Bicycle Assist Using Regenerative Braking

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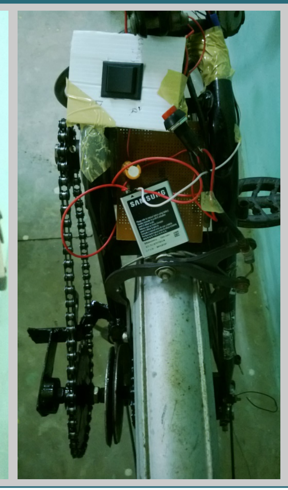
ABSTRACT

This design project is aimed at providing a comfortable and affordable means of transport for workers (who earn their daily wage by doing demanding physical work) and school children who predominantly use a bicycle to travel back home. The design makes amendments on the bicycle using equipment such as a DC motor and batteries that are easily available in the market so as to keep the product cost around 2000 INR. Experiments and theoretical analysis suggest that this design has the potential to assist the cyclist.



INTRODUCTION

MOTIVATION:

- To offer assistance to tired workers and school children.
- To visualize an economical design to assist the rider.
- To minimize the components added onto bicycle without altering its original design.

CONCEPT:

- Kinetic energy of bicycle is stored as electrical energy, instead of being dissipated as thermal energy due to friction braking.
- The energy thus restored is discharged, and used to maintain the bicycle at a uniform speed as and when required.

Existing Products in the Market

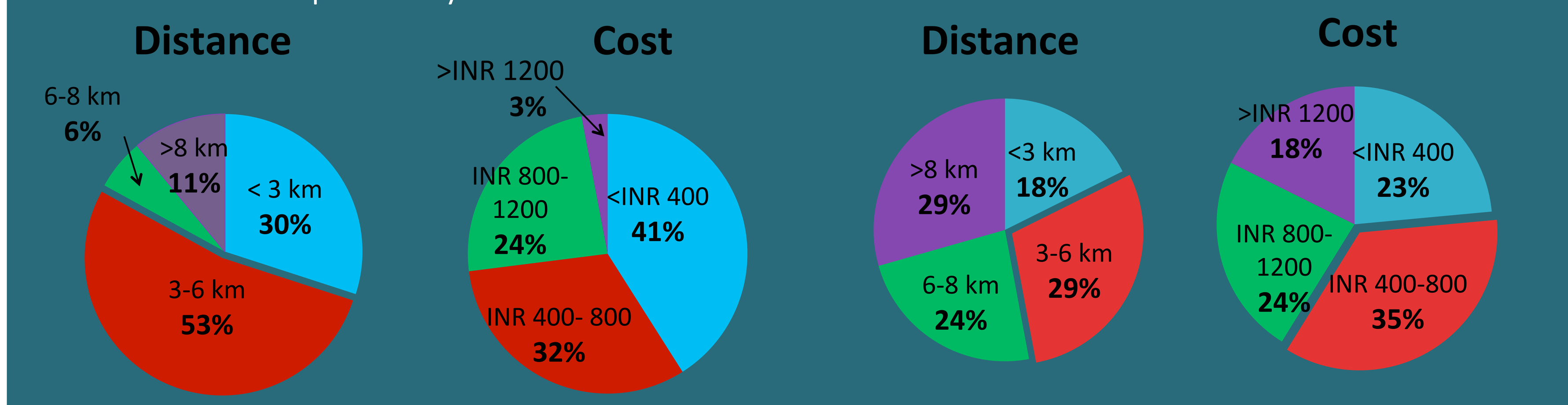
Sanyo hybrid pedal assist ebike

Seattle electric bike

Market Survey: To find customer needs and expectations

Survey subject : Students of IIT Madras, whose main mode of transport is bicycle.

Survey subject : Workers who travel distances carrying goods like stationary etc.

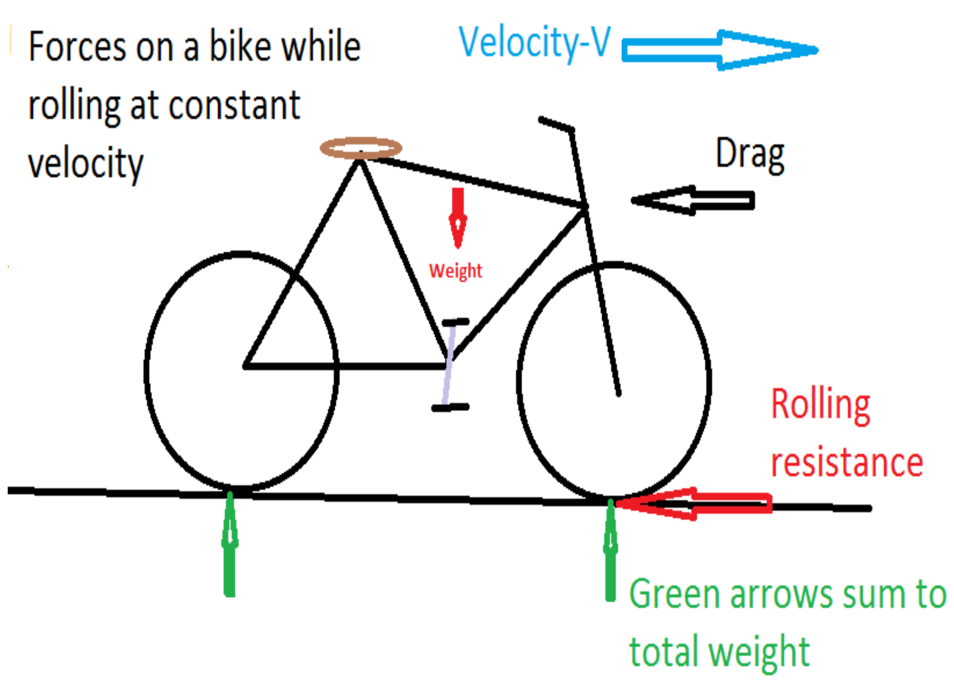


COAST DOWN TEST

- This test is done to evaluate aerodynamic and rolling resistance forces and corresponding losses.
- After reaching a certain speed the bicycle is left to slow down and velocity, time data is recorded.
- Least square approximation method was used on acceleration-velocity data to estimate the forces.

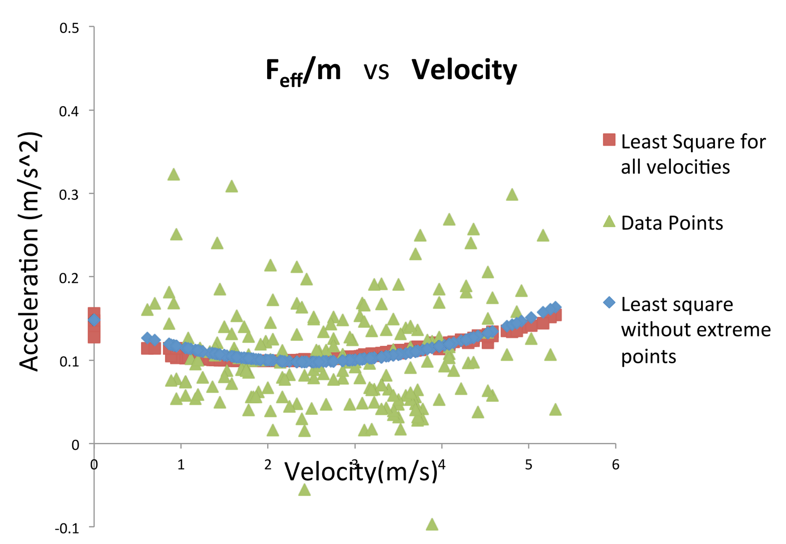
Test Conditions

- Mass of the system 95kg.
- Zero gradient road, Zero wind velocity
- Data recorded from 17 km/hr to 9 km/hr.



Results

- For a human of 80kgs, friction + drag force is given by **$F = 0.779\,v^2 - 3.857\,v + 14.08$**
- 10% of kinetic energy is lost to rolling friction and drag force, during braking.
- Braking torque required is about 0.9 Nm.
- Ideal Axial force required to brake - 80 N ; Considering losses it is 150N.

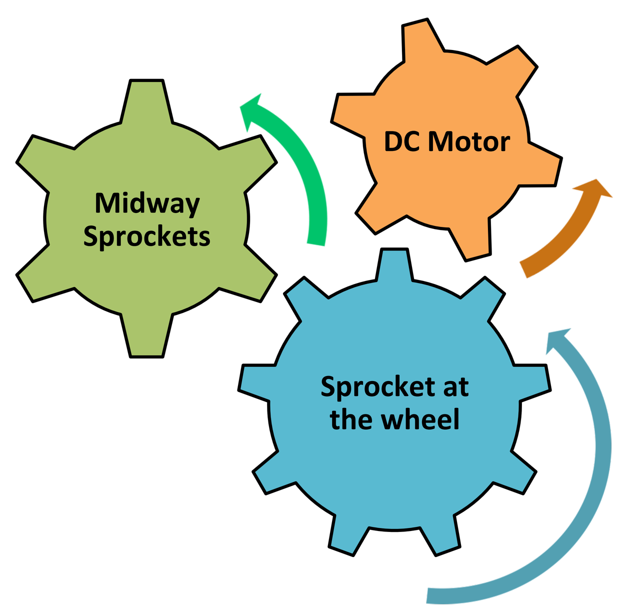


This plot helps understand the variation of the aerodynamic drag and rolling resistance with velocity.

DESIGN

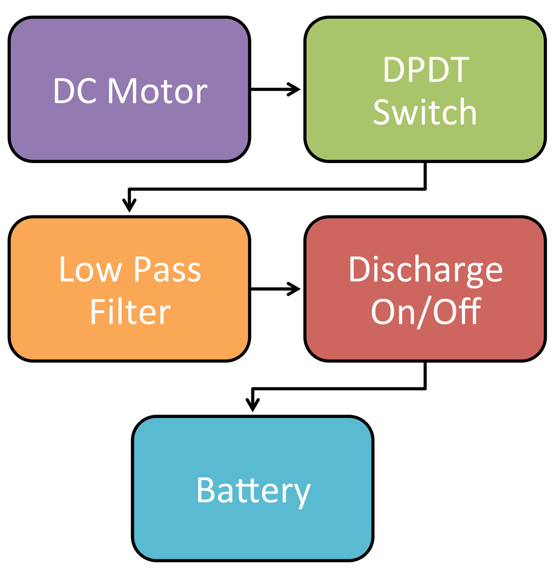
Mechanical Design

Goal: To transmit wheel's motion to DC machine



Electrical Design

Goal: To store the energy generated and use it later

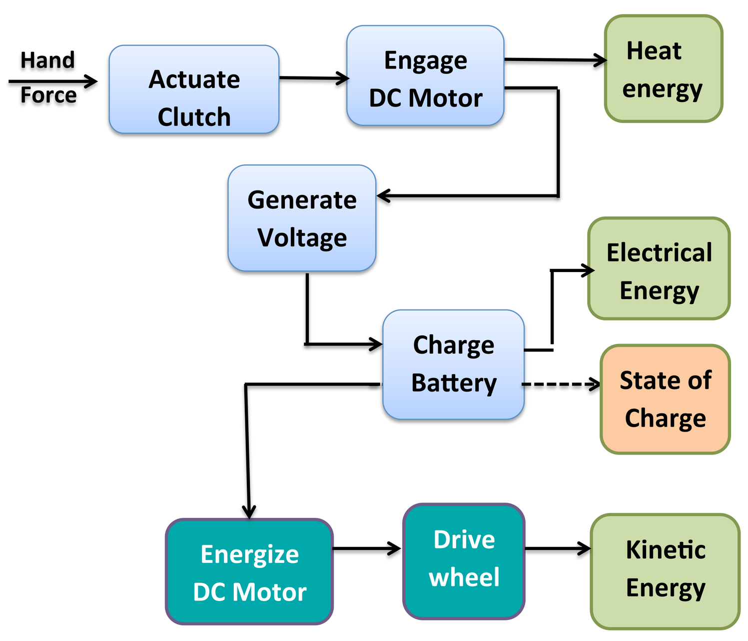


- Braking torque calculated from coast down test results, braking time and deceleration.
- Motor chosen to meet braking torque, no load rpm vs. voltage and cost.
- Sprockets designed to meet motor specifications and braking torque requirement.
- Low pass filter eliminates fluctuations and ensures constant voltage off the DC generator to ensure efficient charging .
- Direct discharge from battery to meet current requirements of the motor.

Specifications:

- 12 V , 25 kg-cm Permanent Magnet DC motor.
- Gear ratio 8:1 between wheel and DC machine.
- Circular friction clutch.
- Low Pass Filter : R = 100 Ω , C = 1000 μF
- Battery Pack : 3.7 V, 1500 mAh NiMH rechargeable batteries
- Discharge current > 0.5A at 3.7V

FUNCTIONAL DECOMPOSITION



FINDINGS

Decelerating from approx **17 km/hr to 9 km/hr in 3 seconds**, the following was observed:

- While regeneration, output voltage: approx 6 V at 20 km/hr & 3.5 V at 10 km/hr.
- Average power extracted : 25 W during braking.
- Energy stored per braking cycle is 75 J.
- Unwanted discharge of battery – below speeds of 10 km/hr.

Assisting the rider in standalone mode

- Average power required for boosting : 50 W.
- One Li ion battery of 3.7V can provide 7.5W, reducing speed to about 3 km/hr.

CHALLENGES

- Integration with the friction brakes both during normal braking and emergencies.
- Regeneration at low speeds: Below a certain speed, when the EMF across generator is lower than that of the battery.
- Minimising the number of electronic components to reduce power losses.
- Low efficiency of motor when used as generator.
- Controlled discharge: controller provides insufficient current and has to be powered. Economically infeasible.
- Batteries dissipate power faster than they accumulate charge to cater to the needs.
- Batteries of higher capacity need larger voltage inputs to undergo charging, this increases the gear ratios and correspondingly increase the required braking torque to be generated by the user.

RESULT

Using current system

- Meets economic requirements
- Needs some additional input from the rider to maintain its speed

To maintain speed at 10 km/hr as a standalone device,

- Higher gear ratio and higher rated batteries raise cost by INR 4000
- With this design, braking once can assist the user for 1.5 s.

This system will provide a power assistance of about 6 W to the rider, in addition to the rider's own input.

REFERENCES

*Regenerative braking on bicycles to power LED safety flashers, Ian Collier, Massachusetts Institute of Technology.
*Fundamentals of Vehicle Dynamics –Thomas D Gillespie.
*Coast Down Test- Theoretical and Experimental Approach, Ion Preda, Dinu Covaciu, Gheorghe Ciolan, Transilvania University of Brasov, Romania.
* Electrical Circuit Theory and Technology, John Bird

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