DESIGN AND FABRICATION OF AN EFFICIENT HYBRID OF FRICTION AND EDDY CURRENT BRAKES

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ABSTRACT

Using conventional friction brakes in automobile vehicles has numerous drawbacks. Apart from being polluting in nature, they dissipate a large amount of waste heat energy into the atmosphere. Moreover, using alternatives such as eddy current brakes also has its own disadvantages such as inefficiency at low speeds. In this paper, a hybrid of the two braking mechanisms has been proposed. The advantages and consequences of using this proposed system have also been discussed in detail.

Keyword: - *Thermoelectric Generator (TEG), Friction brake, Eddy current brake, Regenerative Braking.*

1. INTRODUCTION

A brake is a mechanical device that inhibits motion by absorbing energy from a moving system [1]. It is used for slowing or stopping a moving vehicle, wheel, axle, or to prevent its motion, most often accomplished by means of friction [2]. Braking forms an important part of motion of any automobile or locomotive.

1.1 Drawbacks of Conventional Braking System

The conventional frictional brakes have certain drawbacks like low response time, wear and tear of the rotor pads, and weakening of braking torque due to elevated temperature [3].

Moreover, if the speed of the vehicle is very high, then it may not provide a high enough braking torque. This may lead to less frictional resistance and problems like skidding and accidents [4].

Whenever the brakes are applied, the vehicle's kinetic energy is converted into heat energy at its brakes. This energy conversion happens due to the friction between brake pads and the brake disc. The generated heat and the resulting rise in temperature have a significant impact on the brake parameters such as coefficient of friction and wear rate. The brake wear rate increases at high temperatures creating uneven disc and brake pad surfaces. [5]

1.2 Regenerative Braking

Regenerative braking is an energy recovery mechanism that slows down a moving vehicle or object by converting its kinetic energy into a form that can be either used immediately or stored until needed. This contrasts with conventional braking systems, where the excess kinetic energy is converted to unwanted and wasted heat due to friction in the brakes, or with dynamic brakes, where the energy is recovered by using electric motors as generators but is immediately dissipated as heat in resistors. [6]

In fact, energy equivalent to as much as 13 grams of Diesel is lost as heat every time a normal sized sedan car running at 70 mph is brought to a complete halt. Moreover, a sports car like Regera, which has a combined horse power of more 1500 hp and can reach speeds of over 300 km/hr, has been estimated to dissipate about 1MW power on an average when brought to a halt. [7]

2. THERMOELECTRIC GENERATORS (TEGs)

A device commonly associated with regenerative braking technologies is the thermoelectric generator (TEG), also called a Seebeck generator. It is a solid-state device that converts heat flux (temperature differences) directly into electrical energy through a phenomenon called the Seebeck effect (a form of thermoelectric effect). Thermoelectric generators function like heat engines, but are less bulky and have no moving parts [8].

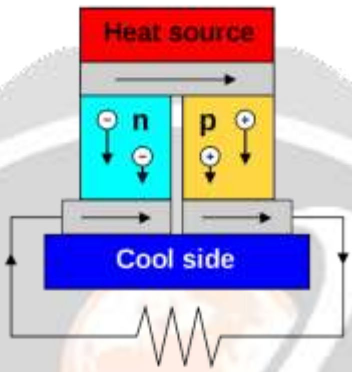

Fig -1: A thermoelectric circuit composed of materials of different Seebeck coefficient configured as a thermoelectric generator.

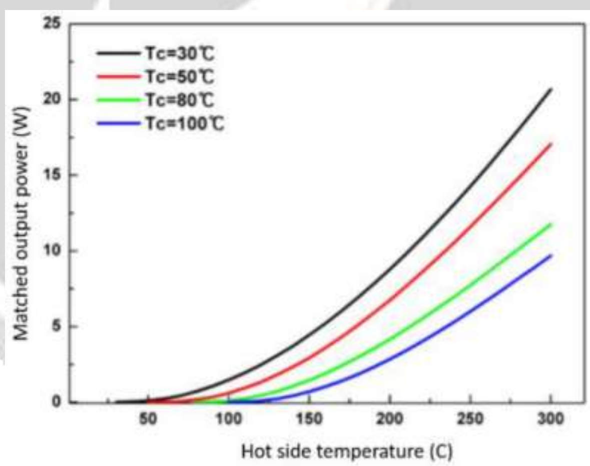

Fig -2: Power Characteristic of TEG241-60BA

2.1 Regenerative Braking using Thermoelectric Generators

Prakhar Tonk et al [10] intended to use the heat generated in the brakes of an automobile by converting it into electric energy with the help of TEGs to charge the batteries of an automobile, thus reducing the alternator load on the engine, and improving fuel efficiency.

In their model, they designed a disc with TEGs installed inside the cavity between the two plates as shown in the picture. They took the inner side of the brake disc as the hot side for the TEG and five such TEGs were installed on both sides of the inner surface of the discs.

Fig -3: Installation of TEGs on the inner sides of the disc (Model by Prakhar Tonk et al [10])

They found the combined power produced from the brakes of a regular four-wheeler (Maruti Swift) to be 1618.28 W, which is equivalent to saving 1078.85 W of engine power. Thus, they concluded that significant reductions in fuel consumption can be achieved by using TEGs in disc brakes. This generated heat is otherwise wasted to the atmosphere.

3. EDDY CURRENT BRAKES

An eddy current brake, also known as an induction brake, is a device used to slow or stop a moving object by dissipating its kinetic energy as heat. Unlike friction brakes, where the drag force that stops the moving object is provided by friction between two surfaces pressed together, the drag force in an eddy current brake is an electromagnetic force between a magnet and a nearby conductive object in relative motion, due to eddy currents induced in the conductor through electromagnetic induction. [12]

A disk eddy current brake consists of a conductive non-ferromagnetic metal disc (rotor) attached to the axle of the vehicle's wheel, with an electromagnet located with its poles on each side of the disk, so the magnetic field passes through the disk. The conductive disc moving past the stationary magnet develops circular electric currents called eddy currents induced in it by the magnetic field, as described by Faraday's law of induction. By Lenz's law, the circulating currents create their own magnetic field that opposes the field of the magnet. Thus, the moving conductor experiences a drag force from the magnet that opposes its motion, proportional to its velocity. [12]

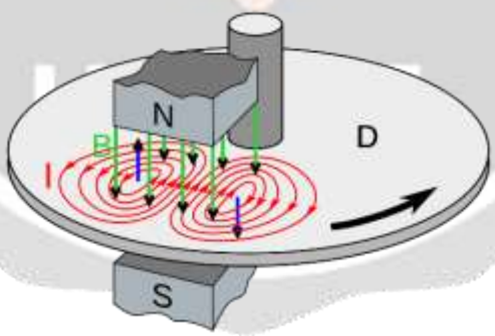

Fig -4: A circular or disk eddy current brake

3.1 Advantages of Using Eddy Current Brakes

Eddy current brakes were initially invented to counter the problems like skidding, wear and tear, high maintenance costs, low reliability, etc., faced due to frictional brakes in high-speed vehicles [3].

Eddy braking also finds application in high-speed vehicles as their braking force is proportional to speed of vehicle [13]. Such brakes can control high speeds with utmost stability.

There are no contacting elements or moving parts involved in an eddy current brake, leading to negligible wear of brake pad.

Moreover, its installation is easy and it only consumes a small amount of space. It is also light weight, fully resettable and reduces maintenance costs as no parts need to be replaced.

Lastly, eddy current brakes are more environment-friendly and have faster reaction time than conventional frictional brakes [3].

3.2 Drawbacks of Using Eddy Current Brakes

Eddy current brakes are dependent on battery power to energize the brake system. This drains down the battery much faster [4].

Moreover, eddy current brakes can't be used in a vehicle running at a low speed. This is because their braking force diminishes as speed diminishes with no ability to hold the vehicle in position at a standstill [13]. They can only lower the speed up to a certain nominal value and when the speed of the vehicle reduces below the nominal speed, the operation of the brakes decreases significantly [3].

Lastly, all the heat energy generated at the brake disc as the kinetic energy of the vehicle is converted into Eddy current is lost in the atmosphere.

4. PROPOSED SETUP

Since both frictional and eddy current disc brakes have drawbacks of their own, I tried to combine the two technologies into one hybrid setup in a way such that the setbacks of each are fulfilled by the other.

The setup is a direct combination of an eddy current brake and the modified brake disc proposed by Prakhar Tonk et al [10] embedded with thermoelectric generators. However, instead of supporting the alternator, the electricity produced by the TEGs on the brakes is to be used to power an electromagnet located with its poles on each side of the disk such that the magnetic field passes through the disk just like that on a conventional eddy current brake.

Fig -5: Schematic of the proposed hybrid setup

This way, as soon as the brakes are applied, a braking torque will initially be produced by the action of the friction brake. Consequently, a large amount of heat will suddenly be produced on the discs which would in turn be used up by the TEGs to power the electromagnets. Constant feeding of heat would help to increase the efficiency of the TEG module (i.e., generate more voltage), thus increasing the braking torque produced by the eddy currents due to the magnet. Therefore, at any instant of time during the braking process, there will be a braking torque produced not only by the action of the regular friction brake but also by the eddy currents acting on the disc, making the entire braking system much more efficient than a conventional frictional one.

However, there will be one minor change in the disc material. Ford and Fagor Ederlan [14] have jointly developed a full aluminium brake rotor for passenger and SUV applications made from a hypereutectic aluminium alloy being corrosion resistant and fully benefiting from the aluminium's low weight. In contrast to known technologies there is no use of ceramic or similar reinforcements nor coating. Compared to standard grey iron disc, the aluminium disc technology provides three main benefits: low weight (up to 60% weight save), stable friction level in a wide temperature range and no corrosion. [14]

The conversion of heat energy to electricity with the use of thermoelectric generators will reduce the amount of time which the brake is subjected to heat up at very high temperatures. This will improve the lifetime of the brake discs and minimise the thermal stresses and distortions occurring due to high surface temperatures. Gunathilake et al [5] showed that, without TEGs, a city driving vehicle's brake disc can heat up beyond 200° C within 100 s of continuous application of brakes. The same vehicle under similar driving conditions but the braking system is adapted with TEGs will reach only up to 130° C within the same time. Further, the continuous application of brakes will slightly increase the disc temperature, but will not go beyond 150° C for a long time [5]. This would make the use of aluminium as the disc material feasible as aluminium weakens at lower temperatures compared to cast iron. This is the main reason aluminium is not used in conventional friction brakes, where much higher temperatures are reached for longer periods.

Aluminium is the best material to be use as the disc brake for the setup. Aluminium reacts better and faster compared the other materials. Besides that, increasing the current induced will increase the drag force and slow down the motion better. Further, aluminium does not get attracted in a magnetic field. [13]

4.1 Other Significant Advantages of this Setup

Unlike the conventional eddy current brakes which depend on battery power, the eddy currents in this setup are directly powered by the heat energy produced in the brake disc. Thus, there will be no additional load on the battery.

Any heat produced as a result of the eddy currents, just like the heat produced due to friction, will be converted back to electricity by the TEG modules and directed to the electromagnets.

Further, since the eddy current brakes are accompanied by friction brakes, the setup can now be used to stop the vehicle from any speed, unlike conventional eddy current brakes which are ineffective at low speed.

5. CONCLUSIONS

Using the proposed hybrid setup not only increases the efficiency of the braking process of the vehicle by increasing the net braking torque on the brake disc, but also overcomes the drawbacks of using either of the friction or eddy current brakes independently. Further, it is more environment-friendly and leads to less wastage of energy than either of these two systems.

6. REFERENCES

[1] Bhandari, V.B. (2010), "Design of machine elements," Tata McGraw-Hill, p. 472, ISBN 9780070681798. Retrieved 9 February 2016.

[2] "Definition of brake," The Collins English Dictionary. Retrieved 9 February 2016.

[3] Mishra, D. P., and Jyoti Prakash Sarangi. "Identification and analysis of different parameters for eddy current braking system along with its applications." IJRTER 5.11 (2019): 23-29.

[4] Singh, Ashutosh, et al, "Contactlesss Eddy Current Braking System in Automobiles," International Journal on Future Revolution in Computer Science & Communication Engineering 4.4 (2018): 801-805.

[5] Gunathilake, W. A. D. N., M. S. M. Perera, and M. A. Wijayawardhana, "Mathematical Modelling and Analysis of Wear Characteristics of Vehicle Brakes with TEGs."

[6] “Regenerative brake,” Wikipedia (en.wikipedia.org). (Accessed: 5 August 2021)

[7] Haroon, “How much energy is lost in brakes,” Synergy Files, 31 July 2017.

[8] Adroja, Mr Nikunj; B.Mehta, Prof Shruti; Shah, Mr Pratik (2015-03-01), "Review of thermoelectricity to improve energy quality", 2 – Issue 3 (March-2015). JETIR.

[10] Tonk, Prakhar, V. K. Singh, and Naman Jain. "Using Thermoelectric Generators to Utilize Heat generated in Disc Brakes." IRJET, 2018.

[12] “Eddy current brake,” Wikipedia (en.wikipedia.org). (Accessed: 5 August 2021)

[13] S. Nath, R. Babu, G. Biju, Ashin S, C. Varghese, “Eddy Current Braking In Automobiles,” IRJET, April 2018.

[14] M. Rettig et al., “Aluminium Brake Disc,” Euro Brake, 2020.