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Design and Fabrication of Regenerative Braking System integrated in Drum Brakes with Scissor Linkage Mechanism

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ABSTRACT :

Traditionally, braking systems dissipate kinetic energy as heat, wasting energy and contributing to environmental impact. Regenerative braking offers a transformative solution, capturing this energy and reintroducing it to the system, enhancing efficiency and sustainability. Regenerative braking systems have garnered significant attention in recent years due to their potential to enhance energy efficiency in automotive applications. This study investigates the integration of regenerative braking technology into conventional drum brake systems through a scissor linkage mechanism. The conventional drum brakes are augmented with a scissor linkage mechanism to facilitate the conversion of kinetic energy into electrical energy during braking, thereby improving overall vehicle efficiency. This paper presents the design, analysis, and simulation of the regenerative braking system, focusing on its effectiveness in capturing and storing energy during deceleration. The proposed system aims to harness energy that would otherwise be dissipated as heat in traditional braking systems, thus offering a sustainable solution for reducing fuel consumption and emissions in internal combustion engine vehicles. Experimental validation and comparative analysis are conducted to evaluate the performance and efficiency of the regenerative braking system against conventional braking systems. The findings demonstrate the feasibility and potential benefits of integrating regenerative braking technology with conventional drum brakes, highlighting its significance in advancing the sustainability and energy efficiency of automotive transportation.

Keywords: Regenerative braking, electric vehicles, energy recovery, sustainability, efficiency, electric motors, batteries, range, emissions, fuel consumption, future of mobility.

INTRODUCTION:

In the world of automotive engineering, now we are moving towards more eco-friendly electric vehicles. We're facing a big problem there aren't enough charging stations around, and the batteries in these vehicles don't last very long and also, they are heavy, which makes the problem even worse because heavier cars use up more energy. All these issues combined mean that electric cars can't go as far as we would like them to. But there's a bright spot in this situation, something called regenerative braking. It's a cool technology that helps electric vehicles to go further by capturing energy when they slow down and using it to recharge the battery. This article is all about how regenerative braking can help solve these problems and make electric vehicles a better option for everyone. An automobile rear wheel with drum brake is used by removing internal brake pads and the dynamos are used to stop the wheel by absorbing kinetic energy of it and produce the electrical energy. For support the wheel is supported on the frame made with MS bars and motor with pulley and v belt is used to rotate the wheel. The output wires of the dynamos are connected to the battery to recharge it but in this project, we attached the wires to the lights to show the output. Thus, batteries can be recharged which can give the more range in electric vehicle. The braking systems play a critical role in ensuring vehicle safety and control. Conventional braking systems, notably drum brakes, have been widely employed for their simplicity, reliability, and cost-effectiveness. Drum brakes consist of brake shoes that press against the inner surface of a rotating drum to generate friction and decelerate the vehicle. This mechanism effectively converts the kinetic energy of the moving vehicle into heat energy, dissipating it into the surrounding environment. While effective, this process is inherently inefficient, leading to energy loss and wear on braking components. That energy, which could have been used to do work, is essentially wasted. The solution for this kind of this problem is Regenerative Braking System which offers the potential to recover and utilize the kinetic energy dissipated during braking and converting the kinetic energy of the vehicle into electrical energy. This technology typically involves the use of electric motors or generators integrated into the braking system to capture the rotational energy of the wheels during deceleration. The captured energy is then stored in batteries or capacitors for later use, such as powering auxiliary systems or providing additional acceleration.

Need of this project:

The integration of regenerative braking systems into conventional drum brakes offers a transformative approach to enhancing vehicle efficiency and performance. By harnessing and storing kinetic energy otherwise lost as heat during braking, regenerative braking systems significantly improve energy recovery, leading to reduced fuel consumption and environmental impact. Moreover, this technology extends brake life by alleviating the workload on conventional drum brakes, thereby minimizing wear and tear on brake components, potentially extending the lifespan of brake components such as brake pads and drums. Furthermore, the additional braking force provided by regenerative braking enhances vehicle control and safety, particularly in challenging driving conditions or emergency situations. By capturing and utilizing energy that would otherwise be wasted, regenerative braking systems contribute to reducing greenhouse gas emissions and environmental impact associated with vehicle operation. Despite potential technical challenges, such as retrofitting older vehicles, the manifold benefits of regenerative braking underscore its promise as a pivotal technology for optimizing the functionality and sustainability of conventional drum brake-equipped vehicles.

LITERATURE REVIEW:

Xu et.al [1] discusses on the history, present, and future of braking systems. It highlights advancements in braking technology from the past to current times. Various types of braking systems such as electromagnetic, vacuum, aerodynamic, and regenerative braking are explained. The importance of braking systems in vehicles, including high-speed cars and aircraft, is emphasized. The transition from drum brakes to disc brakes and the challenges faced in brake technology evolution are discussed. The impact of braking systems on vehicle safety and performance is explored.

Malode et.al [2] have said that the vehicle technology, including integrative and control technologies, has been growing rapidly throughout the 20th century. For whatever reason, the restricted driving range continues to be a barrier to the advancement of electric cars.

Binggang et.al [3] have mainly focused on the topic fuzzy logic based regenerative braking system integrated with the braking system with advanced level of energy saving. They improved the maximum driving range of LF620 EV by 25.7% compared with non-RBS conditions.

Islam et.al [4] have discussed on the concept of regenerative braking in electric vehicles. Found that the Regenerative braking can save up to 8-25% of waste energy in electric vehicles. Advanced technologies like ultra-capacitors and DC-DC converters have improved the regenerative braking system. The regenerative braking system reduces fuel costs, increases fuel efficiency, and lowers emissions. The brake controller monitors the speed of the wheel and calculates the torque and electricity to be generated during regenerative braking.

Yoong et.al [5] has proven that it be extremely difficult to build a disc brake adequate for holding a parked automobile, drum brakes are still often employed for handbrakes. Furthermore, it is quite simple to install a drum handbrake inside of a disc brake, allowing one device to function as both a handbrake and a service brake.

Sharma et.al [6] have discusses on the concept of regenerative braking in electric vehicles. Found that the Regenerative braking can save up to 8-25% of waste energy in electric vehicles. Advanced technologies like ultra-capacitors and DC-DC converters have improved the regenerative braking system. The regenerative braking system reduces fuel costs, increases fuel efficiency, and lowers emissions. The brake controller monitors the speed of the wheel and calculates the torque and electricity to be generated during regenerative braking.

Bhatt et.al [7] have reviewed the potential need for the design and development of a small, globally competitive electric concept vehicle for India, EVs are the best way to reduce pollution in cities, and the use of HEVs and EVs would have significant positive effects on the economy and society. The major goal of the paper is to design and execute a regenerative braking system that aids in recovering the energy lost while braking and storing it back in the battery for use during subsequent drives with the aid of the circuit.

Senthilkumar et.al [8] In their paper, the regenerative braking system (RBS) is implemented in the hybrid vehicle which is made to run using internal combustion engine and batteries. It is also observed that the current produced by the RBS in the vehicle is about the 30% of the heat generated by the braking system on the wheels components. This current measured by the multimeter and is stored in the battery for the later purpose.

Chougule et.al [9] have created a novel approach for the regenerative braking system using an external generator. Matlab Simulink simulation is used for result verification. The ability to recover and store 10–12% of battery energy results in a 10–12% improvement in the mileage of electric cars.

Mamgai et.al [10] have found that it reduces wear and tear on the braking system. Increases overall efficiency and reduces exhaust gas emissions. generative Braking Systems (RBS) are used to convert a vehicle's kinetic energy into electrical energy and store it for later use. RBS can improve efficiency and reduce exhaust gas emissions in vehicles. RBS can be used in conjunction with friction brakes and is used in both pure electric and hybrid electric vehicles. RBS can increase the overall weight of the vehicle by around 25-30 kilograms.

Ronald et.al [11] designed to recover energy that is normally lost during braking. By recovering energy that would normally be lost during braking, regenerative braking systems improves the fuel efficiency of a vehicle. Because regenerative braking systems improve fuel efficiency, it also helps reduce emissions from vehicles. This is particularly important in the context of electric vehicles, which produce no tailpipe emissions, but may still rely on energy generated by power plants that produce emissions.

Geng et.al [12] found that the regenerative braking system can produce noise, which can be a concern for some drivers. The system requires a complex arrangement of components, which can make it difficult to install and maintain. The system reduces emissions by reducing the amount of energy wasted during braking.

Hasan et.al [13] researched on the topic of Regenerative braking system that is a process that converts kinetic energy into electrical energy during braking. The electrical energy can be stored in a battery and used later to power the vehicle. Regenerative braking can improve fuel economy and reduce emissions. It can also reduce wear on brakes and engine. Hybrid vehicles use both an electric motor and an internal combustion engine
.

Nian et.al [14] have been examined using the MATLAB and Simulink environments, the driving cycle is carried out, and the RBS is modelled. The simulation runs for fifty seconds. After the vehicle achieves its top speed of 20 m/s, it begins to brake. Throughout the regenerative region, the DC bus voltage maintains a high value even when the EV speed drops from 70 km/h to around 30 km/h.

Bhandari et.al [15] investigated on the Regenerative braking and said that recaptures energy lost during braking and converts it to electrical or mechanical energy. It uses electric motors as generators to convert kinetic energy to electrical energy. Flywheel RBS stores energy mechanically in a rotating disc for later use. Hydraulic RBS uses pressurized fluid to store and reuse energy. Regenerative braking can improve fuel efficiency by 10-25%. Future advancements include more efficient motors, powerful batteries, and improved drive trains.

OBJECTIVE & METHODOLOGY:

OBJECTIVE:

- To develop a system that make vehicle brakes that can save some of the vehicle’s energy when you stop, so you can use it later and use less energy.
- To design a regenerative braking system with simple design and easy installation.
- To use the new energy-saving brakes to also make the regular brakes last longer, so you don't have to replace them as often.
- To make a vehicle to utilizing regenerative braking and aims to reduce fuel consumption and lower emissions, contributing to a more environmentally friendly and sustainable vehicle operation.

METHODOLOGY:

The integration of regenerative braking technology into conventional drum brakes with scissor mechanism represents a promising avenue for enhancing the energy efficiency and sustainability of braking systems. The scissor linkage mechanism, commonly associated with suspension systems, is integrated into the braking system to optimize the energy transfer during braking. This dynamic mechanism consists of linked bars that move relative to each other, resembling the action of a pair of scissors. When applied to regenerative braking, the scissor linkage aims to enhance the efficiency of energy transfer from the braking components i.e. two dynamos to the regenerative system. By modulating the motion and force distribution, the scissor mechanism contributes to maximizing the capture of kinetic energy, further improving the overall effectiveness of the regenerative braking system. The two dynamos will rotate with by touching with the internal drum surface when the links of the scissor linkage mechanism stretched by engaging the pedal. The electric power developed by the dynamos is connected to the batteries or capacitors to recharge it by using some additional rectifiers and boosters. Thus, the regenerative braking system will be useful which helps the vehicle to move further distance i.e. increased range, time to recharge the vehicle will also be reduced.

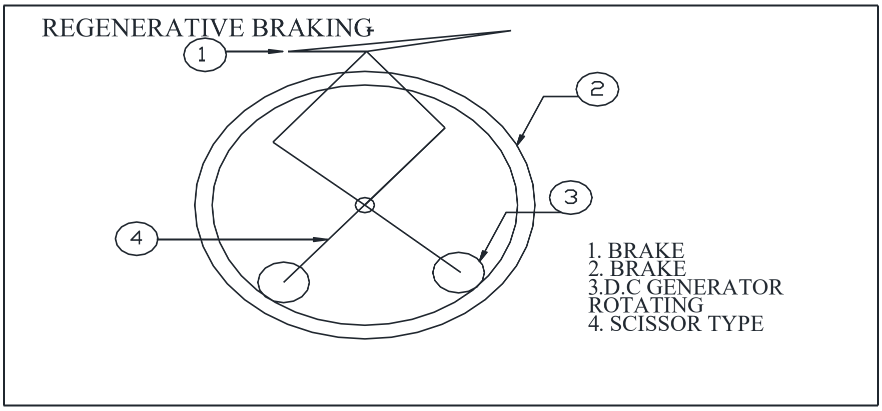


Fig 1. Methodology of Regenerative braking system

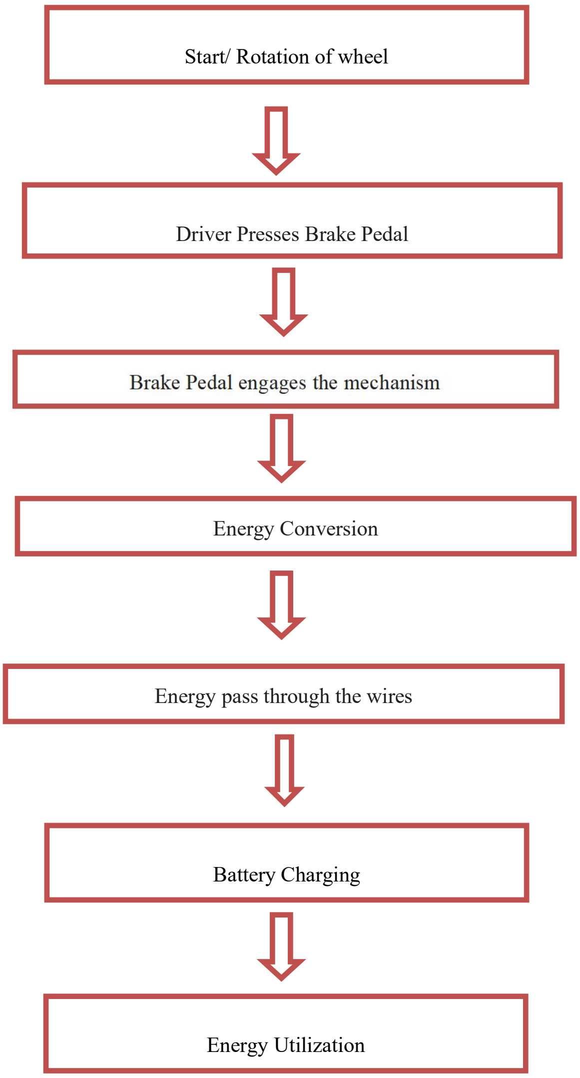


Fig 2: Flow chart of working

The above flow chart gives an idea about the working way of the Regenerative braking system. The explanation is given below.

1. **Start:**

   - It is the initiation of the system i.e. vehicle is running.

2. **Engaging:**

   - When the driver presses the pedal while stopping or slowing, the pedal engages the mechanism of the RBS

3. **Energy Conversion:**

   - The kinetic energy of the moving vehicle is transformed into electrical energy by the dynamo-generating setup

4. **Energy passage through wires:**

   - The electrical energy produced from the dynamo will pass to the storage unit through wires

5. Battery Charging:

- The energy from the wires is used to charge the battery and can be used when we want.

6. Energy Utilization:

- After it can be used various purposes like for to move the vehicle for further distance and also to blow the horns, lights.

CONSTRUCTIONAL DETAILS:

1) Wheel with brake drum

Fig 3 represents the drum wheel used for a regenerative braking system involves modifying the circular side by adding 5mm grooving internally. After removing all the brake pads, drum was grooved and the generator shaft would have driven contact with the grooved drum wheel to absorb the kinetic energy generated during braking. The mechanical energy from the wheel's motion is converted into electrical energy by the DC generator. This regenerated electrical energy is then used to reduce the motion of the wheel, acting as a form of braking and ultimately bringing the wheel to a stop.

Fig 3. Wheel

2) Solid Shaft

A shaft is a long, slender, and cylindrical object widely used in various fields. In mechanical engineering, it denotes a rotating machine element transmitting power, while in automotive engineering, a drive shaft transfers torque between distant drivetrain components. In this project, a mild steel of 15mm diameter Solid shaft was used in order to rotate the wheel. The wheel was fitted on the shaft on one end, on another end of the shaft was connected to the electric motor to the help of pulley and pulley rope. This shaft is supported through the bearings which are welded to the frame which is represented in fig 4.

Fig 4. Solid shaft

3) Bearing

Bearings are crucial mechanical components that facilitate smooth rotation and movement between two parts. They are designed to reduce friction and support loads, enabling various machinery and equipment to function efficiently. Bearings come in diverse types, including ball bearings, roller bearings, and plain bearings, each tailored for specific applications. Two ball bearings of size 15mm x 35mm x 11mm are used for support which is represented in fig 5.

Fig 5. Bearing

4) Dynamos:

Dynamo is a term often used to refer to a type of electrical generator that converts mechanical energy into electrical energy through electromagnetic induction. The rotating spindle has kinetic energy and due electro-magnetic force the kinetic energy is converted into electrical energy. The motor tip is fitted that when the brakes engages the tip meshes with the brake wheel i.e. to the inner circumference of the wheel, thus the motor spindle rotates. The motor has the capacity of 10V and 2 amps.

Fig 6. Dynamo

5) DC Motor

A DC (direct current) motor is an electro-mechanical device that converts electrical energy into mechanical motion through the interaction of magnetic fields. It operates on the principle of Ampere's Law, utilizing a magnetic field created by the flow of direct current through the motor's coils. DC motors come in various types, such as brushed and brushless, each with its own set of advantages and applications. The specifications of motor we used for this project are 240 v and 300 W power to rotate the wheel at required speed which is connected to the solid shaft with the help of pulley and the V-Belt. The motor is supported on the frame we made.

Fig 7. Motor

6) Pulley & Belt

A belt and pulley are used to rotate the wheel. The pulley is connected to the solid shaft which is connected to the wheel. V- belt is fastened to the motor spindle and pulley.

Fig 8. Pulley

7) Frame

Frame is made up of mild steel bars for support the system. A rectangular cross section of size 82 × 30 × 15 centimetres with mild steel bars is made. From ground about one feet rods are welded to the rectangular frame to make a ground clearance of one foot. Another small rectangular cross section of 50 × 20 centimetres is made to mainly support the wheel with scissor mechanism of size 3 feet long bars are used to support the brake pedal are welded to it.

Fig 9. Frame

8) Wire

In the project setup, wires are employed to connect the ends of the two dynamos in a parallel connection configuration. This arrangement allows for the collective electrical output of both dynamos to be harnessed simultaneously. Typically, in applications aimed at recharging a battery, such a parallel connection would enable efficient charging by combining the output of multiple generators. However, in this particular project, the electrical output from the dynamos is directed towards powering an LED instead of recharging a battery. By connecting the dynamos in parallel and redirecting the electrical output to power the LED, the project effectively showcases the functionality of the dynamos in generating electrical energy from mechanical motion. This setup offers a practical and visible demonstration of the power generation process within the system.

Fig 10. Wire

Fig 11. LED

9) LED

In the project setup, the LEDs are directly connected to the ends of the dynamos in a parallel configuration. This parallel connection allows for each LED to receive electrical output from its respective dynamo simultaneously. By connecting the LEDs in parallel with the dynamos, the electrical output generated by the dynamos is utilized to power the LEDs, thereby providing a visual indication of the project's output. This setup enables real-time monitoring of the electrical energy generated by the dynamos, as the LEDs will illuminate in response to the power produced. Overall, this configuration allows for a straightforward and effective demonstration of the project's functionality, as the illumination of the LEDs directly corresponds to the electrical output generated by the dynamos.

10) Bolts and Nuts:

Bolts and nuts are ubiquitous components in the world of engineering, construction, and manufacturing, serving as the fundamental elements that hold structures together. Bolts, typically cylindrical rods with threads at one end, are designed to pass through a hole in various materials, while nuts, small metal blocks with an internally threaded hole, secure the bolt in place when tightened. This simple yet ingenious pairing forms the basis of countless mechanical assemblies, from household furniture to towering skyscrapers. Bolts and nuts come in a variety of sizes, materials, and designs to accommodate different applications, ranging from delicate electronics to heavy-duty machinery. Their versatility and reliability make them essential in ensuring the integrity and stability of structures and equipment across various industries.

Fig 12 bolts and nuts

Fig 13 Helical Spring

11) Spring:

In a drum brake system, the purpose of the spring braking mechanism is to provide emergency braking and parking brake functionality. Within the drum brake assembly, springs play a critical role in retracting the brake shoes away from the drum when the brakes are released. During normal operation, when the brake pedal is pressed, hydraulic pressure forces the brake shoes against the inner surface of the brake drum, generating friction and slowing down the vehicle. When the brake pedal is released, the springs retract the brake shoes, allowing the wheel to rotate freely. In the event of a hydraulic system failure or loss of pressure, the spring brake mechanism serves as a fail-safe mechanism. The springs are designed to automatically apply the brakes if hydraulic pressure is lost, ensuring that the vehicle can still come to a stop in emergency situations. Additionally, the spring brake system functions as a parking brake when the vehicle is stationary. By applying mechanical force to the brake shoes, the springs keep the brakes engaged, preventing the vehicle from rolling when parked on inclines or uneven surfaces. Overall, in a drum brake system, the spring braking mechanism provides essential safety features for emergency braking and parking, ensuring the vehicle's control and stability in various driving conditions. In this project we used 5cm diameter spring is used for purpose of 15cm length.

12) kill switch:

kill switch, also known as an emergency stop switch, is a safety mechanism commonly used in various machines, vehicles, and equipment to quickly and effectively shut down operations in emergency situations. The primary purpose of a kill switch is to provide a rapid means of cutting power to the device or system, thereby preventing or mitigating potential hazards or accidents. Kill switches come in various forms, depending on the specific application and requirements. In automotive contexts, a kill switch may be a simple toggle switch or button located within easy reach of the driver. When activated, it interrupts the flow of electricity to essential vehicle components such as the engine, ignition system, or fuel pump, effectively stopping the vehicle's operation. Similarly, in machinery and equipment, kill switches are often integrated into control panels or positioned at strategic locations where operators can quickly access them. They may be designed to disconnect power supplies, shut down motors, or engage safety mechanisms to halt machine operations and prevent injury or damage. The functionality of a kill switch is vital in emergency situations where immediate shutdown is necessary to avoid accidents, fires, or other hazardous scenarios. Examples include cases of engine malfunction, vehicle fires, or runaway machinery. By swiftly cutting off power, a kill switch can help prevent further escalation of the situation and allow for timely intervention by operators or emergency responders. Overall, kill switches play a critical role in enhancing safety and minimizing risks in various applications. Their presence ensures that operators have a reliable means of stopping operations quickly and effectively in emergency situations, thereby safeguarding both personnel and equipment. Regular maintenance and testing of kill switches are essential to ensure their proper functioning when needed most. whenever we engage the brake the pedal will push the button of the switch to cut the supply and switch will came to ON position after the pedal came to rest position.

Fig 14. kill switch

EXPERIMENTATION:

Fabrication Procedure:

- The scooty rear wheel having a drum is taken and removed all the brake parts of it.
- Mild steel rods are used to make a frame for supporting purpose and bearings, shafts, motor, dynamos and some wires are taken.
- Inner circumference of the wheel is knurled little bit for gripping purpose when it comes contact with the dynamos tips while engaging the brake pedal.
- A 16 mm diameter shaft is inserted into the wheel through the two bearings both at a distance of 15cm from each.
- They are supported on frame which is 82 × 30 × 15 cm made from mild steel.
- One end of the shaft is connected to the pulley which connected to the motor of 240V and 2400RPM capacity through the V-Belt.
- For scissor linkage mechanism we used flat mild steel bars of length 15cm of 2 pieces and another one with size of 30cm of 2 pieces are used. The dynamos of 12 volts capacity are fitted to the bars which are 30cm length.
- They are drilled at each corner for fastening purpose.
- The long bars of size 30cm are fixed like X shape and fastened to the frame with bolt.
- The dynamos fixed likely to make a contact when scissor mechanism links are expanded.
- A kill switch is used to make open circuit when pedal the kill switch to cut the power.
- The wires are connected to the output source to recharge the battery.
- For our purpose for visible output we connected to the LED.

Modelling:

In the realm of product development and design engineering, creating accurate prototypes is paramount. These prototypes serve as the foundation for testing, validation, and eventual production. Among the plethora of software available for this purpose, Solid Edge stands out as a powerful tool for modelling and simulating prototypes.

This paper delves into the process of modelling a prototype using Solid Edge, highlighting its features, benefits, and applications in modern engineering. The Solid Edge, developed by Siemens Digital Industries Software, is a comprehensive computer-aided design (CAD) software renowned for its robust capabilities in 3D modelling, simulation, and manufacturing. Its intuitive interface coupled with advanced tools makes it a preferred choice among engineers and designers worldwide. Whether it's conceptualizing a design, simulating its performance, or generating detailed manufacturing drawings, Solid Edge offers a holistic solution throughout the product development lifecycle. The process of modelling a prototype using Solid Edge typically begins with conceptual sketches or ideas. These initial concepts are then translated into digital form within the software's environment. Solid Edge provides various tools for creating 3D models with precision and efficiency. From basic geometric shapes to intricate assemblies, designers can bring their ideas to life seamlessly. Key features such as synchronous technology enable real-time editing and modification of designs, ensuring flexibility and adaptability throughout the modelling process. Additionally, Solid Edge offers parametric modelling capabilities, allowing designers to establish relationships between different features of the prototype. This parametric approach facilitates quick iterations and design optimizations, leading to superior end results. Furthermore, Solid Edge encompasses simulation functionalities, enabling engineers to assess the performance and behaviour of the prototype under different conditions. Whether it's stress analysis, motion simulation, or thermal evaluation, Solid Edge empowers designers to validate their designs virtually before physical prototyping, saving time and resources.

In today's interconnected world, collaboration plays a vital role in product development. Solid Edge facilitates seamless collaboration through its cloud-based platform, enabling team members to share, review, and collaborate on designs in real-time. This enhances communication and accelerates decision-making processes, ultimately expediting the overall project timeline. Moreover, Solid Edge offers advanced visualization tools, allowing designers to create photorealistic renderings and animations of the prototype. These visualizations not only aid in conveying design concepts effectively but also serve as valuable marketing assets for presenting the product to stakeholders and potential customers.

In conclusion, Solid Edge emerges as a powerful ally in the process of modelling prototypes. Its comprehensive feature set, intuitive interface, and robust simulation capabilities empower designers and engineers to bring their ideas to fruition with precision and efficiency. By leveraging Solid Edge, organizations can streamline their product development workflows, reduce time to market, and achieve greater innovation in today's competitive landscape.

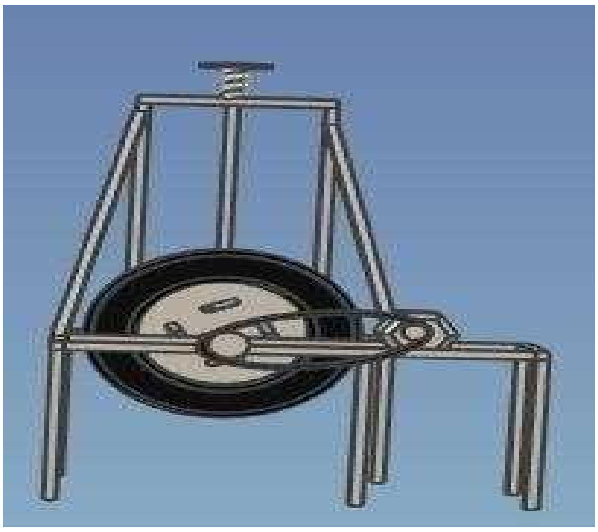


Fig 15. Front view

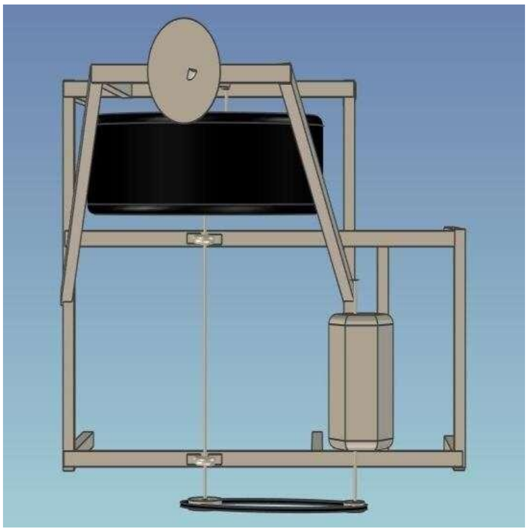


Fig 16. Top view

In the above figures we can clearly see that the front and top view of the design, the wheel which is connected to the shaft is rotating with the help of a motor through pulley, v-belt.

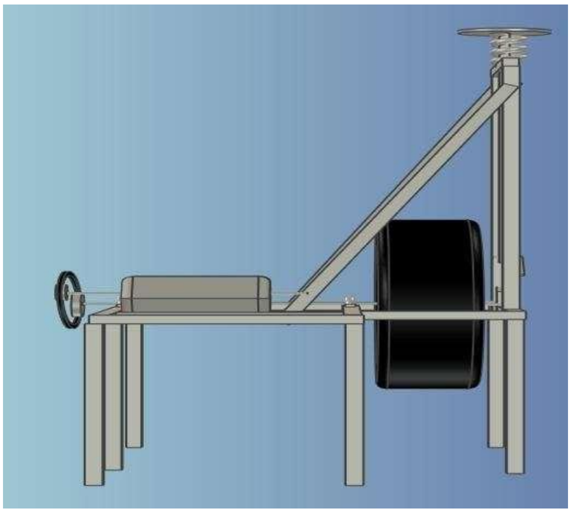


Fig 17. Right Side View

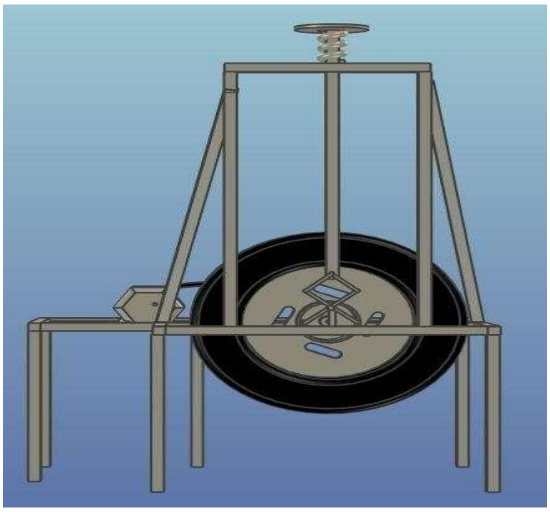


Fig 18. Left Side View

The above figures 17 and 18 represents the Right-Side View (RSV) and the Left side view (LSV) of the design respectively. In this view we can clearly see the construction of the frame.

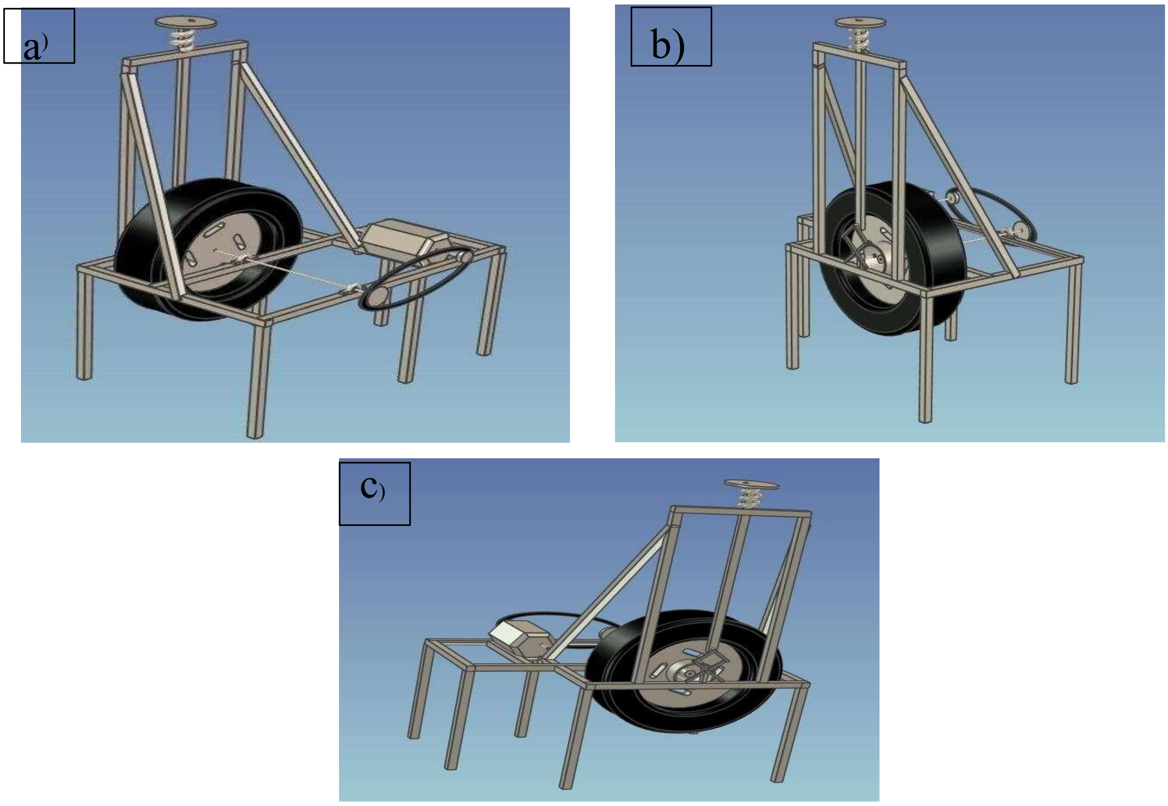


Fig 19. a) b) c) Isometric view

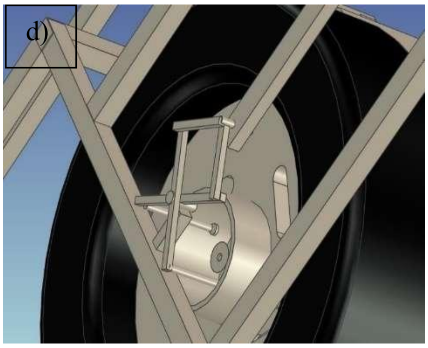


Fig 20. Scissor mechanism

In the above view we can clearly see the mechanism of the project which represents the scissor mechanism which is made by two 2 different pairs of links which are fastened by the help of bolts. The top end of the link is fastened to 3feet brake pedal bar. The two dynamos are connected to the bottom end of the links separately.

Prototype:

Figure 21: a), b), c) Prototype

Figure 22: Working of Prototype

CALCULATIONS:

The efficiency (η) of a regenerative braking system can be calculated using the following formula:

(η) = Total Energy Input ÷ Useful Energy Output

In the context of regenerative braking, the useful energy output is the electrical energy generated and stored, while the total energy input is the initial kinetic energy of the moving vehicle. The electrical energy generated is typically stored in a battery or another energy storage system.

The formula for electrical energy (E) is given by: $E = P \times t$ where:

- E is the electrical energy in watt-hours (Wh),
- P is the power generated by the regenerative braking system in watts (W).
- t is the time of braking system is active in seconds (s) i.e. time taken until to stop the vehicle.

Calculate Power Generated

$P = V \times I$

Where P is power generated in watts,

V is voltage generated by dynamos in volts, I Amperes of the dynamos i.e. 2amps

Table 1.Voltage generated by single dynamo at different speeds.

S.No	R.P.M	Voltage produced (Volts)
1	20.1	0.9
2	56.8	3
3	94	4
		Avg = 3.95 volts

So, for two dynamos it will be 2×3.95 = 7.9 volts.

Therefore, power generated will be $P = V \times I$

$= 7.9 \times 2$

Power (P) = 15.8 watts.

Calculate Initial Kinetic Energy

Initial Kinetic Energy=$1/2 \times I\omega^2$

where:

I is the moment of inertia of the wheel,

ω is the angular velocity in radians per second.

Moment of Inertia (I) = $1/2\ mr^2$ kg·m²

Where:

- I is the moment of inertia.
- m is the mass of the wheel
- r is the radius of the wheel. Moment of Inertia (I) = $1/2\ mr^2$

$= 1/2 \times 2 \times 0.35^2$

$= 0.1225$ kg·m²

The weight of the wheel changes according to the air inside in it. So, roughly taking an average weight of 2kgs and radius of the wheel is around 35cm.

Table 2. Angular velocity at different RPM's

S.No	Trial	R.P.M	Angular velocity (ω) rad/sec
1	Slow speed	20.1	2.1

2	Medium speed	56.8	5.95
3	High speed	94	9.92
			Average = 5.99 rad/sec

Initial Kinetic Energy = $1/2 \times I\omega^2$

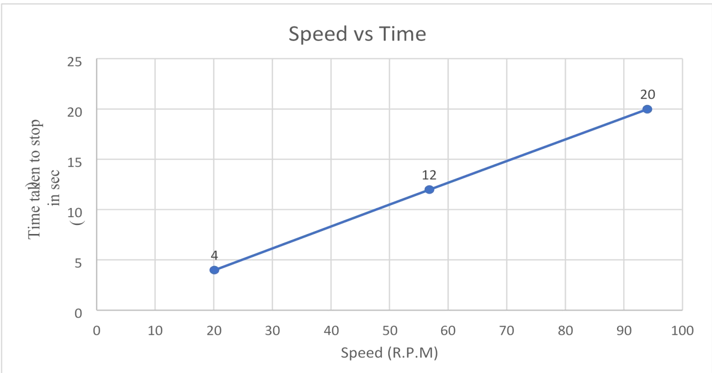
$= 1/2 \times 0.1225 \times 5.99^2$

= 2.19 Joules.

Calculate Time Taken to Stop

Table 3. Time taken to stop the wheel

S. No	R.P.M	Angular velocity (ω) rad/sec	Velocity (kmph)	Time taken to stop (in sec)
1	20.1	2.1	2.64	4
2	56.8	5.95	7.49	12
3	94	9.92	12.4	20
		Avg		12



Graph 1. Speed vs Time

Remarks:

- We can see that it takes around 20 seconds at a R.P.M of 94 and 4 seconds at low R.P.M.
- It takes roughly 12 seconds at an average speed of 7.5 Kmph.
- By seeing the above graph, we can conclude that the time taken to stop the wheel is more which is more dangerous in actual conditions.
- So, there is need to use external brakes for effective braking.

Efficiency of the Regenerative Braking System (η):

Efficiency (η) = Useful Energy Output / Total Energy

Useful Energy Output refers to the electrical energy generated and stored during the braking process. It's the energy that can be utilized to power other systems or stored for future use. In the provided context, it's the electrical energy (E) calculated using the formula E = P×t. Total Energy Input represents the initial kinetic energy of the moving vehicle. It's the energy that the system initially possesses before braking begins. It's the initial kinetic energy calculated using the formula Initial Kinetic Energy = 1/2 $I\omega^2$.

Therefore,

$$\text{Efficiency } (\eta) = E \;/\; 1/2 \quad I\omega^2$$

$$= (P\times t) \;/\; (1/2 \quad I\omega^2)$$

$$= (15.8 \times 12) \;/\; (1/2\times 0.1225 \times 5.99^2)$$

$$= 189.6 \;/\; 2.19$$

$$\text{Efficiency } (\eta) = 86.5\%.$$

Thus, we got the efficiency of 86.5%. by using the scissor mechanism for working of regenerative braking system.

RESULTS AND DISCUSSION:

RESULTS

- The development of the regenerative braking system is crucial for modern automotive world to increase its efficiency and to reduce the fuel cost.
- It will generate the voltage of 7.9 volts during work.
- By using this type of mechanism in RBS, we got an efficiency of 86%.
- Our model works with the 10 volts dynamos. They have capacity to produce a power of 10 volt due to diameter ratio they are limited up to produce 7 volts.
- It takes an average time of 12 seconds to stop the wheel which is at an average speed of 7.5 Kmph.
- In practical, it may vary due to the high moment of inertia of vehicle because of the vehicle weight.
- The produced power will be used to recharge the battery which give extra range in EVs which directly reduces the recharging time and money for the owner.
- It can be easily adopted to every vehicle with some minor modifications.

CONCLUSION:

- This Regenerative braking system will help the automotive industry to go further distance with less fuel consumption.
- It also takes less time to charge the battery if it is installed in electric vehicles. The weight of the vehicle will also become less due to its less components.
- The scissor mechanism we implemented will make this system easy to install and maintenance.
- But to stop the vehicle we have to use another braking system as it unable to completely stop the vehicle because only small tip of the motor is contact with it.
- The scissor mechanism will make the brake mechanism simple and easy to design and maintenance will also easy.
- Installing regenerative braking system in conventional brakes i.e. drum brakes will make more reliability and cost-effectiveness.
- This system makes the investment for the installation due to its cost effectiveness.

FUTURE SCOPE:

- By making the system in less size that it can fit into the inside of the drum, will be more helpful to install it in the vehicle.
- If you make the tip of the dynamos like gear and the circumference of drum also having gear profile made the system to exactly meshing while engaging the brake pedal. This may make the system more brake efficient.

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