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Pneumatic Regenerative Braking System for Bicycle

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Abstract – *Regenerative braking system commonly abbreviated as RBS is a system to recover kinetic energy of a moving vehicle under braking. In this system the kinetic energy is stored in the form of compressed air. While the bicycle is moving through slope minimum energy is required to move the bicycle. It is often seen that brakes are used in such conditions brakes to reduce the speed. And in contrast while riding uphill it becomes too tiresome to move the bicycle. If the bicycle is provided with regenerative braking system then the rider can have extra power source that he can use at his will. In general conditions when brakes are applied the kinetic energy is wasted because the kinetic energy gets converted into heat energy due to friction between rim and brake pad. The vehicles equipped with RBS are able to take some amount of kinetic energy while slowing down the vehicle. This kinetic energy using proper mechanism can be used to give the vehicle some extra power. In this project we have prepared a system which can do all above mentioned tasks effectively.*

Key Words: **Regenerative braking, Pneumatic, Compressor, Energy Recovery**

1. INTRODUCTION

At present, most of the bicycles do not have regenerative braking, and hence, all the power is wasted due to application of brakes at number of occasions through heat. Hence, there is no method by which one can stop wastage of power or use it for later purposes. Some of the bicycles have regenerative braking technology by using flywheel as an energy storage device. Some of the bicycles have electrical generator-motor arrangement for regenerative braking.

But in both the cases, there are two major issues. First is, due to the mounting of electric motor or flywheel on the bicycle, the weight of bicycle almost becomes double, hence it becomes difficult to propel bicycle even on flat roads. Hence, we can't see applications of these systems yet. Secondly and most importantly, in the case of flywheel it is very difficult to accelerate the bicycle at will, because flywheel tries to maintain the speed of the bicycle constant. Overall, one can't make use of power at will. In the case of electric motor, the resistance of alternator during transmission of power is very high which is uncomfortable. The present invention provides the solution to above mentioned problems, as it has a pneumatic system which has very negligible weight as compared to weight of bicycle. Also, by very easy engaging and disengaging mechanism, the system can come into picture at will. It has no impact on normal running of bicycle and it solves the problem of additional power required going uphill

2. LITERATURE REVIEW

The motto for the project was to demonstrate a regenerative braking system on an electric bicycle. The ultimate goal was to use the energy recovered from the regenerative braking system as acceleration on the bicycle. Battery, Controller, Capacitor, Throttle, Regenerative circuit were the main components. The final aim of recovering the stored energy into an acceleration boost was not possible due to certain reasons. The recovered energy was even stored in a capacitor, so finding an appropriate use for that electricity should not be difficult. But the main factor was time. Possible changes for the required outcomes could be reworking on the circuitry so as the recovered energy could be used as an acceleration boost and can also be used to recharge the battery. Also switching from pedal-assist mode to regenerative mode was tedious work. For braking purpose it was necessary to use the conventional friction brakes in cope up with the regenerative braking. [1]

The purpose of the work is to lower down individual's effort during cycling. This paper presents configuration for hydraulic regenerative braking system by the Matlab Simulink Environment. The effect of the main component parameters over the performance, braking and rate of energy recovery is determined. Result from simulation helps in selecting proper components which will suit the proposed system most neatly. Overall cost of the system is high. It costs three times the amount of a regular bicycle. [2]

This paper presents a flywheel-based regenerative energy recovery system. It is developed at the author's laboratory. It recovers and store regenerative energy developed by breaking a motion. It has generator with intermittent rotary velocity like the rotor of a wind turbo generator. Releasing the stored regenerative energy in the flywheel is converted to electricity by the attached alternator. A concept prototype named as the SJSU-RBS was designed at laboratory. Problems like the design of flywheel to get maximum net recovery as well as storage of regenerative energies; weight of the

flywheel, unbalancing of system makes the system uncomfortable for use. [3]

3. CONSTRUCTION AND WORKING OF THE SYSTEM

We will now see the construction of the whole system.

1. The compressor coupler assembly consists of compressor, compressor frame, coupler, coupling and supports. The coupler and compressor are bolted to the supports. A coupling is used to connect the coupler with the compressor. The whole compressor coupler assembly is fixed to sub frame of the supporting structure, wherein there is a circular member which allows relative motion between subframe and main frame which is fixed to the bicycle.

Fig. 1 Compressor coupler assembly

2. When bicycle is running downhill, instead of applying brakes to slow down the speed, the coupler is engaged to the rim of bicycle wheel from inside due to the actuation of sub frame by the knob which actuates tension cable and power gets transmitted to coupler which was being wasted earlier. This power is transmitted to the compressor through the coupling and air gets compressed in Compressor. Pressure gauge is provided to measure the pressure of air at compressor outlet. The spring allows the sub frame to hold the engaged position by applying sufficient force and it also accounts for any bumps on a road during engagement time. The frame supporting spring holds the spring in its position during above operation.

Fig. 2 Compressor with supporting structure

3. The compressed air is delivered by the compressor to the receiver. The valve circuit is provided to guide the compressed air in and out of the receiver. The valve circuit consists of a) Non-return valve b) pressure relief valve c) Bicycle Tire valve. The non-return valve is used to pass the compressed air into the receiver. The pressure relief valve as the name suggests limit the maximum pressure in the system (5 Bar). The bicycle tire valve is used to fill the air receiver externally. A flow control valve is provided to control the flow of air to the air motor.

Fig 3 Valve Circuit

4. The air motor and air receiver is mounted on the on the frame, wherein the frame rests on the bicycle carriage. The air motor is clamped to the air motor frame means of U clamps and bolts. The air motor has free speed of 20000 rpm.

Fig. 4 Air Receiver, Air Motor Frame

5. The power at the end of the air motor is transmitted to the bicycle wheel through chain drive. The roller chain is passed over two sprockets, smaller sprocket which is coupled to air motor and said bigger sprocket which is coupled to bicycle wheel. Chain drive is always in an engaged position and air motor output shaft runs freely when said air motor is not in operation taking engagement disengagement mechanism out of the equation.

Fig. 5 Chain Drive

6. Figure below depicts whole project assembly mounted on the bicycle.

Fig. 6 Full Assembly

4. AVAILABLE DATA

a.	Smaller sprocket diameter	= 35 mm
	Teeth on smaller sprocket	= 16
b.	Bigger sprocket diameter	= 93 mm
	Teeth on bigger sprocket	= 42
c.	Compressor cylinder bore	= 16 mm
	Compressor cylinder stroke	= 16 mm
d.	Bicycle wheel diameter	= 290 mm
	Coupler diameter	= 15mm
e.	Maximum air pressure noted from compressor	= 5 bar
f.	Chain drive efficiency considered	= 90%
g.	Speed of compressor uphill	= 150 RPM
h.	Average power required to drive bicycle uphill	= 40 W

TRIAL RESULTS:

a. Maximum torque obtained from air motor at max system pressure:

Trial	Torque Measured
Trial 1	0.04N.m
Trial 2	0.0398N.m
Trial 3	0.0409N.m

Fig. 7 Torque testing

b. Speed of air motor obtained at max flow rate:

Trial	Speed measured
Trial 1	2488 RPM
Trial 2	2540 RPM
Trial 3	2577

5. CALCULATIONS.

a. Speed ratio for sprockets = (42/16)
= 2.625
b. Speed of compressor = (29/1.5)*150
= 2900 RPM
c. Slip considered = 30%
d. Speed of compressor considering slip = 2900*0.7
=2030 RPM
e. Compressor stroke volume
= $(\pi/4)*(16)^2*16$
= 3.216 cm^3
f. Volume flow rate from compressor
= (Compressor stroke volume * speed of compressor in RPS.)
= 3.216*(2030/60)
= 108.808cm^3/s
= 0.108 liter/s
g. Receiver capacity= 8 liters
h. Approximate time required to store compressed air in receiver = 5 minutes
Power delivered by air motor = $\frac{2*\pi*N*T}{60}$
$= \frac{2*\pi*2577*.0409}{60}$
= 11.03037 W
j. Power available at wheel= 0.9 * 11.0307
= 9.9333 W
k. Percentage of required power delivered travelling uphill
= 9.9333/40
= 24.83%
Therefore it can be concluded that the above system assists the rider by up to 25%.

FUTURE SCOPE:

1. The work done on this project wasn't at professional level. If same work is done at higher levels with more standard processes and using standard parts, efficiency and effectiveness of the system can be raised.
2. The receiver used in this system can be completely eliminated by using bicycle frame as a receiver. This will lead to more compact construction and effective use of available space and will also be reduction in weight of the system.

6. CONCLUSION

The waste power due to the application of a brake is fully recovered using the system. It is the regenerative braking system which removes disadvantages of previous systems, as it is pneumatic. It also allows the rider to use this system at his will which provides great comfort and doesn't put any restrictions or doesn't hamper bicycle's normal performance. Also, there is a scope of further modification in the system which will lead to a full-proof system.

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