Analysis of Temperature Distribution Behavior of Motorcycle Brake Pads

Khairul Shahril bin Shaffee, Mohd Khairuddin Hj. Ali Musa, Mohamad Sabri Mohamad Sidik, Mior Firdaus Mior Abd. Majid and Muhamad Husaini Abu Bakar

Abstract The gradual phasing-out of asbestos in motorcycles brake friction materials in many parts of the world has sparked the onset of extensive research and development into safer alternatives. As a result, the brake friction industry has seen the birth of different brake pads and shoes in the past decade, each with their own unique composition, yet performing the very same task and claiming to be better than others. This suggests that the selection of the brake pad design geometry surface is based more on original shape and simulation trial and error rather than fundamental understanding. This analysis strives to eliminate the cloud of uncertainty by providing an insight into the pros and cons of the geometry surface shape of motorcycle brake pad and make-up used in contemporary temperature behavior distribution on pads and shoes. In this analysis brake pad designs are reviewed and their advantages and disadvantages in contemporary brake applications are discussed.

Keywords Different brake pads geometry surfaces · New design Temperature distribution · Brake friction · Advantages and disadvantages brake pads

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K. S. bin Shaffee (✉) · M. K. Hj.A. Musa · M. S. Mohamad Sidik
M. F. M. Abd.Majid
Mechanical Section, Universiti Kuala Lumpur Malaysian Spanish Institute, Kulim Hi-Tech Park, 09000 Kulim, Kedah, Malaysia
e-mail: khairuls@unikl.edu.my

M. K. Hj.A. Musa
e-mail: khairuddin.jpm@gmail.com

M. S. Mohamad Sidik
e-mail: msabri@unikl.edu.my

M. F. M. Abd.Majid
e-mail: miorfirdaus@unikl.edu.my

M. H. A. Bakar
Manufacturing Section, Universiti Kuala Lumpur Malaysian Spanish Institute, Kulim Hi-Tech Park, 09000 Kulim, Kedah, Malaysia
e-mail: muhamadhusaini@unikl.edu.my

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1 Introduction

Brake pads are a component of disk brakes used in automotive and other applications. Brake pads are steel backing plates with friction material bound to the surface that faces the disk brake rotor. Brake pads convert the kinetic energy of the car to thermal energy by friction. Two brake pads are contained in the brake caliper with their friction surfaces facing the rotor. When the brakes are hydraulically applied, the caliper clamps or squeezes the two pads together into the spinning rotor to slow/stop the vehicle. When a brake pad is heated by contact with a rotor, it transfers small amounts of friction material to the disc, turning it dull gray. The brake pad and disc both now with friction material, then “stick” to each other, providing the friction that stops the vehicle.

Brake pad materials range from asbestos to organic or semi-metallic formulations. Each of these materials has proven to have advantages and disadvantages regarding environmental friendliness, wear, noise, and stopping capability. Semi-metallic pads provide strength and conduct heat away from rotors but also generate noise and are abrasive enough to increase rotor wear.

Asbestos was widely used in pads for its heat resistance but, due to health risks, has been replaced with alternative materials, such as mineral fibers, cellulose, aramid, chopped glass, steel, and copper fibers as shown in Fig. 1. Depending on material properties, disc wear rates vary. The properties that determine the material’s wear, involve trade-offs between performance and longevity. Newer pads can be made of exotic materials like ceramics, aramid fibres, and other plastics. Vehicles have different braking requirements. Friction materials offer application-specific formulas and designs. Brake pads with a higher coefficient of friction provide good braking performance with less brake pedal pressure requirement, but tend to lose efficiency at higher temperatures which increases the stopping distance. Brake pads with a smaller and constant coefficient of friction do not lose efficiency at higher temperatures and are stable, but require higher brake pedal pressure.

Fig. 1 Brake pads

1.1 Problem Statement

The disc brake is a device for slowing or stopping the rotation of a wheel of vehicles. To stop the wheel, the friction material in the form of brake pads is forced mechanically, hydraulically, pneumatically, or electromagnetically against both sides of the disc and causes the wheel to slow down or stop.

By the First Law of Thermodynamics, when the brake pedal is pressed, the brakes on the vehicle heat up, slowing it down. But if the brakes are used rapidly, the discs and brake pads will stay hot and get no chance to cool off. The brake cannot absorb much more heat because the brake components are already so hot. The braking efficiency is reduced. This malfunction of the brake system is called the brake fade. In every brake pad there is the friction material which is held together with some sort of resin. Once the brake pad starts to get too hot, the resin holding the pad material together starts to vaporize forming gas. This gas cannot stay between the pad and the disc, so it forms a thin layer between the brake pad and rotor trying to escape. The pads lose contact with the disc, thus reducing the amount of friction. The design of the brake pad is important to determine the rate of cooling and uniform wear of disc and brake pad and thus affecting the braking efficiency.

This project will focus on the simulation analysis of the temperature distribution behavior of motorcycle brake pads during operation when forces and moments generated from the braking are applied. The temperature distribution of the brake pad from the simulation result can be analyzed. To study about the effect of motorcycle brake pads performance includes the following variables:

- Contribution on heat transfer coefficient (h),
- Temperature (T),
- Total heat (q),
- Brake pads geometry (surface, area) and provide result of area.

There is never a right analysis data about motorcycles brake pads.

High temperature distributions at disc brake components may cause undesirable effects, leading to brake failure.

1.2 Objective

The aim of this project is to determine the temperature distribution and to study the temperature behavior from the new design geometry shape of motorcycle brake pad. To achieve this project, the objectives are set as below:

1. To analyze the temperature distribution as well as the maximum temperature attained.
2. To design a new model of motorcycle brake pads.
3. To compare the datum design with the new design to determine the best design of motorcycle brake pads.

1.3 Scope and Limitation

The scopes and limitation of this project are:

1. Literature review on the working principles, component, standard and theories about the brake system.
2. To analyze the temperature distribution behavior of the best geometry shape design for the motorcycle brake pad.
3. Develop a new design geometry surface of brake pads.
4. Simulation of the thermal transient behavior using ANSYS software.
5. Construction of 3D modeling for motorcycle brake pad design.

2 Literature Review

The braking system used in the car is used primarily to help the driver to control the vehicle deceleration. It is one of the major systems and specifically designed to reduce the speed of a fast-moving vehicle. An ordinary car braking system consists of a brake device having different components, which are used to slow down or stop the vehicle. More precisely, the tools to reduce or stop the speed of a moving or rotating body by absorbing kinetic energy mechanically or electrically. The system automatically controls the wheel slip and prevents the wheels from spinning. They are widely used in motor vehicles, buses, trucks, trains, airplanes, motorcycles and other types of vehicles. The braking system used in cars has come a long way in recent years. The use of anti-lock braking system along with the introduction of different brake components made of carbon fiber, steel, aluminum and others have completely stopped giving better performance compared to traditional brake system.

Sliding contact member brake discs result in the conversion of kinetic energy into heat at the pad and disc interface. Increase in friction is a limited quantity and depends on the coefficient of friction, rubbing the radius of the road, and the forces acting on the pad. The slip process leads to a rise in temperature, while the peak is one of the most important factors in the action to occur. The temperature at the contact surfaces during the quarter emergency brake system is intensified by a significant heat load caused by the friction force and high velocity of this process [1].

Temperature and thermal constriction resistance as a function of the parameters of the velocity is determined. Temperature and thermal stresses pad (band) with retarded continuous sliding on the surface of the disk (a half) both during and after the heating studied [2].

However these geometric configurations can study with the actual engineering applications, where there is no perfect solution, particularly the application of finite frictional heating system needs to be recognized. Simplification of the actual

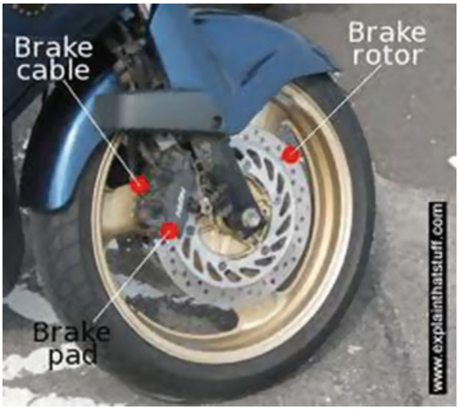

Fig. 2 Motorcycle brake pads system

modeling techniques from three-dimensional to two-dimensionality associated with the rate of heat uniformly distributed circumferentially were so far achieved [3].

Disc brakes consist of a cast iron disc that rotates with the wheel, caliper fixed to the steering knuckle and the friction material (brake pads) as shown in Fig. 2. When the braking process occurs, the hydraulic pressure forces the piston and therefore the pad and the disc brakes are in sliding contact. This prepares a resistance movement and the vehicle slows down or eventually stops. The friction between the disc and the pads are always opposes to the motion and the heat generated by the conversion of kinetic energy. Under the influence of temperature, friction elements, the operating conditions become less favorable friction patches and result in decreasing wear and friction coefficient decreases, which can lead to emergency situations. Therefore, experimental, mathematical and numerical modeling of the temperature distribution is a significant problem in the design of the braking system.

The experimental determination of the surface temperature of objects authentic touch in most cases significant technical problems and expenses [4]. Therefore, the analytical or numerical definition of a temperature regime of friction pair elements obtained with the corresponding problem solving frictional heat during braking attracted great interest.

3 Methodology/Experimental Set-Up/Model Set-Up

There is an advantage of brake pads, where most of them are poor to thermal conductivity which protects the hydraulic actuating elements from overheating. It is also ease to manufacture and low cost. However, the pads needs to be inspect frequently due to rapid wear as a result from higher temperatures and contact pressures associated with the operation of a brake disc. Figure 3 shows a typical geometry of the brake pad design.

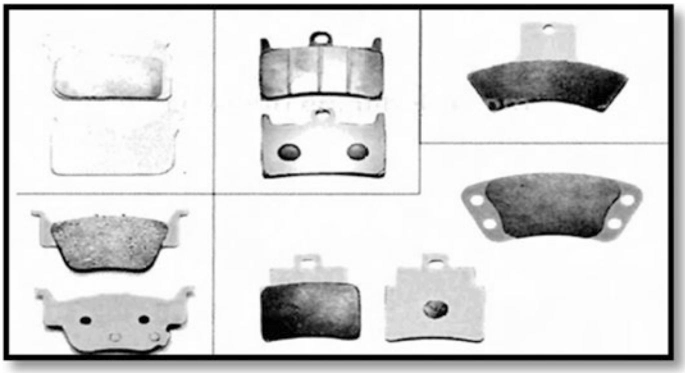

Fig. 3 Motorcycle brake pads geometry shape

3.1 Modeling Software

There are different softwares available for modeling some of them are:

- Solid works
- Pro-E
- Ideas
- Inventor
- Catia v5.

Solidworks a multi-platform CAD/CAM/CAE is used as the modeling tool in this project.

3.2 Solidworks (Part Modeling)

The SolidWorks is a Parasolid-based solid modeler, and utilizes a parametric feature-based approach to create models and assemblies. Parameters refer to constraints whose values determine the shape or geometry of the model or assembly. Parameters can be either numeric parameters, such as line lengths or circle diameters, or geometric parameters, such as tangent, parallel, concentric, horizontal or vertical, etc. Numeric parameters can be associated with each other through the use of relations, which allow them to the capture design intent. SolidWorks allows the user to specify that the hole is a feature on the top surface, and will then honor their design intent no matter what height they later assign to the model as shown in Fig. 4.

Building a model in SolidWorks usually starts with a 2D sketch (although 3D sketches are available for power users). The sketch consists of geometry such as points, lines, arcs, conics (except the hyperbola), and splines. Dimensions are added

Fig. 4 Brake pads part design using solidworks

to the sketch to define the size and location of the geometry. Relations are used to define attributes such as tangency, parallelism, perpendicularity, and concentricity. The parametric nature of SolidWorks means that the dimensions and relations drive the geometry, not the other way around. The dimensions in the sketch can be controlled independently, or by relationships to other parameters inside or outside of the sketch.

3.3 Material Properties

Young's modulus (EX) must be defined for a static analysis. If we plan to apply inertia loads (such as gravity) we define mass properties such as density (DENS). Similarly if we plan to apply thermal loads (temperatures) we define the coefficient of thermal expansion (ALPX) as shown in Table 1.

3.4 Thermal Analysis

A thermal analysis calculates the temperature distribution and related thermal quantities in a system or component. Typical thermal quantities are:

- The temperature distributions
- The amount of heat lost or gained
- Thermal fluxes.

Table 1 Material properties for asbestos

Thermal conductivity	2.06 wm/k
Density	2798 kg/m^3
Specific heat, c (J/kg k)	691
Poisson's ratio, v	0.25
Thermal expansion (×10.5)	1.0
Elastic modulus	14.25 GPa
Coefficient of friction, μ	0.2

Types of Thermal Analysis:

1. A steady state thermal analysis determines the temperature distribution and other thermal quantities under steady state loading conditions. A steady state loading condition is a situation where heat storage effects varying over a period of time can be ignored.
2. A transient thermal analysis determines the temperature distribution and other thermal quantities under conditions that vary over a period of time. The expected result at the end of the research is when the measurement surface geometry changes, the temperature conditions will decrease and produce better results.

3.5 Mesh Generations

In the finite element analysis the basic concept is to analyze the structure, which is an assemblage of discrete pieces called elements, which are connected, together at a finite number of points called nodes. Loading and boundary conditions are then applied to these elements and nodes. A network of these elements is known as the mesh (Fig. 5).

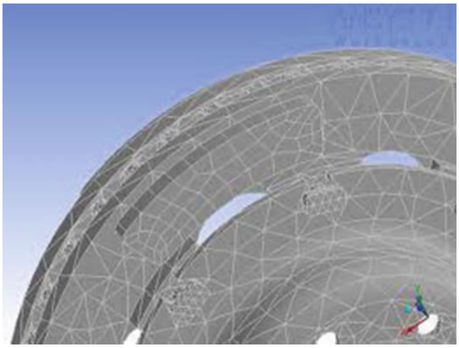

Fig. 5 Meshed model of the brake pads

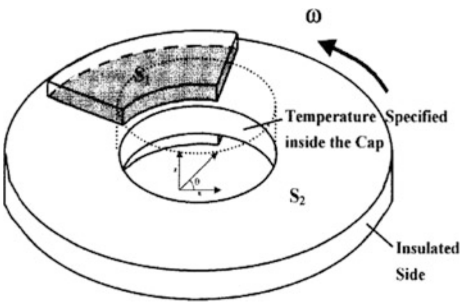

Fig. 6 Boundary condition

3.6 Condition

As shown in Fig. 6 a model presents a three-dimensional solid disk squeezed by two finite-width friction material called pads. The entire surface, S, of the disk has three different regions including S1 and S2. On S1 the heat flux is specified due to the frictional heating between the pads and disk, and S2 is defined for the convection boundary. The rest of the region, except S1 and S2, is either temperature specified or assumed to be insulated: the inner and outer rim area of the disk.

4 Results and Discussion

Design analysis

From the ten design variations, the best design has been chosen which is the design that had a lower maximum temperature distribution. Value of material properties has been added to the new design and then the analysis has been done. The result is shown in Fig. 7.

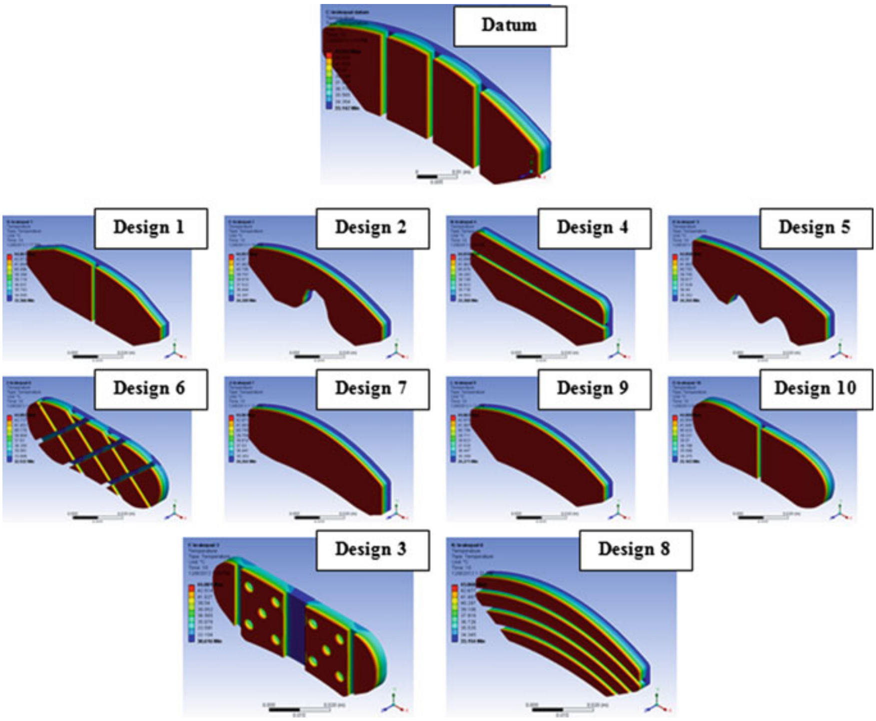

Fig. 7 Design analysis using thermal approach

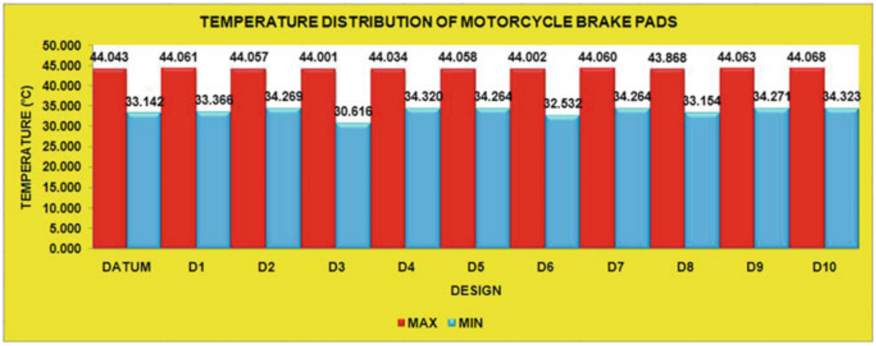

Fig. 8 Temperature distribution

Criteria to determine a good design with datum design

The graph in Fig. 8 shows that the lowest maximum temperature is design 8, compared with the datum design. The results shown in the graph of the temperature distribution, that the actual design 8 is the best compared with the other design. The graph in Fig. 9 shows the total heat flux for all designs compared with the design datum. In this analysis, the determination of the best design is dependent on the highest total heat flux. What can we see in this graph is that the design 3 is the best from the datum design and the design 8 the best design and was selected in the graph of temperature distribution.

Comparison of the new design with the datum design

The pie chart in Fig. 10 shows the difference in percent of each design compare to the design datum. This percentage pie chart shows that the design 8 is the best with 46.54%, while design 3, shows the percentage of 11.17% is moderately good and the percentage of the worst in this analysis is the design 4 which is 2:39% compared to the datum design.

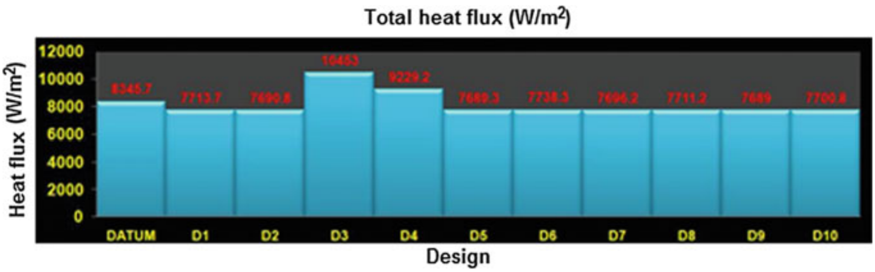

Fig. 9 Total heat flux

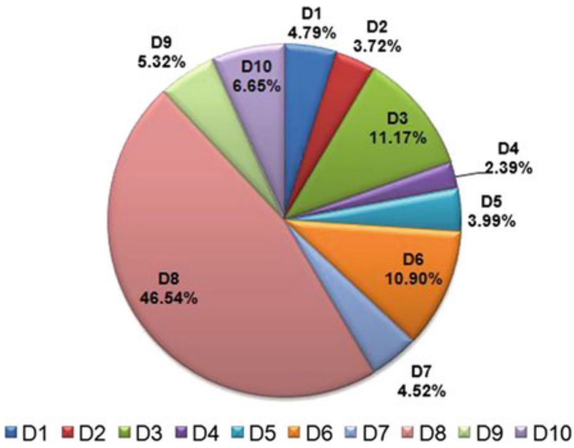

Fig. 10 Percentages new design compared to datum design

5 Discussion

After all the analysis has been completed and the data collection in each analysis, some problems have occurred in the analysis. To find the best design is so difficult because there are two designs, which have their own advantages in the design. First, design 8 (the best lower temperature distribution) and second, design 3 (the best total heat flux), this decision has to be made, with a look at some of the factors that enabled the results to be accurate. Therefore, an additional analysis was made which makes the analysis of the distribution of the temperature, for all design including the datum design to see the movement of the temperature, from the front temperature to the center/grooving surface to the back surface. Among other factors to be considered are analyze the pro & contra between the two designs in Fig. 11 are:

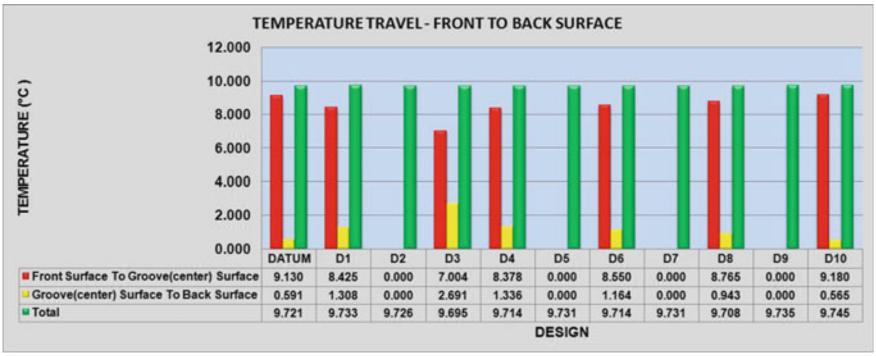

Fig. 11 Percentages of new design compared to datum design

- (Design 3—easy to wear and suitable for superbike racing only)
- (Design 8—can be used for long time and suitable for all standard bikes).

Finally, after consideration of all the mentioned factors, design 8 has been selected to be the best design in the analysis.

6 Conclusion

The conclusion can be made from the result obtained from different forms, the modified model with different surface pads has a better result than the datum design. So the best design option is design 8, after a comparisons made according the criteria required to achieve the objective of the analysis. Finally, it can be concluded that the temperature is slowly expanding by the selected design from design 3, is due to the large surface area and temperature distribution for the selected design is the best design of the datum and nine others.

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