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Design and Simulation of Self Charging Electric Bicycle

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Abstract: *Now-a-days it can be seen that most of people are focusing on cycling for exercising and short distance traveling due to unhygienic lifestyles and increase in environmental pollution and its harmful effect on human. Looking at such circumstances our paper is proposed to generate electrical energy produced by the person via paddling and later consume the same energy for automatic running of the cycle. The demand for Electric Bikes is growing throughout the world due its characteristics of zero emission effects and longer life cycle. An electric bicycle uses electric motors for the purpose of moving which run on different types of Batteries. These batteries undergoes many charging and recharging cycles in running conditions. Through our paper the required amount of external energy for charging the batteries can be reduced which will also reduce the use of fossil fuels and also will help to reduce the environmental pollution. The theme of paper is comprised in two sections, in first part a paddling mechanism is proposed which will do the energy conversion from mechanical to electrical and in later part the stored electrical energy is converted into mechanical energy to run cycle on charged batteries. A comparative analysis is also proposed for different batteries to find out efficient types in terms of economic aspects such as cost, thermal runaway, etc. in this work an electric generation mechanism by paddling the cycle is proposed for specified amount of time and based on that the generated electricity is calculated to be stored in battery for charging. Further the simulation results using MATLAB/Simulink has been analyzed for the proposed electric bicycle with different types of batteries, to study the various characteristics of the proposed set up with variation of battery parameters and distance covered by the cycle.*

Key Word*: Self charging electric cycle, Simulink, Paddling, lithium ion batteries, lead acid batteries.*

I. Introduction

The Electric Vehicle was firstly built in the early 19th century between 1832 and 1839, by Robert Anderson. He also created the first crude electric carriage. Later in 1895, after that an electric tricycle was built by A.L. Ryker and William Morrison manufactured a six passenger wagon. There was a decline in use and production of the electric vehicle in the 1920s. The major causes of the decline in production were: a better road system, decline in prices of gasoline due to the discovery of the Texas crude oil, electric starter were invented, and the bulk production of the internal combustion engine vehicles. The Electric Vehicle consists of an electric motor and it is powered by rechargeable batteries instead of a gasoline cylinder. There are various type of batteries which can be used for propelling the electric vehicle .But these batteries can also increase the weight of the vehicle. From outside the design of all the vehicles are same weather it is electrical or other vehicles. An Electric bike can also be identified as a silent vehicle that does not make noise and prevents noise pollution. Electric bikes are classified according to the power that their electric motor can deliver and the control system that is when and how the power from the motor is

applied.

Components of the system:
1. DC Motor
2. Batteries
4. Dynamo/Generator
5. Frame

DC Motor: DC motors run on batteries and can be directly connected to the batteries. Motors provide the motive power for the electric vehicles and hybrid cars and other electric vehicle.
Batteries: A battery is used for several purposes in various sectors such as marine, manufacturing and pharmaceutical industries. It is an energy storage device that is used mostly in automobile and energy storage industries. There are various types of batteries available in market such as Lithium-Ion battery, Lead-Acid battery etc.
Dynamo/Generator: The important component in project is dynamo or generator which will be used in energy conversion from mechanical to electrical. A dynamo will convert mechanical energy into electrical energy will be later stored in batteries and will be used later.
Frame: The frame is not a simple support but is carefully designed to distribute the weight equally. Frames are not fully rigid. Rigid frames would result in less comfortable ride. Hence all bike frames flex and bend a little so they absorb some of the shocks of riding, though other factors such as the saddle and tires have much more effect on ride comfort.

Problem definition:
The main theme of the project is conversion of mechanical energy into electrical energy by means of paddling of cycle and storing the energy in suitable energy storage unit and further it will be used for running e-cycle using stored electrical energy for a short distance. This will help in two ways, first for exercise of the person while paddling and second the converted energy which may be lost to environment will be used to charge the battery which will be helpful to run the bicycle for a short distance travelling.

Objectives:
1. Fabrication and FEA analysis of proposed bicycle for optimized weight to manufacture and structural analysis of energy storage system for bicycle.
2. Evaluation of energy conversion mechanism parameters and applied components to get maximum energy to be stored for battery charging through paddling of bicycle.
3. Design of proposed set up using MATLAB / Simulink to simulate the results of battery performance.
4. Comparative analysis of different battery types using the same Simulink circuit for finalizing the effective types of battery to be useful for the proposed work.

Methodology:
1. Selection of Design Parameters
2. Design Calculation using selected parameters and assumptions
3. Conceptualized CAD Model
4. FEA analysis of approximately 150kg load
5. Conversion and storage of mechanical energy into electric energy mechanism
6. Modelling of Electric bicycle in Matlab / Simulink.
7. Battery Comparison using various results obtained by simulation

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II. Literature Survey

We did the literature review referring to various literatures and research papers.We came to know that many work has been done taking hybrid bicycle into consideration. Hybrid bicycles includes use of solar energy, wind energy, use of batteries etc.
In batteries different types of batteries are available such as Lithium Ion battery, Lead Acid battery, Nickel Cadmium Battery, Nickel Hydride battery etc. And also we reviewed the literature on various energy storage devices such as capacitors. Vehicle manufactured before 2010 had used Lead Acid, Nickel Cadmium and Nickel Hydride batteries mostly but after 2010 Lithium Ion batteries have replaced Nickel Cadmium and Nickel Hydride batteries. Lithium Ion battery provides higher energy and power densities and better energy efficiencies than earlier batteries system

Table 1: Characteristics table of some energy storage devices

Type Of Battery	**Energy Effeciency (%)**	**Power Density (W/kg)**	**Energy Density (Wh/kg)**	**Life Cycle (Cycles)**	**Rate of Discharge**
Li-ion battery	70-85	360	100-200	500 to 2000	Medium
Ni-MH battery	50-80	220	60-80	<3000	High
Ni-Cd battery	60-90	14-180	40-60	500 to 2000	Low
Li-polymer battery	70	250-1000	200	>1200	Medium
Lead-Acid battery	70-80	25	20-35	200-2000	Low
Flywheel (composite)	95	5000	>50	>20000	Very High
Flywheel (Steel)	95	1000	5-30	>20000	Very High

The above Table 1 shows characteristics of different energy storage devices which includes Lead acid, lithium ion, Ni-Cd, Ni-MH, Li-polymer, Flywheel (steel and composite). From table comparison , we can see that Lithium Ion in most efficient storage device with high Energy Density among others with efficiency of 70%-85% and energy density up to 200Wh/kg followed by Lead Acid battery with efficiency of 70%.-80%. Also both the batteries have medium self-discharge rate. Lithium ion battery is also light weight which is more preferable for our paper

III. Design and Analysis:

Design Calculations for Energy recovery mechanism:
Assuming Total weight = 150kg
Diameter of wheel =0.622 m, radius = 0.311m
Expected speed = 25Km/hr.
Rolling friction = 0.01 and Coefficient of drag= 0.88
Bicycle Length = 6 ft. = 1.82m
Bicycle width = 2 ft. = 0.60 m
Area = length × width = 1.82 × 0.60 = 1.1132 mm^2
Speed = 25 Km/hr. approximately paddling of 2 hours.
Velocity = 25000/3600 =6.94 m/s
Total Power conserved
= [total mass × acceleration due to gravity× velocity× rolling friction] + [air density× coefficient of drag× area× $velocity^3$]
= [150×9.8× 6.94× 0.01] + [0.6465× 0.88× 1.113× 6.94^3]

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= 102.018 + 211.66 =313.678 W.

CAD model of proposed system

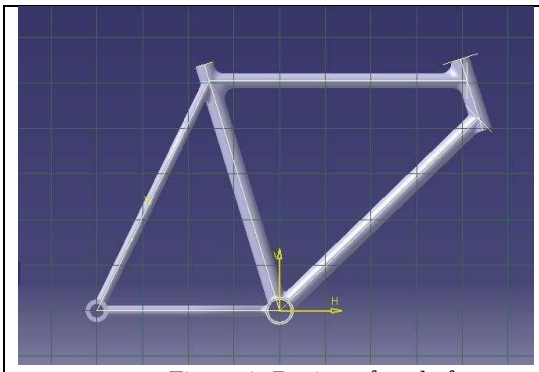

Figure 1: Design of cycle frame

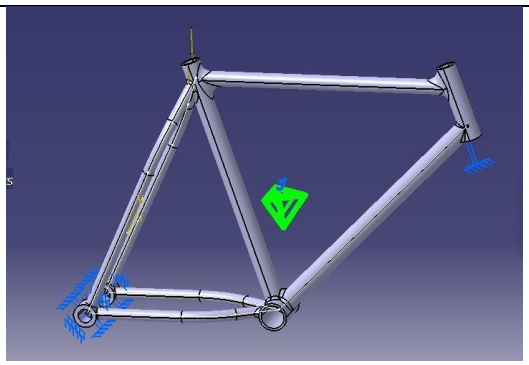

Figure 2: Force Analysis of cycle frame

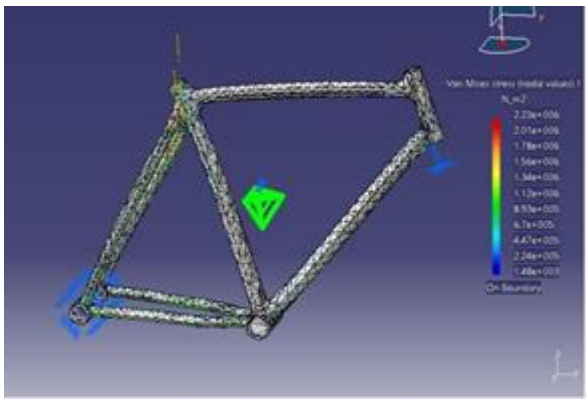

Figure3: Stress Analysis of cycle frame

IV. Experimental Analysis

Table 2: List of parameters for Simulation and circuit design in MATLAB / Simulink

Battery Parameters	Nominal voltage	48 V
	Rated capacity	100 ah
	Initial stage of charge	100%
Vehicle parameters	Mass	100kg
	No of wheels per axle	2
	Horizontal Distance from CG to front axle	0.7m
	Horizontal Distance from CG to rear axle	0.7m
	CG height above ground	0.5m
	Gravitational Acceleration	9.81m/s^2
	Drag coefficient	2
	Air Density	1.18 kg/m^3

Gear, differential and motor parameters	Carrier to drive shaft teeth ratio	4
	Follower to base teeth ratio	2
	Inductance	$12e^{-6}$ H
	No Load speed	2000 rpm
	Rated speed	1800 rpm
	Rated Load	5 kW
	Rated DC supply	50 V

Simulink Model for bicycle:

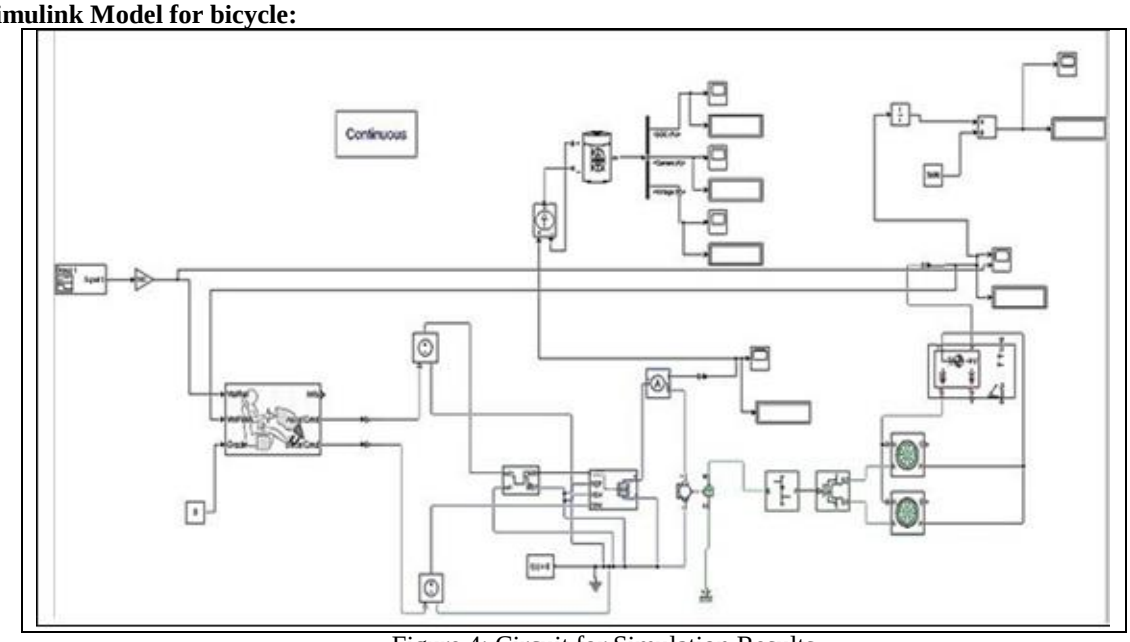

Figure 4: Circuit for Simulation Results

Table No 3: Comparative analysis for different battery parameters for 1000 seconds

Types of Battery	SOC in %	Current in A	Voltage in V	Velocity in Km/hr	Distance in Km
Li-ion	59.97	-5.679	51.91	3.063	20.11
Lead acid	61.57	-5.687	50.57	3.068	20.11
Nickel Cadmium	64.78	-5.679	51.39	3.063	20.11
Nickel metal hydride	62.83	5.679	52.08	3.063	20.11

Table No. 4 Graphical Results for Lithium Ion Battery

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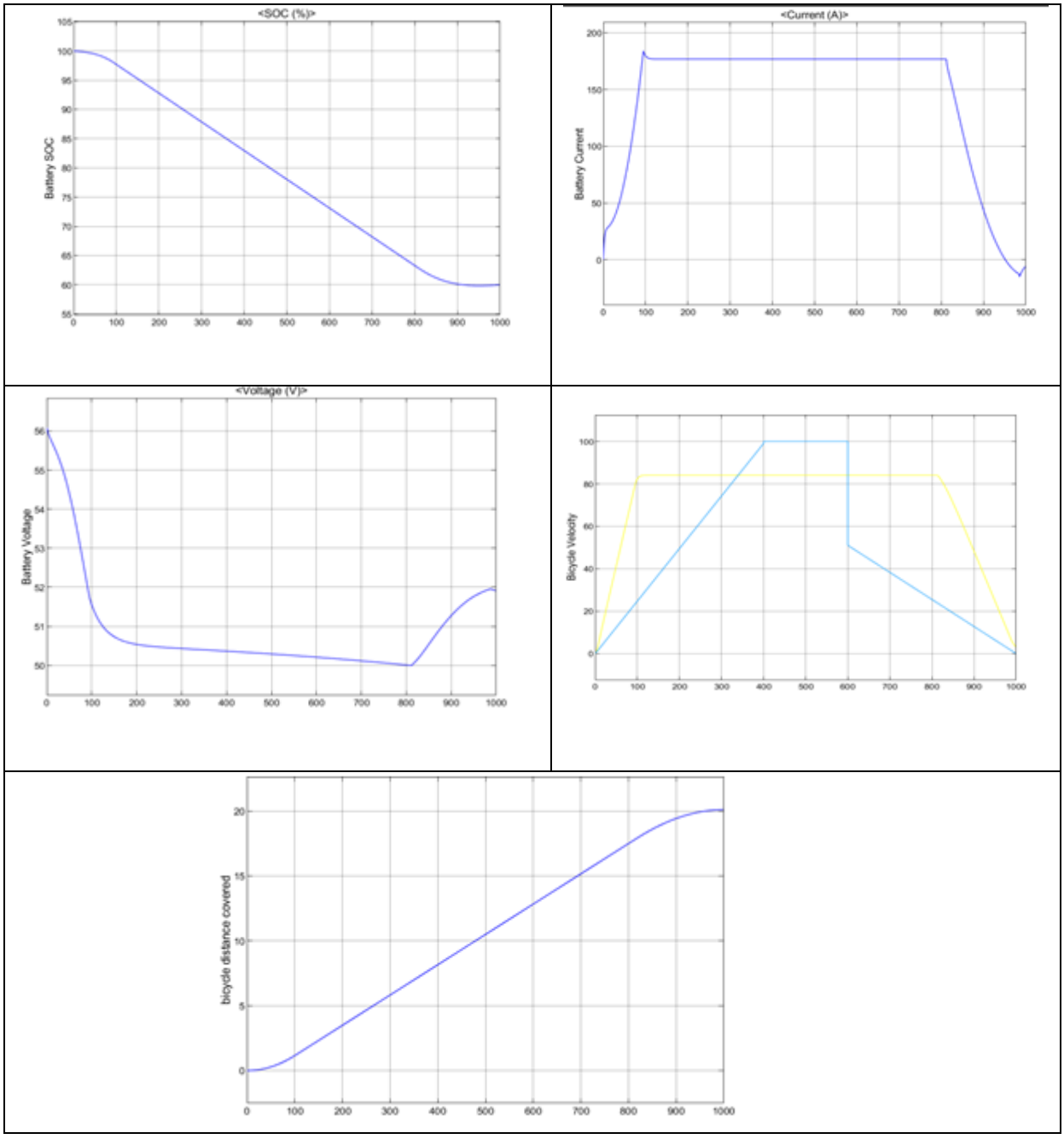

V. Conclusion and Future Scope

Conclusions:

- The Design calculations and Analysis results of Bicycle Frame for 150Kg load was verified with catiav5 software and found to be satisfactory within limit for load effects and stresses incurred.
- The calculation for energy recovery mechanism for the proposed set found that approximately = 313.678 W of energy can be recovered by paddling for approximately 2 hours.

- The Simulink analysis shows different graphical results such as State of Charge (SOC), Voltage, Current, Velocity, and Displacement using Lithium-Ion Battery as an energy sources for running the bicycle which indicates approximately 59.97 state of charge of battery which was initially charged 100 %, velocity of bicycle for 1000 seconds is 3.063 km/hr. and distance covered is 20.11 km which is near to the target value of the proposed project.
- Comparative analysis of lithium ion battery with other batteries shows that approximately same velocity and distance achieved with slight difference in state of charge. But if we go to the charging and discharging cycle and other efficient parameters of those batteries, lithium-ion finds the best suited solution for e-mobility.

Future Scope:

- Further work can be done for different types of batteries and hybridization of different energy storage systems. i.e. hybrid energy storage systems of IC engine and battery, HESS of LPG and Battery, HESS of battery and supercapaciter, HESS of battery with solar panel, and many more to get efficient solution to meet energy and power density requirements.
- The work can be implemented for other types of light vehicles of two wheeler or three wheeler as well as for heavy transport vehicle and four wheelers for further getting effective solution for e-mobility and towards reducing the dependency on petroleum fuels and its harmful effects on human beings.

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