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Modification of Existing Regenerative Braking System for Electric Vehicle

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Abstract: ***Zero emissions producing and propel the vehicle wheels with own battery energy possible only by Electric vehicles. Energy conversion progression completes with little amount of heat lost only. These advantages influences internationally made the electrical vehicle as the new generation transport for the automobile engineering. Electric vehicles incorporated with regenerative braking system. However, electrical automobile on a solitary charge assortment meaningfully less than the motorized automobile. By this system, reuse energy about on fifth of the energy generally lost through put on the brakes. Lack of a serious impact on the development and popularization of electric vehicle, to overcome this hurdle by involving principle of energy regaining method in design of electric mobility operative manner. The mechanism of electric motor's braking method encompassing converts parts of kinetic dynamisms of automobile as electric power while braking. This electric power passes to the battery for further battery charges and electric mobility mileage increases compared to conventional engines. When driving in decelerating the inertia of the vehicle wheels through the transmission of energy to pass through to the motor, to control electrical engineering with the generating electricity a way work refreshes for power battery and achieve the regeneration of braking energy. The power developed in the course of the motor braking torque remain used over transmission of the steering wheel brake, consequential in braking power. The innovative regenerative braking with kinetic energy regenerative system (KERS) saved more energy than normal regenerative braking. The life of the KERS more than the steering wheel brake system. The KERS and normal regenerative pressure is 11.94% and 4.95% respectively, Hence, KERS system more efficient than normal regenerative system.***

Index Terms: ***KERS, braking system, regenerative system, electric power vehicles. and kinetic energy regenerative system.***

I. INTRODUCTION

The automobile researchers have developed brake system by including the advanced technologies. The primary motto of vehicle safety and comfortable. From the 18th century, ending onwards brake system developing starts and endures present day. [1] Different types of braking systems used to different automobiles over the centuries embrace. As the past of brakes evolved, every innovative system was manufactured by means of the impressions rummage sale to project its prototype. It does not take a rocket scientist to know that it takes a lot of energy to get a vehicle gather momentum. However, what happens to all that energy when you step on the brake? Well, for most conventional vehicles, the majority of the kinetic energy converted during friction breaking, between the brake pads and wheels, into the form of heat. Heat in essence gets emitted unused into the environment as waste, but not if you're driving a hybrid or electrical vehicle, which can use the electric motor to recuperate at least a portion of the kinetic energy for reuse. All that kinetic energy that would have been lost otherwise, can partially be put right back into the battery using regenerative braking system. The process of recovery of kinetic energy during breaking and its storage called regenerative braking. While decelerating and breaking, the vehicles motion drives the electric motor, which switches itself to a generator mode. [2] The wheels transfer the kinetic energy via the drive train to the generator. Through its rotation, the generator converts a portion of the kinetic energy into electrical energy. The electricity generated is stored in a high voltage battery. The generative braking torque of the electric motor, which is the result of energy generation, decelerates the vehicle. The power transmission system directs the energy normally dissipated in the brakes to the energy stored during deceleration. The same converted back into kinetic energy to accelerate the vehicle.

For a given energy input to a vehicle, regenerative braking engenders an increase in energy output, work done by the vehicle engine is reduced, sequentially reducing the amount of prime energy required to propel the vehicle, bringing about an overall improvement in efficiency. For the system to be cost effective the prime energy saved over the period of efficacy must countervail the initial cost, size and weight penalties of the system. The auxiliary energy transfer or energy conversion equipment along with the energy storage unit must be compact, durable and capable of handling high power levels efficiently, and of reasonable cost. High capacity per unit weight and volume energy storage, efficient energy conversion, effortless delivery of power, proportionate absorption and storage of braking energy with minimal delay and loss over, comprehensive wheel torques and road speeds, high power rating, unadorned control systems linked with the vehicle transmission are some of the salient features of a regenerative braking system. [3]

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Depending on how much energy the driver wants to save, regenerative braking can be set in different modes and standards, dependent upon the intervals, intensity and duration of the brakes being applied. At low speeds, shortly before the vehicle comes to a halt, the electric motor can no longer supply sufficient generative braking torque and the friction brake activated. To maintain the required deceleration the breaking torque from the friction brake is continuously adapted to the current generative breaking torque, a process called torque blending. Unstable driving conditions or when applying full braking, the vehicle is usually decelerated slowly via the friction brake as wheel specific interventions are required. Regenerative braking enables an extended range in electric vehicles as well as lowering fuel consumptions and improving CO2 vehicles in hybrid vehicles. There have been many changes in the automotive industries towards future technology and safety. One of the introduction to the industry was brake-by-wire system where traditionally the function of braking was performed mechanically will be done electronically. First, introduce electric and hybrid cars to this type of braking system.[4] Currently automotive engineers all around the globe have come up with different design circuits to handle the complication of regenerative braking system. The most important part of the braking circuitry is the braking controller which are electronic devices that has the capability to remotely control the brakes, like when to start or stop braking and how rapidly the brakes needs to be applied. In case of towing situation brake controllers plays a main role in coordinating the brakes of a trailer with the brakes on the vehicle performing the towing.

In vehicles using regenerative braking system, the brake controllers along with monitoring the speed of the wheel can also calculate amount of torque and rotational force produced to generate electricity to be fed back to the batteries. In braking operation the brake controllers directs the motor produced electricity back to the batteries and capacitor. It uses optimal amount of power by the batteries but also takes care the inflow of electricity is not more than the battery can take.] The brake controller function is to know whether the motor is capable of handling the force required for stopping the car, if not the work is taken over by friction brakes averting maximum catastrophe. In vehicle's that uses regenerative braking system, the brake controller is responsible for the entire braking process.

Regenerative braking system is an important and eventual step taken for the future electric and hybrid vehicles. This type of braking system allows batteries used for longer time without the need to plugged into external charger. This system helps in increasing the range of fully electric vehicles. In fact this technology has already been executed in Tesla Roadster which is full electric car powered by a battery source. If the source of electricity comes from fossil fuels and when the vehicles are out on the road they capability to operate without the use of fossil fuels, which is a big step forward. [4 -6] The future in Electric vehicles has raised people interest in both industries and academics. EVs have the capability of converting the kinetic energy to electrical energy and this system used to be known as regenerative braking system. To get the maximum energy recovery from this system the brake controllers accordingly designed. Many vehicle state parameters like velocity, mass moment of inertia, and sideslip angle and so on cannot easily obtained. The estimation method is need to be designed considering the use of different high precision sensors. Researchers have proposed two different methods for estimation categorized as kinematics-based method and model based method. [7] The increasingly environmental pollution and high demand of fossil fuel, electric vehicles are going to responsible for the future transportation industry. Electric vehicles will ease the problem of environmental pollution and energy consumption. Technology like power management strategy is the key to improve EVs performance. Regenerative braking which is the part of energy conversion process coverts the potential and kinetic energy of braking vehicle into electric energy using generator and store it in batteries. Three braking strategies proposed for the vehicles are namely optimal parallel sensory, optimal series sensory and optimal recovery energy braking strategy. [2 and 8]

Most of the locomotives have the ability to combine pneumatic braking to electrical braking system. Using this system, the kinetic energy of the train directly converted into electrical energy. One of the simplest way achieved by dissipating the energy developed directly to resistor placed on train. Another method is energy recovery method in which electrical energy sent to contact lines, which can be used by other trains during traction or can be stored in a battery located on board of a train. [3 and 9]

In recent years due to increase in carbon emission from vehicles it has now become a major environmental concern. European automobile manufacturer association and European council together has made an agreement to reduce CO2 emission from road vehicles. One method to reduce energy consumption and emission from vehicles is by introducing regenerative braking system. Using this system we can reuse the produced energy by capturing it. During braking by the use of friction brakes the energy is been wasted. A generator can be used for absorbing vehicle kinetic energy by generating electric energy by storing it in batteries for later use. [4 and 10]

CO2 emission is reduced in electric vehicles and they also impact the driving task. Electric vehicles have limited rage which affects the trip and choice of vehicle. Battery based electric vehicle have capability of recapturing the energy during deceleration using regenerative braking system (RBS). It is implemented in the brake pedal, acceleration pedal or sometimes even both. This paper explains depending upon the type of system the driver needs to adapt to the deceleration behaviour using RBS. [5 and 11]

With the increasing fuel prices spending on transportation has become a major economic budget. To decrease capital spent on fuel this can be achieved by the use of hybrid electric vehicles. Installation of regenerative braking system and high power battery packs can improve the driving range in electric vehicles. Maximum electrical energy can be extracted from mechanical energy. However,

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RBS process has to address two major issues: applying brakes which restraints the vehicles speed, maximum recovery of braking energy to increase the efficiency of the battery. [6 and12]

II. Regenerative Braking System

The pure electrical automobiles is fundamentally functioned with regenerative braking system. Electrically operated motor necessary for this system. Here motor acts as a generator and a battery charger while applying brakes. The frictional heat energy converted into useful energy on braking. It produced electricity when this motor "performance in opposite".Generally friction involved in braking system the automobile moves with low speed.

III. NEED OF REGENERATIVE SYSTEM FOR BRAKING

Brakes convert mechanical into thermal energy only when applied otherwise they do nothing. Driving on a highway at constant speed, they waste no energy at all. Driving in a city, they convert kinetic into thermal energy at each traffic light. Taking the foot off the gas pedal farther away from the traffic lights, if possible, helps reducing the waste of energy. The mechanical brakes replaced by electric motors to slow down the cars, the kinetic energy would be converted into electrical, is tead of thermal energy, and stored in batteries or capacitors, and could be used to accelerate the car after the light turned green again - that is what hybrid cars do [13]. Mostly braking system in automobiles convert whirl motion into heat energy while pushing the brakes towards inside. Else, brake system sort out nonentity. Automobile moves at higher cruising speeds on main road, all the energy utilizing no wastage of energy. Metropolitan city driving conditions are different form high ways maximum energy is wasting due to frequently stops and starts vehicle due to traffic and signal lights. Now the time to introducing the new technique of regenerative braking system and replace the conventional braking system. In this system the motors converts heat energy in to electrical energy and charges the batteries and capacitors available in the automobiles. In addition, might be recycled to speed up the automobile subsequently the light signal changes to green again – same principle keep an eye on in hybrid automobiles also. [13]. The conventional brakes have low complexity and cheap when compared to regenerative braking system.Regenerative braking system works all the way of vehicle propels. Depress the brake plate on a hybrid vehicle or electric mobility, these brakes change the vehicle's electric motor into opposite which creates it track recessive, in order decelerating the automobile steering wheel.

Hence, on the trot retrograde, the mechanical device like motor performances as an electric device like originator by creating current power that's transported into the hybrid electric vehicle batteries [14]. All automobiles equipped with steering system with all the wheels while turning in confined space follow the four wheel steering and careless for parallel lane parking and guiding the automobile reasonably through not at all misfortune taking place main and public road [15].

At higher cruising speeds, this regenerative braking system gives results that are more fruitful. It effectively works on metropolitan cities because more traffic and signals due to this the automobile moves in press- and-depress manner.

Electric automobiles and hybrid vehicles maintains friction brakes. These friction brakes acts as standby system where proper power not supplied by the regenerative braking system [16]. These situations overcome by giving training to automobile drivers to avoid dread situations. That means furthermore pressure applied on the brakes.

IV. Kinetic Energy Recovery System (KERS)

High cruising speed automobiles equipped with kinetic energy recovery systems (KERS) are systems. Automobile decelerates at that movement these kinetic energy recovery systems comes to the picture and converts the power of motion into electrical power. This power recharges the batteries - capacitors provided in the automobile. Trained cab drivers press the button available on the dash - board clearing the battery to motion of the energy shaft and philanthropically their automobile a improvement of electrical energy power. [Ref 8]

Three main parts of kinetic energy recovery systems

A Motor/Generator Unit (MGU): Mechanical power to Current power and vice versa.

Power Control Unit (PCU): Regulatory device between battery-operated unit and Motor/Generator Unit

Storage stratagem: Chargeable battery, High capacity capacitor and flywheel.

Automobile in deceleration phase - to store the kinetic power "charge cycle" used in kinetic energy recovery systems.

The "boost cycle"— used driver pushes the KERS button on dash - board in kinetic energy recovery systems.

V. METHODOLOGY

Experimental set-up:

Case 1(Regenerative braking without Kinetic Energy Regenerative System)

A) Parts Used / Apparatus

1. Power Supply – 220V, 2. Transformer – Stepdown (220V to 12V), 3. Rectifier (AC to DC) Voltage/RPM Regulator, 4. Switches, 5. Motor (300 RPM), 6. Pulley and Belt, 7. Bearings and Shaft, 8. Tires and Wheels, 9. Generator Indicating Bulb, 10. Battery (8V), 11. Voltage Controller, 12. USB Cable and 13. Tin Wires.

B) Mechanism of Regenerative braking without Kinetic Energy Regenerative System

The circuit starts when current of 220V flows from source (in our case source is normal power supply) to the Transformer. A two pin socket is provided for easy and safe connections. Then the current flows to Transformer (Stepdown) which helps to lower down the voltage of current to 12V. This is done to ensure the safe working of model as the parts are designed to work on low voltages.

After the voltage is changes to desire, the current moves onto a Full Wave Rectifier which converts AC current to DC current (our other parts work on Direct Current)
A voltage regulator is fitted between Rectifier and Switches. Function of a voltage regulator is to fluctuate voltage due to which RPM is controlled. A rotating switch has been provided on the regulator chip, which is rotated clockwise or anticlockwise to maintain RPM.
Two switches have been provided from voltage regulator:

a) First is attached directly from rectifier which rotates the motor in Clockwise Direction.
b) Second one is attached by reverse connection (polarity) from voltage regulator chip, this helps the motor to moves Counter clockwise direction.

Wires from voltage regulator is directly connected to motor (which can rotate between 50-300 RPM). The other end is connected to a pulley and a belt. Material of belt – Rubber.

The motion provided to Pulley is transferred to shaft with the help of a belt without any motion loss. Shaft is fixed on two wooden bars fitted vertically to the base, and fixed with the help of bearings which helps the shaft to rotate in both the directions. On the shaft a main wheel is attached and in parallel to the wheel a small wheel (Gear). The second wheel will rotate with a same speed as of a shaft.A braking system which consists of wooden pedal hinged to the supports in fixed onto the base. Is works same as normal brake of a four wheeler is functioned.

One end of the wooden panel attached with a Generator. On Generator a small wheel (Gear having 4:1 ratio to the previous gear) attached. When we press the Pedal the small gear comes in contact with the main moving gear, due to design of small gear it starts to rotate in reverse direction with a RPM of about 4:1 ratio of main RPM. This reverse motion of small gear rotates the generator in opposite direction from which generator generates reverse current (Generator converts Mechanical Energy into Electrical Energy). The generated reversed current then transferred to a Rectifier. This rectifier changes the polarity of current to normal, which then transferred to a switch.

The two ends of the switch connected to Indicating Bulb and other side to Battery. The opening and Closing of the switches decides whether the current will flow either to bulbs or to battery. When the switch closed the current flows on to indicating bulb that glows when current flows through them. And when the switch is opened the current flows to battery thus charging the battery.

A set of wires are also connected to the Polarity rectifier which is used to measure the voltage or current which is flowing in the circuit.This whole parts and wires are fitted or fixed onto a wooden board so that safety is maintained. All connections are made from Tin Wire and has been soldered for better and long lasting connections.

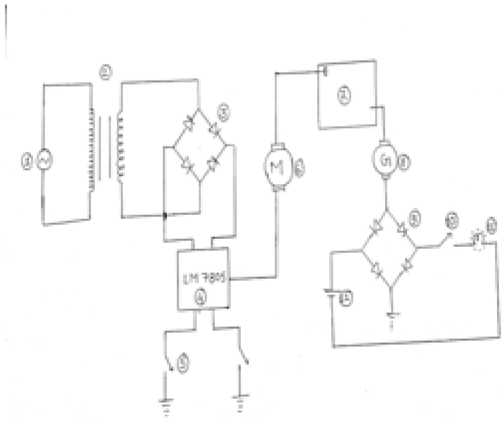

Fig 1: Circuit diagram of regenerative braking system

Vehicle can be operated in two phases according to the requirement a) Four wheel steering: Steering wheel is used to turn both front and rear wheels b) Two wheel steering: Steering wheel is used to turn only the front wheels

Case 2- Regenerative braking with Kinetic Energy

Regenerative System

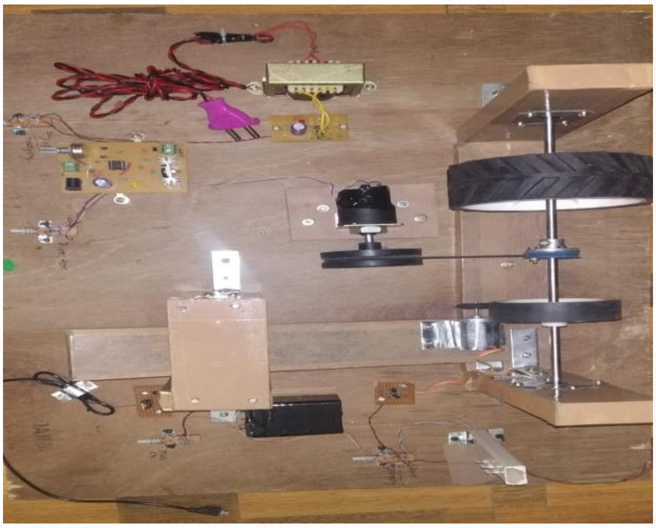

Fig 2: Experimental lab setup

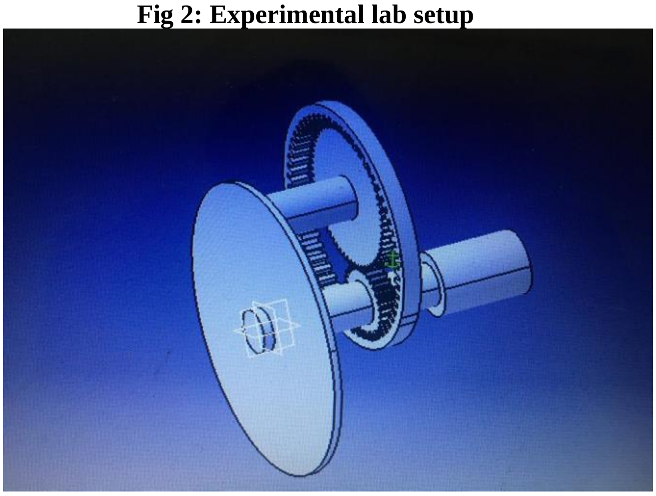

Fig 3: Braking gear setup

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Mechanism of Regenerative braking Kinetic Energy Regenerative System

Two gears namely, gear 1 and gear 2 are meshed. Gear 2 is then meshed with a ring gear. Reaction member is connected to gear 2 via a shaft.

When ac motor is rotated with the help of battery , gear1 rotates. As ring gear is kept stationary at that time, gear 2 rotates about its axis and revolves around gear 1. This motion leads to rotation of reaction member.

Now when brake is applied, reaction member comes to rest. This makes the ring gear rotate about its axis and gear 2 stops revolving about gear 1. When this happens an opposite force is applied to ac motor which induces an emf.

While the motion by ring gear produced kinetic energy which is converted to electrical energy by a generator and stored in battery.

Gear 1 is taken smaller than gear 2 and so teeth in gear 2 are more than that of gear 1. As we know that induced emf = blv where 'b' is flux density, 'l' is number of loops and 'v' is velocity.

It implies that ring gear due to its much higher speed and greater flux density will produce greater emf. This is how by kinetic energy recovery; regenerative braking is applied.

VI. CALCULATIONS

Case 1(Regenerative braking without Kinetic Energy Regenerative System)

Power supply = 12V

Table 1: Power supply with load

Voltage (V)	RPM (No Load)	Stall torque (Kg/cm)	Stall Curren
2	40.9	1.56	1.2
4	96.8	4.29	2.5
6	157.8	7.8	4.5
8	198.5	10.53	5.9
10	269.8	12.09	7.0
12	325.3	22.62	8.4

This power supply will provide rpm of 300 when load is connected to it.

Stall Current at 12V will be 8.4A according to table 1.

Power = V*I = 12*8.4

Power = 100.8W.

energy consumed in 1 hour = P*Time

- ⇨ Energy consumed = 100.8*3600
- ⇨ E.C. = 3,62,880 Whr

VII. GEAR MECHANISM

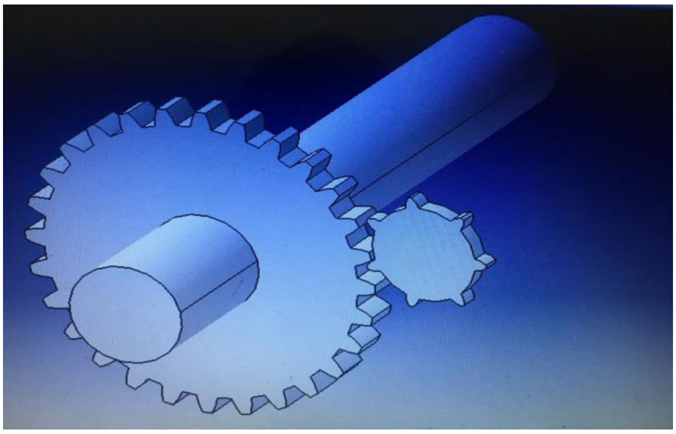

Fig 4: Braking gear Mechanism setup

The first gear which is directly connected to axle shaft and runs at input rpm. SO, gear 1 has diameter of 8.5cm, mass of 30 grams and 28 teeth. When braking pedal is pressed, gear2 meshes with gear 1 to stop the wheel from rotating. Gear 2 with diameter of 3cm and mass 10 grams, has 7 teeth.
Kinetic energy in gear 1 = 1/2[Iw^2]

Where I = moment of inertia

w = angular velocity.

I= 1\2[m1r1^2]

- ⇨ I = ½*30*(4.25)^2
- ⇨ I = 270.94g cm^2.

w1 = v1/r1 = {(2pie*r1*N1)/60}*1/r1

- ⇨ w1 = {(2*3.14*4.25*300)/60}*1/4.25
- ⇨ w1 = 31.4/sec

KE1 = ½*(270.94)*(31.4)^2

- ⇨ KE1 = 1,33,568 g cm^2/sec^2

Law of gears,

T1/T2=N2/N1

28/7=N2/300

- ⇨ N2= 1200 rpm.

This lead to Induced kinetic energy KE2.

KE2 = 1/2[Iw^2]

Where I = moment of inertia

w = angular velocity.

I= 1\2[m2r2^2]

- ⇨ I = ½*10*(1.5)^2
- ⇨ I =11.25g cm^2.

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w2 = v2/r2 = {(2pie*r2*N2)/60}*1/r2

- ⇨ w1 = {(2*3.14*1.5*1200)/60}*1/1.5
- ⇨ w1 = 125.6/sec

KE2 = ½*(11.25) *(125.6)^2

- ⇨ KE2 = 88736.4 g cm^2/sec^2

So, if in a journey of 1 hour in traffic, brakes are applied 50 times and braking action lasts for 5 secondsSo total energy consumed is 3350*1,33,568 = 44,74,52,800 J

Total energy regenerated is 250*88736.4 = 2,21,84,100 J

Efficiency = (Total saved electrical energy/Total consumed electrical energy)*100

- ⇨ (2,21,84,100 /44,74,52,800)*100
- ⇨ **4.95%**

Case 2 (Regenerative braking with Kinetic Energy Regenerative System)

Sun gear (G1) is connected to motor and so rotates at motor rpm. It is denoted by purple colour in the figure. G1 has 90 teeth and has a mean diameter of 30cm. It rotates at 1500 rpm. A planetary gear is in mesh with sun gear. It is denoted by blue colour in the figure. Planetary gear carries reaction member along with it. It has 30 teeth and a mean diameter of 10cm.

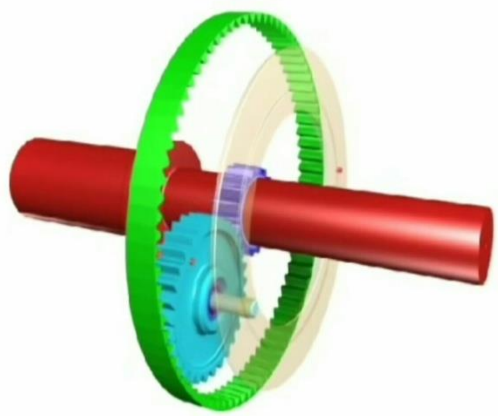

Fig 5: Sun gear and motor mechanism setup

Law of gear ratios, N1/N2= T2/T1

1500/N2= 30/90

N2= 4500rpm

The planetary gear is connected to ring gear. It has 150 teeth and mean diameter of 50cm. It is denoted by green colour in the figure. This ring gear is kept stationary by friction pad which locks the gear at the time vehicle is in motion. At this time, planetary gear revolves around sun gear thus rotating reaction carrier. When brakes are applied, reaction member gets stationary due to hydraulic braking and planetary gear starts to rotate about its own studs. Ring gear which is released by friction pad thus starts to rotate in direction opposite to sun gear at N3 rpm.

N2/N3= T3/T2

4500/N3= 150/30

N3= 900rpm

This opposite rpm of ring gear induces an emf in the coil of ac motor and thus recharges the battery.

Battery:

Nominal Voltage = 8V

So, Power = V*I = 12*8.4

Power = 100.8W.

So, energy consumed in 1 hour = P*Time

- ⇨ Energy consumed = 100.8*3600
- ⇨ E.C. = 3,62,880 Whr

Energy consumed for rotation at 1500rpm = ½*Iw^2

- ⇨ I= mr^2
- ⇨ I= 2.5*(.15)^2= 0.05635
- ⇨ w1= 2 pie N1/ 60
- ⇨ w= 2*3.14*1500/60= 157

energy = 693.25 J

Energy regenerated while braking at 900 rpm= ½*I'(w')^2

=> I= m'(r')^2

=> I= 4*(.25)^2= .25

=> w3= 2*3.14*900/60=94.2

energy = 1109.20J.

If vehicle runs for an hour in which brakes are applied 50 times say for 5 sec each.

So time for which energy is consumed is 33350sec.

So total energy consumed is 3350*693.25= 23,22,387.5J

Total energy regenerated is 250*1109.20= 2,77,300J

Efficiency:

=> (Total energy regenerated / total energy consumed)* 100

=> (2,77,300/ 23,22,387.5)* 100

=> 11.94%

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Design

The design of 3D model is done using CATIA V5 software with proper dimensions. All the linkages of the system are shown using line diagrams.

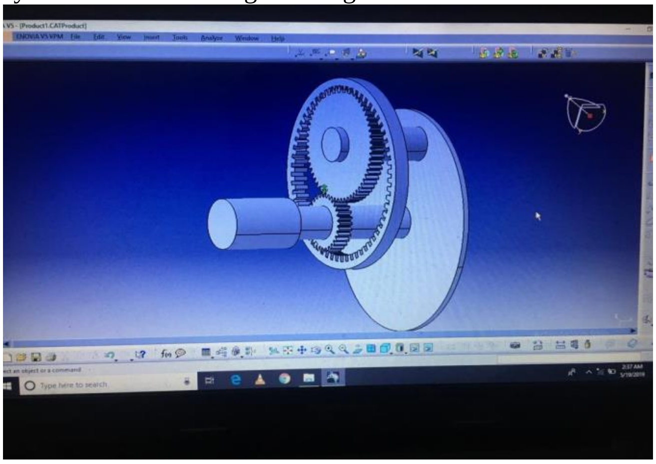

Fig 6: Braking gear mechanism CAD model

CAD parametric modelling is widely consider by engineers for representation of variety of design. CAD modelling can create 3D representation of complex design with the flexibility of instant modification of design considering cost factor as low as possible. In the case of geometric modelling it provides a virtual environment which is similar to real in which the physical structure/ model is constructed or designed and manipulated accordingly.

In the process of creating a shape using engineering models include ads, deforming and editing parts. The virtual model and physical model that looks same but virtual design is intangible. However, virtual 3D model represented with all parameters, restraints and mathematical descriptions, which eliminated the requirement of measurement for mass production or prototyping. Modified at modelling phase and tested in various ways that can be a disadvantage of using physical phase. This thesis represents theoretical aspects of design process of products showing case studies creating complex surfaces with the use CATIA v5 modelling software.

VIII. CONCLUSIONS

From the experimental results and the theoretical results, we conclude the following:

Regenerative braking can save up a lot of lost energy as well as can sustain life than conventional braking system.

- ➢ The innovative regenerative braking with KERS saved more energy than normal regenerative braking.
- ➢ Total saved electrical energy without Kinetic Energy Regenerative System is 2, 21, 84,100 J
- ➢ Total saved electrical energy with Kinetic Energy Regenerative System is 2, 77,300 J
- ➢ But the energy consumption rate is more in without Kinetic Energy Regenerative System compared to with Kinetic Energy Regenerative System.
- ➢ Hence efficiency more in with Kinetic Energy Regenerative System. Efficiency is as follows.
- ➢ Efficiency of normal regenerative pressure is 4.95%.
- ➢ Efficiency of KERS regenerative pressure is 11.94%.

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