2

$F_{wf}$ = Windage + Friction Drag

$F_d$ = Downhill force from gravity

$F_p$ = Propulsive force

$Fp = F_{wf} + F_d$

$P_d = F_d \text{ X } Vb$

Where $F_d = m \text{ X } \sin\theta$

Vb=motorcycle speed

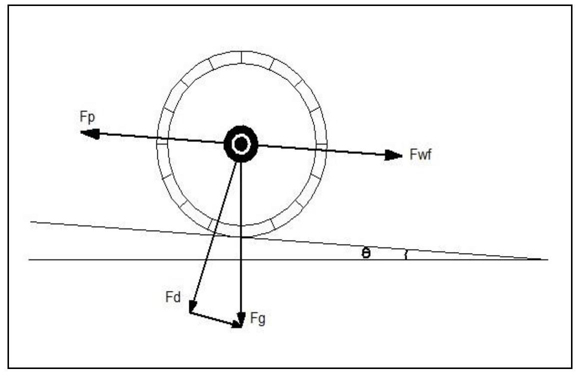


Fig.2- Power Required to Develop Necessary Torque

Designing for Headwind speed=25 km/hr, it adds up to approx. 30W extra to propel the vehicle.

So, considering the required data to calculate power for one-wheeled motorcycle, such that it has to carry a person having mass of 80kg at a speed of 20 km/hr. Motorcycle requires 680W power. So from standard motors available in the market, two motors of combined power of 800W are selected.

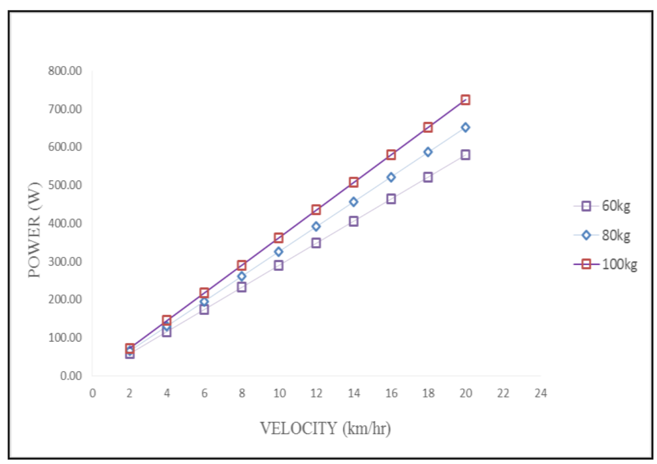


Fig. 3- Mass influence on total power required

## III. CHOICE OF MOTOR

Comparing five main motor types viz. DC, permanent magnet synchronous, induction, switched reluctance and brushless DC motors of the motors widely used in electric vehicles, induction motors are most suitable for the EV's application due to its certain advantages of robustness, cost effective and less maintenance. However, considering the critical factors that must be taken into account while designing electric drive system of one-wheeled motorcycle, BLDC motor is most suitable due to its requirement of less space, less energy consumption more volume to weight ratio and long life due to elimination of brushes [4]. Therefore, for one-wheeled motorcycle two 400W BLDC motor are selected to have a total power of 800W as required from the calculation carried out earlier. Selection of two motors instead of one motor is done due to the space constraint to accommodate one single large size BLDC motor.

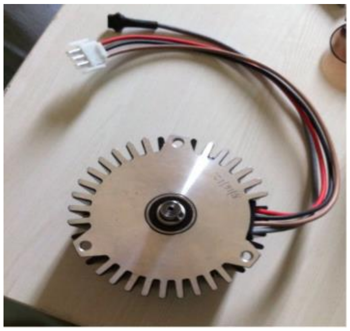

Fig. 4-Brushless DC Motor

## IV. TRANSMISSION SYSTEM

Design of transmission system plays very important role in effective working of electric drive for one-wheeled motorcycle. Transmission system consists of belts, pulleys, bearings and intermediate shaft to transmit power from motors to wheel rim. Based on available torque and desired maximum speed at wheel, transmission system is designed with reduction stages. Single stage reduction is more preferable option but considering limitation of space as it could not be employed due to large component size required to obtain desired reduction of speed at wheel. Hence, two stage reduction is designed and implemented which minimizes the component size in system. Splitting the transmission system in two stages increases the complexity but decreases the size of components which is more critical factor than minimizing the components. Design of Two stage of transmission system consists of primary stage and secondary stage.

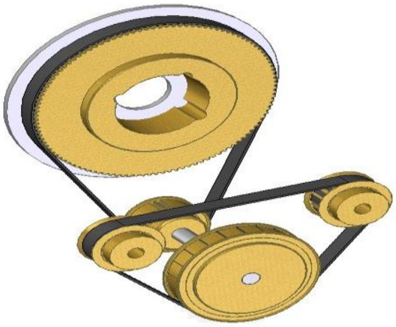

Fig. 5: Two stage Transmission System

Primary stage: Primary stage (fig 6.) is designed to transmit power from motor to intermediate shaft (jackshaft). For designing of primary stage selection of components, certain design consideration had to be take into account such as center to center distance available, gear reduction ratio to obtain required speed from motor to intermediate shaft and transmission drive which can transmit the power with maximum efficiency and less maintenance. Taking into consideration of a number of electric bike hobbyist, timing belt drive are most preferable drive for transmitting the power than chain drive when motor rpm exceeds 1000rpm [3]. Timing belts are less noisy and efficient than chain drive making it suitable to transmission.

Designing transmission system in electric drive for one-wheeled motorcycle to provide maximum speed of 25km/hr is done after acquiring required data such as

For primary stage center to center distance from motor to jackshaft=104.24

Design HP=0.8*1.2=0.96(where 1.2 is service factor from Gates design manual)

1$^{st}$ stage reduction ratio=2.15

From the above data, selection for standard best suited belt and pulley for transmission system in primary stage are obtained from POWERGRIP® GT®3 drive design manual [11].

Belt=565-5MGT P.L.22.0244-113

No. of teeth's on driving pulley=30

No. of teeth's on driven pulley=64

From the obtained data diameter of pulleys are found from Gates-sprocket specifications manual [11.]

Driving pulley diameter=1.88 in.

Driven pulley diameter=4.010 in.

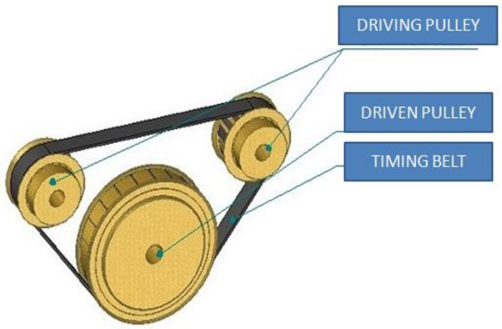


Fig.6: Primary Stage

Secondary stage: This stage is relatively simpler to design and it transmits power from intermediate shaft to the wheel. Intermediate shaft (fig 7) is simple shaft which connect two transmission stages and is supported with bearings. Design of jackshaft is done by material -Mild steel C45 for 142mm length with thickness of 20mm. Components selection for secondary stage is by considering gear reduction ratio to obtain desired speed at wheel rim and center to center distance between wheel rim and intermediate shaft.

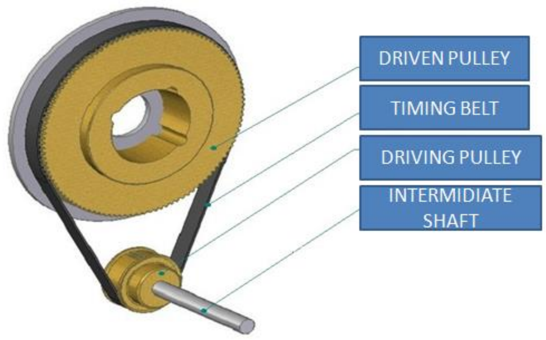


Fig. 7- Secondary Stage

Calculations for determining required belt and pulley to design secondary stage to transmit power from intermediate shaft to wheel rim are done by obtaining required data as,
Center to center distance=158.208
Reduction ratio=3.5
So from POWERGRIP® GT®3 drive design manual obtains best suited belt and pulleys for effective transmission
Belt =700-5MGT.P.L.27.559-140
Teeth on driving pulley=32
Teeth on driven pulley=112
So from Gates-sprocket specification manual we obtain pulley diameters
Driving pulley diameter=2.005 in.
Driven pulley diameter=7.018 in.
Designing of two stage transmission system with the selection of components with the obtained sizes will give desired results for electric drive for one-wheeled bike

## V. CONTROL SYSTEM

Flowchart (fig. 8) shows the proposed design of closed-loop control system for one-wheeled motorcycle to avoid undesired acceleration and balance the one-wheeled motorcycle.

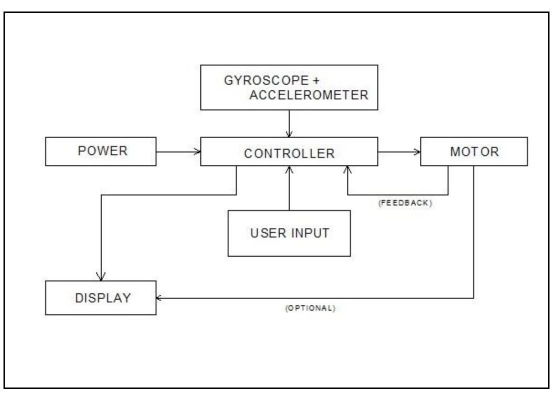


Fig.8- Flowchart for Closed-Loop Control System

## VI. CONCLUSION

Electric drive for one-wheeled motorcycle must be designed and implemented inside the wheel. A closed-loop control system must be designed in such a way that it allows the optimization of component operation to determine the particular required value of torque required with respect to load and absorbs current and control system is also implemented with gyroscope acting as position sensor to send signal to controller to adjust motor speed and balance the one-wheeled motorcycle. Control system reduces the electro-magnetic stress and increases the battery life and reduces maintenance.

## VII. FUTURE WORK

The vehicle can be designed for higher speeds and better control using the closed loop control system. Also the battery can be recharged by implementation of regenerative braking system.

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