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Torsion spring regenerative braking in automobile a conceptual idea

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Abstract
Bringing in the concept of regenerative braking in the field of automobile is the most important part due to the fuel crisis in the current world scenario. But it still requires various improvements in order to fruitfully use it. This project has been done to improve the present level of this regenerative braking. The use of electrical regenerative braking has been limited by the capacity of battery and the strength of braking in case of an emergency braking. Similarly, other types of regenerative brakes like pneumatic brakes, flywheel brakes have their own limitation. A new conceptual idea for the regenerative braking is displayed in this paper. The idea of storing energy in a spring in the form of potential energy and recovering it when required is used. This spring force (during brakes) can be adjusted according to the force applied by the driver on the brake pedal by using a clutch assembly and these two parts (torsion spring & clutch) can be integrated into a single piece and attached to each wheel of the automobile.

Keywords: Regenerative braking, conventional brakes, spring regenerative braking

Introduction
The reason for choosing this type of topic is the increasing consumption of fossil fuels and the decreasing level of available resource. This increasing fuel consumption and vehicle number also has created pollution in the environment. A green mechanical system is required to overcome these drawbacks. The current existing designs of regenerative brakes have various limitations. So, a design for a regenerative brake which is bereft of these drawbacks is necessary. The drawbacks of the existing regenerative brakes are studied and a better idea for replacement for the drawbacks is mentioned in the paper.

Conventional Brake
Brake is a mechanical device used for inhibiting motion, reducing the speed or brings a moving a body to rest. The conventional brakes use frictional methods to stop the vehicle where the kinetic energy of the vehicle is dissipated to the atmosphere in the form of waste heat. The conventional breakings which are used in the present vehicles are:

Drum Brake
Brake shoes are held stationary and the brake drums are connected to the wheels or the axle. During braking, the shoes expand and rub against the inner part of the drum to produce friction between the rotating and the stationary parts.

Disc Brake
Brake pads are held stationary and brake disk is connected to wheels. During the brakes, the pads come together and clamp against the disc to produce friction. This leads to braking of the wheels.
Increasing the efficiency of an automobile has been a greatest challenge man is facing from the day of its invention. Many methods like hybrid powered vehicles, aerodynamic shape, usage of bio-fuel are of greater success for compensating the losses. The losses produced by the air resistance and other heat loss are brought to minimal possibility with the available patents at present.

But the major loss in the automobile field is observed during the braking where almost all the energy the vehicle has gained for the motion is completely lost in the form of frictional heat from the brakes. Scientists have tried upon new methods, categorized as regenerative braking, to regain the lost energy in the brakes by storing it in any other form of energy and reusing it during the acceleration of the vehicle. But the effective way of fruitful use of it isn't a success till known. The drawbacks of the existing regenerative brakes which are extracted from various statistical analysis papers are exhibited below.

Regenerative Brakes

The present day generation feasible regenerative brakes are discussed below:

Hydraulic Regenerative Braking

In case of need of faster and stronger brakes, hydraulic braking system is usually preferred. In this mechanism on the application of force on brake pedal piston is pushed forward which in turn exerts force on the brake fluid an incompressible fluid (aka brake fluid) is pushed which exerts force on calipers which in turn exerts force on the brake pads. This causes development of friction and braking. The force exerted can increased by varying the area as the pressure in the fluid remains constant.

In case of hydraulic regenerative breaking the kinetic energy will be stored in the form of pressure energy of the brake fluid.

Here an accumulator acts as an energy storing device which stores the high pressure hydraulic energy. This pressurized fluid is stored into the accumulator which can be used as input to the motor during accelerating mode.

The results as researched by Wojciechowski, P. H. and H. Searl Dunn (1975) [8] indicate that the average efficiency of energy recovery of hydraulic regenerative braking system is 66%.

Although in the research done by Dr. S. J. Clegg (1996) [3], the result variation is high, yet it indicates that hydraulic regenerative braking system possesses a high potential of energy recovery.

- Despite having high torque, high amount of energy recovery it has several limitation
- Compressor occupy huge space
- Starting braking power is very less, gradually increase as pressure builds. But, requirement is the opposite of it.
- Requires a separate pneumatic system to extract stored power
- Requires a complicated governor to compensate, hence unpractical
- Hydraulic systems are very noisy, an undesirable feature for most drivers.

Electro-Magnetic regenerative breaking

The braking system works on the principle of formation of eddy currents in the rotating part. When a current carrying conductor is placed in a magnetic field it creates a reverse magnetic field and the rotational energy is converted to heat energy. Axle or wheels are connected to electro- magnetic rotor part. Stator is kept stationary and an electro-magnet is activated during the application of brakes

In electromagnetic regenerative braking the energy is not dissipated but converted in the form of electrical energy and can be stored in capacitors

This type of braking has several limitations such as

- The braking is not as powerful as frictional braking
- It is not possible to stop the vehicle completely
- By the addition of number of equipment in the braking system, the weight of the vehicle increases considerably
- The braking process is not as simple as in the traditional braking system
- To produce strong magnetic field, this braking requires strong magnets
- The electrical energy produced needs to be stored in batteries which high capacity

Flywheel Regenerative Breaking

In this type of regenerative braking system the kinetic energy of the wheel is stored in flywheel. The weight of the flywheel is generally kept high to be able to store more amount of energy. The flywheel is connected to the axle by the help of clutches during the braking time where the energy gets transferred from the wheels. It loses some of its energy in the form of friction and aerodynamic loses.

As per the tests conducted by Brockbank C., Cross D (2009) [2], at the start of braking the vehicle has a high speed and the flywheel a low speed, giving a certain gear ratio between them. At the end of braking the vehicle has a low speed, and the flywheel a high speed, so the ratio of speeds has changed.

It provides much higher power output and energy efficiency. The increase in efficiency is because there is no conversion of energy from one form to another.

The limitations of this type of braking are -

- Can't be used to bring the vehicle to a complete halt
- Energy can't be stored for a long time
- Flywheel requires high inertia
- Either larger diameter flywheel or heavier flywheel
- Each flywheel to be used requires a clutch
- For efficient use, more number of flywheels are required

Conceptual Idea

The use of the above mentioned types of regenerative brakes have the main draw-back of losing energy when converted from one form of energy to other during their storage and back to its original form while reusing it during acceleration. Hence, an idea of using a single energy form i.e. mechanical energy alone is put forth here.

Parts

The parts which form the brakes are torsion spring, a pair of clutch plates and an idler gear mechanism.

Torsion Spring

The spring chosen depends on the maximum speed attainable by the vehicle and the maximum weight of the vehicle so that the maximum kinetic energy to be obtained by the vehicle can completely store in the spring. The spring material advised for this brake can be spring steel.

The spring wire diameter can be calculated by the maximum shear stress induced on the wire during its maximum twist.

Clutch plates

This idea of using a clutch plate for engaging and disengaging the brakes is derived from the Tai-Ran Hsu (2013) [7] experiment conducted on flywheel regenerative braking.

A pair of conventional clutch plates along with its diaphragm spring and clutch pedal system is used here.
One of the plates is attached to an end of the torsion spring. The other plate is attached either to the wheel the drive axle of the vehicle. The only difference in this clutch assembly from the conventional type is that they only clamp together when the driver presses the pedal and release when the pedals are released.

Idler gear
This is used during the power recovery of the spring. The spring after getting twisted, should have a reversed rotation direction. This reversed direction can be converted to forward motion by using an idler gear mechanism.

Assembly
One end of the spring is attached to the frame (chassis) of the vehicle; the other end is welded with the clutch plate. The dampers are connected to the spring to reduce the possibility of damage as well to increase the energy storing capacity of the spring. The other clutch plate is attached to the axle which is the drive. The clutch is assembled to engage when the pedals are pressed and released when the pedals are released. So, small springs in parallel state are placed in between the plates so that they are always in separation mode when the pedal is not pressed. The hydraulic or the pneumatic systems used for conventional brakes are clamped with this system through a valve. The valve (switch) in turn is connected to the brake pedal and the acceleration pedal which is used for engaging of the clutch. An additional idler gear is also connected with the acceleration pedal.

Assembly Concept
Working
The regenerative braking system is integrated along with conventional braking. When the brake pedals are pressed, the conventional brakes do their usual part of holding down the speed of the wheel. The regenerative brake which is connected to the hydraulic system is also engaged.
As the clutch engages, the spring is twisted by the clutch which in turn is connected to the wheels. Thus, the twisting of the spring reduces the speed of the vehicle. The kinetic energy of the speed gained vehicle is now stored in the form of potential energy into the torsional spring. The clutches now disengage after the braking pedal is released.
Now when the acceleration pedal is pressed, the clutch once again engages with the idler gear mechanism. The energy stored in the spring is transmitted back to the wheels in the forward direction.

Governing Equations
For designing torsional springs

$$\sigma = \frac{32K_bM}{\pi d^3} \qquad (1)$$

$$\theta = \frac{\pi M D n_e}{El} \qquad (2)$$

$$\frac{[\sigma]}{\sigma_u} = 0.9 \qquad (3)$$

Where,

σ	Induced bending stress
K_b	is Wahl factor
D	is wire diameter
Θ (radian)	is Angular deformation
I	Moment of Inertia
M	Bending Moment
D	is mean coil dia. of spring
nc	is number of active turns
[σ]	is design stress

For design of clutch plates
Transmitted torque

$$M_t = \frac{97400}{n} kW \qquad (4)$$

$$[M_t] = K_w M_t \qquad (5)$$

$K_w = k_1 + k_2 + k_3 + k_4$
Number of friction surfaces
$i = m_1 + m_2 - 1$

$$i_{min} = \frac{[M_t]}{2\pi p_a b \mu r_m^2} \qquad (6)$$

Allowable Pressure
$pa = k\,pb$
Choosing p_b as 2.75 kgf / cm^2
Diameter of clutch shaft

$$d = \sqrt[3]{\frac{495000 * kW * k_w}{n\,[\tau]}} \qquad (7)$$

Where,
kWis power n is rpm
$M_p$is transmitted torque kgf cm
$K_w$is factor based on working conditions
$k1$is driver dynamic characteristic factor. It’s chosen as 0.5 according to our situation
$k2$is driven shaft dynamic characteristics factor. It’s chosen as 1.6
$k_3$is wear factor. It’s based on maximum rpm. Its value can be chosen 0.43.
$k4$is frequency of operation factor. It’s chosen as 2.
$m_1$is number of driving plates.
$m_2$is number of driven plates.

(Both m_1& m_2 are chosen considering space for the clutch assembly near the wheels)$p_a$is 0allowable pressure between plates, kgf / cm^2
p_b is basic pressure, kgf / cm^2
Is speed factor. It’s chosen according to speed at the Maximum radius of the clutch plate.

$$\frac{r_{max} + r_{min}}{2}$$

r_m mean radius, cm
μ is coefficient of friction.

(The value is calculated from experiments conducted on the clutch plate material)

$[\tau]$ is allowable shear stress, kgf / cm^2 b is width of friction surface, cm$d$is shaft dia., cmcis plate thickness, cm
Qis axial force between plates, kgf σ is pressure between the plates, kgf / cm^2

Energy Regeneration Efficiency
The experiment conducted by Zhongyue Zou, Junyi Cao, Bing gang Cao, Wen Chen (2015) [9] showed that the efficiency of converting kinetic energy into regenerative energy is governed by the equation

$$E = \frac{1}{2}mv^2 - fs - \frac{1}{2}J_e\omega^2 - E_d \qquad (8)$$

Where,
f resistance of the vehicle (N)
E available recyclable energy in the vehicle
(j) m mass of the vehicle (kg) v vehicle's speed before braking (m/s)
s braking distance (m)
J_e moment of inertia of rotating parts in the vehicle
ω angular velocity

However, the above is done for an eddy current braking in which mechanisms are used to transfer mechanical energy is converted to electrical and vice versa. So, the efficiency of this would be comparatively less when used with a spring based braking due to energy conversion. The only loss is the hysteresis loss of the spring which would not be very significant when storing large energy. Hence, the above formula can be considered to energy distribution between the regenerative braking and conventional braking.

Materials
Torsion Spring
For spring 50 Cr 1 V 23 Alloy steel is chosen. Its tensile strength is 190-240 kgf / cm2. The yield strength is 180 kgf / cm2.

Clutch plates
For clutch plates, we use grinded carbon plates with μ as 0.045(taking least possibility for safety reasons).

Advantages
- Research done by Guoqing Xu, Weimin Li, Kun Xu, Zhibin Song (2011) [4] shows Enhanced travelling distance
- Energy loss in braking is minimized
- Energy saving is significant in large vehicles like trains and busses.
- R. Simpkin, C D Ambrosio, J Simonsson, Dr. M Abele, Dr. A Ferre, L Rollenitz, R Estrada Vazquez, Prof. I Boldea, Dr. S Scridon (2012) [6] Concluded that Greenhouse gas emission is reduced from such vehicles
- Bin Wang, Xiaoyu Huang, Junmin Wang, Xuexun Guo, Xiaoyuan Zhu (2015) [1] found out that there is increased traction on wheels due to faster response of regenerative braking

Disadvantages
- Consumes lots of volume and added mass to vehicle
- Both conventional braking should also be integrated to have proper braking on roads in case of an emergency as the force of braking cannot be easily controlled in regenerative braking which is similar to pneumatic braking
- Ki Hwa Jung, Donghyun Kim, Hyunsoo Kim and Sung-Ho Hwang (2010) [5] found out that Special Algorithms required to distribute braking to regenerative and conventional brakes.

Conclusion
The conceptual idea mentioned in the paper has a potential to reduce energy losses when compared to other regenerative brakes because of the fact that there is no conversion of energy from one form to another. Hence, the paper would give on some extent for reducing the idea of reducing greenhouse gases emitted from vehicle and give a harmonious and go-green environment.
The future scope of the project is very vast as the main target to reduce fuel consumption and reducing pollution is on the ultimatum. The idea of braking is also feasible to some extent.

References

1. Bin Wang, Xiaoyu Huang, Junmin Wang, Xuexun Guo, Xiaoyuan Zhu, A robust wheel slip ratio control design combining hydraulic and regenerative braking systems for in-wheel-motors driven electric Vehicles, Journal of the Franklin Institute. 2015; 352:577-602.
2. Brockbank C, Cross D. Mechanical Hybrid System Comprising a Flywheel and CVT for Motorsport & Mainstream Automotive Applications, SAE 2009 World Congress, Detroit, MI, USA, 2009.
3. Dr. SJ. Clegg. A Review of Regenerative Braking Systems. 1996.
4. Guoqing Xu, Weimin Li, Kun Xu, Zhibin Song. An Intelligent Regenerative Braking Strategy for Electric Vehicles, Energies. 2011, 1461-1477.
5. Ki Hwa Jung, Donghyun Kim, Hyunsoo Kim, Sung-Ho Hwang. Analysis of the Regenerative Braking System for a Hybrid Electric Vehicleusing Electro-Mechanical Brakes, Urban Transport and Hybrid Vehicles, 2010, 192.
6. Simpkin R, Ambrosio CD, Simonsson J, Dr. Abele M, Dr. Ferre A, Rollenitz L *et al*. Vazquez, Prof. I Boldea, Dr. S Scridon, Energy Efficient vehicles for road transport, Procedia - Social and Behavioral Sciences Transport Research Arena- Europe. 2012; 48:3613-3621.
7. Tai-Ran Hsu, On a Flywheel-Based Regenerative Braking System for Regenerative Energy Recovery, Proceedings of Green Energy and Systems Conference. 2013.
8. Wojciechowski PH, Searl Dunn H. Energy Regeneration and Conversion Efficiency in a Hydraulic Hybrid Propulsion System, High Speed Ground Transportation Journal. 1975; 9(1):383-392.
9. Zhongyue Zou, Junyi Cao, Binggang Cao, Wen Chen, Evaluation strategy of regenerative braking energy for super capacitor vehicle, ISA Transactions.2015;55:234-240.