

Elimination of Brake Fade in Vehicles by Altering the Brake Disc Size (A Concept)

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ABSTRACT: Brakes are one of the most important control components of the vehicle. They contribute very much in the movement of the vehicle. . Brakes are generally applied to rotating axles or wheels. The momentum or kinetic energy to stop the vehicle when in motion is converted to heat energy by the friction of brake pads and the rotors which is dissipated into the surrounding air. The main functions of brakes are mainly to stop the vehicle in shortest possible time and to help in controlling the speed of the vehicle. However, with long term use of brakes many problems occur which results in brake failure, leading to a fatal injury caused to the driver and co-passengers. One of the most important causes of brake failure are brake fades. Vehicle braking system fade, or brake fade, is the reduction in stopping power that can occur after repeated or sustained application of the brakes, especially in high load or high speed conditions. For elimination of brake fade, it is necessary for maximum temperature to be less than fade stop temperature. So, to have lesser temperature we alter the parameters dependent on it. Since, stopping time, density of material, specific heat capacity, thermal conductivity and ambient temperature are constants, it is possible to alter heat flux. . If the value of fade stop temperature is higher than maximum temperature , then fade doesn't occur. So for a higher fade temperature, we should have the volume of disc minimum. Thus, in here we prove that fade stop temperature is higher than maximum temperature. So, theoretically proving fade is not possible. Advantages- Low-fade brakes such as disc brakes in steered wheels can do more braking without causing brake steer, Elimination of brake fading provides a larger leverage and mechanical advantage to resist the turning of the rotor itself and It also provides a longer life time for the braking system, thus reducing the maintenance cost of the vehicle.

KEYWORDS: brake disc, fade temperature, heat flux, maximum temperature of disc.

I.INTRODUCTION

Brakes are one of the most important control components of the vehicle. They contribute very much in the movement of the vehicle. Most brakes commonly use friction between two surfaces pressed together to convert the kinetic energy of the moving object into heat, though other methods of energy conversion may be employed. Brakes are generally applied to rotating axles or wheels, but may also take other forms such as the surface of a moving fluid. [1]

In an automobile, if the pressure from the accelerator is removed, the vehicle tends to slow due to wind resistance, drag of engine and road friction. These forces of course would stop the vehicle, but in modern day traffic, this would be quite unpractical and dangerous. The braking system provides added friction, to overcome motion and to slow up or stop the vehicle. The momentum or kinetic energy to stop the vehicle when in motion is converted to heat energy by the friction of brake pads and the rotors which is dissipated into the surrounding air. The main functions of brakes are mainly to stop the vehicle in shortest possible time and to help in controlling the speed of the vehicle. It is also used to reduce the speed at turnings and other crowded places. [2] Thus making brakes an important control system of the car.

However, with long term use of brakes many problems may occur which results in brake failure, leading to a fatal injury caused to the driver and co-passengers. One of the most important causes of brake failure is brake fade. Vehicle braking system fade, or brake fade, is the reduction in stopping power that can occur after repeated or sustained application of the brakes, especially in high load or high speed conditions. [3] Brake fade occurs when the brake pad and the brake rotor no longer generate sufficient mutual friction to stop the vehicle at its preferred rate of deceleration and can happen on motorcycles cars and trucks. [4]

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The brake pad in any brake system is designed to work at certain operating temperatures. Being made of many different formulations brake pads perform in very different ways under temperature. This certainly indicates the fitness of a brake pad for application and its general quality.

II. TERMINOLOGIES

A. Brake disc material- Most of industrial automobiles companies produced the brake rotor part from a grey cast iron. The cast iron material differs from standard steels by having significantly higher carbon (C) and silicon (Si) contents. So, for best reduction of fade, we can use grey cast iron or carbon ceramic materials. Since, the cost of carbon ceramic materials is too high we use grey cast iron. Also, modern automobile sector uses grey cast iron in their disc brakes.

B. Deceleration of vehicle- If the speed of the car decreases, this is an acceleration in the opposite direction of the direction of the vehicle, sometimes called deceleration.[5] It is given by, coefficient of friction * acceleration due to gravity(g).

C. Stopping distance- Stopping distance refers to the distance a vehicle will travel from the point when its brakes are fully applied to when it comes to a complete stop. It is given by, (velocity of vehicle)²/(2*coefficient of friction*g)

D. Stopping time- It is the time required for a vehicle to completely stop, when brakes are applied. It is given by, (stopping distance)/(acceleration).

E. Average power (P) - It is the ratio of kinetic energy to stopping time. It is given by, [kinetic energy (E)]/[stopping time (T)]

F. Heat flux (Q) - Heat flux or thermal flux is the rate of heat energy transfer through a given surface, per unit time. Heat flux density is the heat rate per unit area. In SI units, heat flux density is measured in [W/m²]. [6]

It is given by, $[4*P*]/[(D^2-d^2)]*3.14$

Where, 'P' is the Average power.

'D' is the outer diameter on the rotor disc.

'd' is the inner diameter on the rotor disc.

G. Maximum temperature- It is the maximum temperature experienced by the rotor disc when brakes are applied.

It is given by, $\{(0.527*Q*\sqrt{T})/[\sqrt{(\text{density of the material} * \text{specific heat capacity} * \text{thermal conductivity})}]\} + T(\text{amb})$

Where, 'Q' is the heat flux

'T' is the stopping time

'T (amb)' is the ambient temperature. It is defined as the temperature of the surroundings.

H. Fade stop temperature rise- The reduction of friction termed brake fade is caused when the temperature reaches the "knee point" on the temperature-friction curve and gas builds up between disc and pad. This temperature is called as "fade temperature".

It is given by, $(P*T)/(\text{Density of material} * \text{specific heat capacity} * \text{volume of rotor disc.})$

Where, 'P' is the average power.

'T' is the stopping time.

III. DESIGN FOR ELIMINATION OF FADE

For elimination of fade, it is necessary for maximum temperature to be less than fade stop temperature. So, to have less maximum temperature we alter the parameters dependent on it. Since, stopping time, density of material, specific heat capacity, thermal conductivity and ambient temperature is constant; it is possible to alter heat flux. Heat flux is dependent on average power and inner and outer diameter of the rotor disc. Since, average power is constant; we should have a rotor disc of minimal value for a lesser maximum temperature. Also, ensuring that maximum temperature is not too minimum, otherwise resulting in fatal injury of the passengers. If the value of fade stop temperature is higher than maximum temperature, then fade doesn't occur. So for a higher fade temperature, we should have the volume of disc minimum, since other quantities like average power, stopping time, density of material and specific heat capacity are constants.

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IV.CALCULATIONS

Mass of vehicle – 250kg.
Coefficient of friction – 0.75
Outer diameter of brake disc- 200mm
Inner diameter of brake disc- 90mm
Speed of vehicle (V) - 50km/hr (13.89m/s)
Volume of brake disc-125663.70mm³
Density of brake disc material- 7250(kg/m³)-grey cast iron
Specific heat capacity of grey cast iron – 0.5 (kJ/kg/k)
Thermal conductivity of grey cast iron – 54(W/m K)
Ambient temperature- 22° Celsius.
Acceleration due to gravity- 9.81(m/s).

I. Deceleration of vehicle-

$$\begin{aligned} &= \text{coefficient of friction} * \text{acceleration due to gravity (g)} \\ &= 0.75 * 9.81 \\ &= 7.35(\text{m/s}^2) \end{aligned}$$

J. Stopping distance-

$$\begin{aligned} &= (\text{velocity of vehicle})^2 / (2 * \text{coefficient of friction} * g) \\ &= (13.89)^2 / (2 * 0.75 * 9.81) \\ &= 13.125\text{m}. \end{aligned}$$

K. Kinetic energy of the vehicle-

$$\begin{aligned} &= .5 * m * V^2 \\ &= .5 * 250 * 13.89^2 \\ &= 24.116\text{KJ}. \end{aligned}$$

L. Stopping time-

$$\begin{aligned} &= (\text{stopping distance}) / (\text{acceleration}) \\ &= 13.125 / 7.35 \\ &= 1.89 \text{ seconds}. \end{aligned}$$

M. Average power-

$$\begin{aligned} &= [\text{kinetic energy (E)}] / [\text{stopping time (T)}] \\ &= 24116.51 / 1.89 \\ &= 12760.05\text{W}. \end{aligned}$$

N. Heat flux-

$$\begin{aligned} &= [4 * P] / [(D^2 - d^2) * 3.14] \\ &= [4 * 12760.05] / [(.2^2 - .09^2) * 3.14] \\ &= 509500(\text{W/m}^2) \end{aligned}$$

O. Maximum temperature-

$$= \{ (0.527 * Q * \sqrt{T}) / [\sqrt{(\text{density of the material} * \text{specific heat capacity} * \text{thermal conductivity})}] \} + T(\text{amb})$$

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$$= \{(.527*509500*1.38)/[7250*500*54]\}+22$$

$$=48.48^{\circ} \text{ Celsius.}$$

P. Fade stop temperature rise-

$$= (P*T)/ (\text{Density of material} * \text{specific heat capacity} * \text{volume of rotor disc.})$$

$$= (12760.05*1.89)/ (7250*500*0.000125)$$

$$= 53.22^{\circ} \text{ Celsius.}$$

Thus, in here we see that fade stop temperature is higher than maximum temperature. So, theoretically proving fade is not possible.

V.ADVANTAGES

Q.Low-fade brakes such as disc brakes in steered wheels can do more braking without causing brake steer. [7]

R.Elimination of brake fading provides a larger leverage and mechanical advantage to resist the turning of the rotor itself.

S. It also provides a longer life time for the braking system, thus reducing the maintenance cost of the vehicle.

T. It also helps in ensuring that the brake pads have a sustained and longer life time.

VI.CONCLUSION

In this research paper, we have discussed the various terminologies involved in the braking system and their relation with respect to brake fade. We have also seen their dependence on temperature and heat flux. We also proved theoretically the elimination of brake fade in vehicles. Thus, ensuring that vehicles can experience a longer and sustained braking system.

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