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Development of Flywheel-Based Regenerative Braking System

H. D. Vaishnani [1], B. N. Vara [2], H.M. Pansuriya[3], H.M. Makada[4], S. S. Kanjiya[5], B. J. Vegada[6]

[1,2,3,4] *B.E. Mechanical Engineering, Darshan Institute of Engineering & Technology Rajkot, Gujarat, INDIA*
[5] *Assistant professor, Department of Mechanical Engineering, Darshan Institute of Engineering & Technology Rajkot, Gujarat, INDIA*
[6] *Head of Mechanical Department, Darshan Institute of Engineering & Technology Rajkot, Gujarat, INDIA*

Abstract: *In a conventional braking system most of kinetic energy losses during braking. It can recover and store regenerative energy produced by braking by regenerative braking system. Releasing of the stored regenerative energy in the flywheel is converted to electricity by the attached alternator. Now a days this techniques is mostly useful in car for more acceralation, in this study first of all we learn conventional braking system, then we will find possible ways to improve the design and efficiency of the braking system. In this project we presents a flywheel based mechanical regenerative braking system (F-RBS) concept for a car application, to improve the performance and/or efficiency of the car. A mechanical system is chosen to eliminate losses related to energy conversion while capturing the rotational braking energy. The Flywheel-Regenerative Braking System (F-RBS) concept consists of a metal flywheel design of truncated cone geometry for the energy storage system (ESS).*

Keywords: *Energy generation, Save energy*

1. Introduction

The Age of Industrialization, since the late 1800's, has been nothing short of remarkable. The world has vastly benefitted with the advancement of technology and knowledgebase which has brought about enormous socio-economic progress and consequently raised the standard of living of humankind beyond comprehension. Among the many resources which have played a major part in the growth, the role of fossil fuels has been undeniably quite significant. But the reserves of these 'nonrenewable' fossil fuels are rapidly declining and at the rate of growth of the humankind, the exhaustion of these resources in near future in inevitable. This has been the one of the major causes of concern in the recent past. The other major concern in the present day has been declining state of environment. The inefficient and excess usage of fossil fuels has caused the pollution of the environment, to the extent of its breakdown. As a result, over the past 40-50 years, the focus has shifted towards finding solutions which combat these issues, with the major areas of concentration being – efficient usage of energy resources (fossil fuels) in various applications like industry, transportation etc., finding alternative and/or renewable energy resources to supplement/replace the fossil fuel, better control strategies and treatment techniques to reduce pollution. [1]

Automobiles are one of the major consumers of fossil fuels and therefore: 1. One of the major sectors responsible for their depletion to the extent of near exhaustion; 2. One of the major contributors to the escalating environmental pollution levels. Due to these problems, in the recent past, the Auto Industry has come to an impasse where they are left with no alternative but to find alternate solutions to conserve natural resources. Over the years, the efforts in this direction have led to research and development in the following areas: [2, 3]

1. Improving engine efficiencies and performance – with the help of innovation in engine design and its components, improved control strategies etc.
2. Emission treatment and control technologies.
3. Vehicle design changes for reduction of thermal, aerodynamic and road losses.
4. Improvised Transmission design to reduce losses.
5. Hybrid and Alternative Energy Propulsion systems e.g. the Hybrid Electric Vehicle (HEV), the Fuel Cell Vehicle (FCV).
6. Recycling Braking energy – Storage and reuse of braking energy which is otherwise lost in the form of heat energy – technology that achieves this purpose is termed as a Regenerative Braking System (RBS).

As an additional tool to improving efficiency, current hybrid vehicles also employ regenerative braking to capture and utilize braking energy. Regenerative Braking Systems (RBS) capture the energy that is usually lost while braking, store that energy in an energy storage system (ESS) and the reuse it to start or accelerate the vehicle. The Kinetic Energy Recovery System (KERS) is a type of regenerative braking system which has the capability to store and reuse the lost energy. In recent years, hybrid electric vehicles were developed in order to meet the demand of reducing energy consumption, the increasing fuel prices and the damage caused by fossil fuel emissions to our environment. Currently, the market for hybrid vehicles is largely comprised of hybrid electric vehicles. These vehicles are partially or fully powered by electric motors that are supplied electricity from rechargeable batteries. Unfortunately the poor conversion efficiencies cancel out most of the advantages these battery powered hybrid vehicles bring with them. [4]

2. Design of Flywheel

The Moment of Inertia of any Geometry is given by [5],

$$I=\int r^2\,dm$$

If solid disc geometry of mass - M and radius - R is considered for the flywheel, then its moment of inertia is given by [5],

$$I_{sd} = \frac{1}{2}Mr^2$$

Kinetic energy equation [5],

$$E_K = \frac{1}{4}MR^2\omega^2$$

The mass density (ρ) and peripheral velocity (V), the equation becomes [5],

$$E_K = \frac{1}{4}\rho VR^2\omega^2$$

The tangential and radial stress profile as a function of the radial distance from the axis of rotation (r), is given by [6],

$$\sigma = \rho\omega^2(\frac{3+\vartheta}{8})(r_i^2 + r_o^2 - \frac{r_i^2 r_o^2}{r^2} - r^2)$$

And ωmax will determine maximum energy that can be stored without failing (EK, max) for the flywheel with a given [6],

$E_{K,max} \propto \omega_{max}$ OR $\omega_{max} \propto \sigma_{max}$

For a solid disc of radius R the relation between ω_{max} and σ_{max} is given by [6],

$$\sigma_{max} = \rho R^2\omega_{max}^2\frac{3+\vartheta}{8}$$

Hence, the equation becomes [5],

$$E_{k,max} = \frac{1}{4}V\frac{\sigma_{max} * 8}{(3+\vartheta)}$$

2.2 Design constraints for the flywheel

The design constraints for the flywheel for the f-RBS system are the following [7]:

Table 1:-List of design constraints for the flywheel [7]

Constraint Type	**Description**
Energy Storage	≈7-10 kJ
Mass	≈8 kg
Space Constraint	Compact
Transmission Constraint	Gear ratio range = 4-24

Out of the above constraints, the critical constraint is the transmission subsystem gear ratio range. Due to limitation placed by the transmission ratio range, the flywheel rotating speeds above 7000 RPM cannot be utilized. Hence, a low speed flywheel design is chosen, which takes the transmission constraint into consideration and is also economical to implement [7].

Now, using the kinetic energy equation, considering the flywheel stores maximum available energy (≈10 kJ) at maximum utilizable rotational speed (≈ 7000 RPM), the moment of inertia of the flywheel (If) needs to be [7]

$$I_f = 0.037\ \text{kg-m}^2$$

2.3 Material Selection

The specific tensile strengths for different metals are calculated to determine the material with better specific energy capability [7].

Table 2:-Specific strength for different materials [7]

Material	Tensile Strength (σ_{max}) [N/m^2]	Density (ρ) [kg/m^3]	Specific Strength (σ_{max}/ρ)
201 Annealed Stainless Steel SS	685000000	7860	87.150
AISI Steel 1045	625000000	7850	79.618
Alloy Steel	723825600	7700	94.003
Cast Iron	414000000	7300	56.71

From the above table, cast Iron is chosen for flywheel material due to its low cost and good specific strength.

3. Geometry

The final design parameters are as given below:

Table 3:-Flywheel design (FW) dimensions and properties

Geometry	Value
Shape	V-shape
Material	Cast Iron
Moment of Inertia (I_f)	0.038 kg-m^2
Mass (M_f)	8 kg or less
Type	Arm type
Total Thickness (t_o)	5 cm
Inner radius (R_i)	3 cm
Outer Radius (R_o)	11 cm

Fig. 1:-assembly of flywheel based regenerative braking system

4. Conclusion

In ordinary braking system there is a huge amount of energy wasted while braking. Generally we uses brake shoe and hydraulic systems are used in locomotives, so the maintenance cost is high and also those system will create noises and pollution.

In our project we can reduce the wastage of energy during the braking time. The regenerative braking technique increases the driving range of vehicles and optimizes the maintenance cost. When the brake pads rub against the wheels the friction is generated and due to this friction the heat energy is generated. This heat energy dissipates into the air while braking, wasting up to 30% of the cars generated power. A modified direct torque control is proposed to regenerate electrical energy from the kinetic energy and bringing it back to the batteries in the motors. Theoretical investigations of a regenerative braking system show about 25% saving in fuel consumption.

5. References

1. F. J. Thoolen, "Development of an advanced high speed flywheel energy storage system," Ph.D. Thesis, Technische Universiteit Eindhoven, Eindhoven, The Netherlands, 1993.
2. R. M. van Druten, "Transmission design of the Zero Inertia powertrain," Ph.D. Thesis, Technische Universiteit Eindhoven, Eindhoven, The Netherlands, 2001.
3. A. Boretti, "Improvements of Truck Fuel Economy using Mechanical Regenerative Braking," SAE Technical Paper 2010-01-1980, 2010.
4. K. Tanaka and T. Shima, "Regenerative braking system for car," 4993780, 1991.
5. J.Uicker, Gordon R Penstock & J.E. Shigley, Theory of Machines and Mechanisms.
6. Yongjie Hana,*, Zhengyi Ren, Yongxiang Tong, General Design Method of Flywheel Rotor for Energy Storage System in 2012 International Conference on Future Energy, Environment, and Materials.
7. Design Principles of a Flywheel Regenerative Braking System (f-rbs) for formula sae type Racecar and System Testing on a Virtual test rig Modeled on MSc Adams.

Biographical notes

	**Honey D. Vaishnani** is pursuing B. E. in Mechanical from Darshan Institute of Engineering & Technology, Rajkot.
	**Bhautesh N. Vara** is pursuing B. E. in Mechanical from Darshan Institute of Engineering & Technology, Rajkot.
	**Hardik M. Pansuriya** is pursuing B. E. in Mechanical from Darshan Institute of Engineering & Technology, Rajkot.
	**Hussain M. Makada** is pursuing B. E. in Mechanical from Darshan Institute of Engineering & Technology, Rajkot.
	**Sagar S. Kanjiya** is working as an assistant professor in Department of Mechanical engineering, Darshan Institute of Engineering & Technology, Rajkot, Gujarat, India.
	**Bhavin J. Vegada** has received M.Tech. in Thermal from Nirma University in 2011. He is Head of Mechanical Department, Darshan Institute of Engineering & Technology, Rajkot, Gujarat, India.

