The effect of disc brake pads conditions on brake performance

Saad A Ahmad [1], Khaled Alrefaei [1], Yousef Ali Mulla [1] , Yousef Alhouli [2]

[1] The Industrial Training Institute – Sabah Al Salem

[2] Automotive and Marine Engineering Technology Dept. / Collage of Technological Studies Public Authority for Applied Education and Training (PAAET), Kuwait

Abstract

As a part of friction material component, brake pads is generally a composite with different combination of materials. Its constituents are in a form of frictional additives, filler, binder and reinforcing fiber. Each constituent plays an important role in ensuring the brake pads are intact together and function properly.

In this paper a study of effect of the coefficient of friction in brake pads to the integrity of brake system is presented. Three brake tests are made on three different cars (Mitsubishi Pajero 2014, GMC Yukon 2016 and Dodge Durango 2013) using a different coefficient of friction of brake pads to simulate brake pads failure. The modifications was done to the three cars on the front right hand side axle by using aftermarket brake pads beside the original (genuine) brake pads on the other axles to simulate a different brake pads coefficient of friction. The test was repeated three times for each car to insure the accuracy of the results. All results were recorded by special device Bosch Brake Test Lanes.

Keywords: ***Disc brake rotor, Brake pads, Automotive brake***.

1. Introduction

The brake system is designed to control the speed or stop of any vehicle by transferring kinetic energy of the vehicle via friction to heat energy. The brake system is made of a combination of hydraulic electric, electronic and mechanical systems in the modern vehicles to achieve the required result of the barking. In this paper the study was focused on using disc brake rotor type system which is used in most of modern vehicles. The hydraulic parts are the master cylinders, pipe lines, ABS system pump, and brake caliper cylinder. The Mechanical parts are the brake pedal, calipers, and the brake discs. When the driver presses on the brake pedal, the master cylinder increase the pressure in the brake lines which result on the brake caliper squeeze/clamp the pads against the disc rotor from each side and rubs it to make it slow down or stop. Consequently, the more pressure applied on the brake pads the higher friction results. However the coefficient fraction of the brake pads plays very important role in the braking force which is considered in the early stages of vehicle design.

The brake pad materials should be designed to achieve the optimum performance of the brake which can achieve the vehicle stability and adequate coefficient of friction (μ) under varying conditions of load, velocity, temperature and high durability.

Brake pads are made of a mix of five types of materials (binder, Abrasive, Performance, Filler and Structural), each material has its own function of friction properties, physical, chemical and mechanical.

These materials encompass more than 2000 substances and brake pads manufacturer such as OEM (Original Equipment Manufacturer) or aftermarket mixing these materials substance to produce 3 main kind of brake pads that are commonly used in today's vehicles: Organic, semi-metallic and ceramic brake pads. Each kind has a different values of coefficient of friction during operating conditions.

The objective of the present study was to examine the failure of brake system by using aftermarket brake pads for the right front hand side axle and original brake pads for the other side axle to simulate a different brake pad coefficient of friction.

2. Literature review

Experimental investigation on disc brake is presented in this paper, the study presents the effect of the coefficient of friction in brake pads to the integrity of brake system. The literature shows different studies on disc brake, Choi and Lee [1] studied a transient analysis for thermo-elastic contact problem of disk brakes with frictional heat generation. Belhocine, Bouchetara, and Mustafa used Finite Element Analysis (FEA) to present the thermo-mechanical Behavior of disc brake rotor. The study focus on the thermo-mechanical Behavior of Dry Contacts in Disc Brake Rotor with a Grey Cast Iron composition and the thermo-mechanical behavior of the dry contact between the brake disc and pads during the braking phase [2].

Cunefare and Graf [3] presented an experimental investigation into the application of “dither” control for the active control and suppression of automobile brake disc squeal. Adamowicz et al. [4] studied and compared the temperature distributions caused by mutual sliding of two members of the disc brake system basing on two- and three-dimensional FEA modelling techniques and complexity of the phenomenon. Also they evaluated an impact of convective mode of heat transfer on the thermal behavior of a disc brake system during repetitive braking process with the constant velocity using fully three-dimensional finite element model [5].

Alnaqi et al. [6] evaluate the thermal performance of a disc brake by using scaling .The result was validated by comparing the results for the full and small scale discs using a conventional brake dynamometer in addition to the numerical simulation. Teoh et al. [7] developed minimal model of drum brake squeal under binary flutter instability which is caused by the velocity independent friction coefficient. They presented and investigated the effect of the friction coefficient, damping coefficient and the location of cater of contact pressure.

More and Sivakumar [8] have utilized Computational Fluid Dynamic (CFD) in their analysis of automotive ventilated disc brake rotor. Ripley et al. [9] reported on their paper neutron-diffraction measurements of the levels and distribution of residual strains in a used cast iron brake disc rotor. Söderberg et al. [10] discussed how wear of the pad-to-rotor interface can be predicted using general purpose FEA software. They developed three-dimensional FE model of the brake pad and the rotor to calculate the pressure distribution in the pad-to-rotor contact.

Antti et al. [11] presented the characteristics and difficulties encountered in tackling brake squeal and provided a review of the analytical, experimental and numerical methods which were used for the investigation of brake squeal.

Despite the numerous studies of the disc brake rotor in the literature, explicit study on the effect of disc brake rotor thickness has not be stated. This paper aim to fill this gab and identify the effect of such problem and recommend what precautions must be taken in such problem.

3. Tests Description and Specifications

Mitsubishi Pajero 2014, GMC Yukon 2016 and Dodge Durango 2013 cars are used in this research as shown in Figure 1 with the cars specifications listed in Table (1) to examine a different brake pads coefficient of friction. Three brake tests were carried out in this work. Test (1) Shows a new original brake pads are using for the front axle of each car to examine the brake force at normal condition. Test (2) shows a new commercial brake pads are using for the front axle of each car. This test is done to simulate the difference in brake force between the original and the commercial brake pads. Test (3) was carried out to simulate a different brake pads coefficient of friction by using aftermarket brake pads on the right hand side front axle, beside the original brake pads on the left hand side axle.

The tires, calipers and disc rotors for the 3 cars were in a good conditions.

All tests on the brake force is then taken for the 3 cars by a special device (Bosch brake test lanes shown in Figure 2 with test specification listed in Table 2) to examine the strength and performance of the brake system.

Table 1: Specifications for the vehicles used in the test

Vehicle data			
Manufacturer	Japan	USA	USA
Model	Mitsubishi Pajero 2014	GMC Yukon 2016	Dodge Durango 2013
Mileage	61151	52456	59046
Engine size	3.5L V6		5.7L V8
Transmission		6-speed Automatic	6-speed Automatic

Table 2: Specifications for the Bosch brake test lanes

Model number	SDL 4330 S40
Maximum test load	2.5 t
Maximum transit load	4.0 t
Dimensions (W x L x D)	2360 x 660 x 250 mm
Roller diameter	205 mm
Roller width	70 mm
Roller elevation	25 mm
Type of display	Analog
Nominal measuring range	0-8Kn

Figure 1: Bosch brake test lanes

4. Test Procedure and Results

Test (1) A new original brake pads are using for the front axles of each car:
Bosch brake test lanes device is used to record the test results and show the strength and performance of the brake system. The devise showed three type of results for both the front and rear axles: suspension test, service brake, and park brake tests as shown in Table 3. However, the main focus of this research is in the front brake test.

Once the new original brake pads shown in Figure 3 fitted on the test vehicles (Figure 4), test was carried out to examine the different brake pads coefficient of friction between the front right and left axles.

Table 3: Mitsubishi Pajero difference-service front brake tests

Test one			
	Left	Diff	Right
Rolling resistance	164 N		192 N
Brake force	4438 N	2 %	4533 N
Pedal force weight	Left	Diff	Right
Test two			
	Left	Diff	Right
Rolling resistance	1540 N		1220 N
Brake force	3649 N	15 %	3111 N
Test three			
	Left	Diff	Right
Rolling resistance	183 N		202 N
Brake force	4920 N	25 %	3668 N

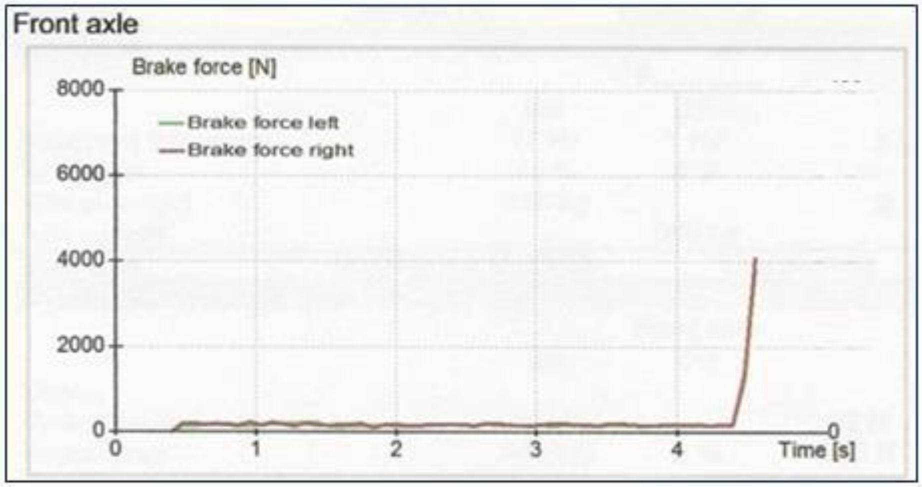

Figure 2 Test one (Mitsubishi Pajero)- breaking force time

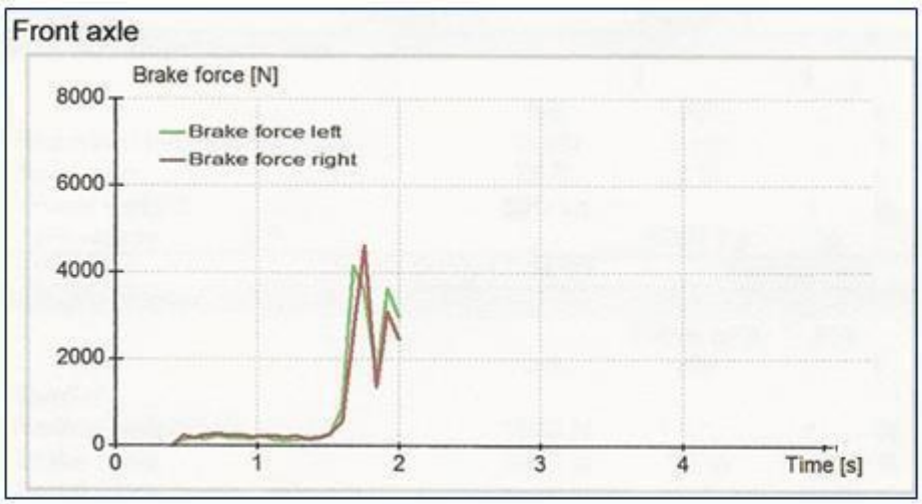

Figure 3 Test two (Mitsubishi Pajero)

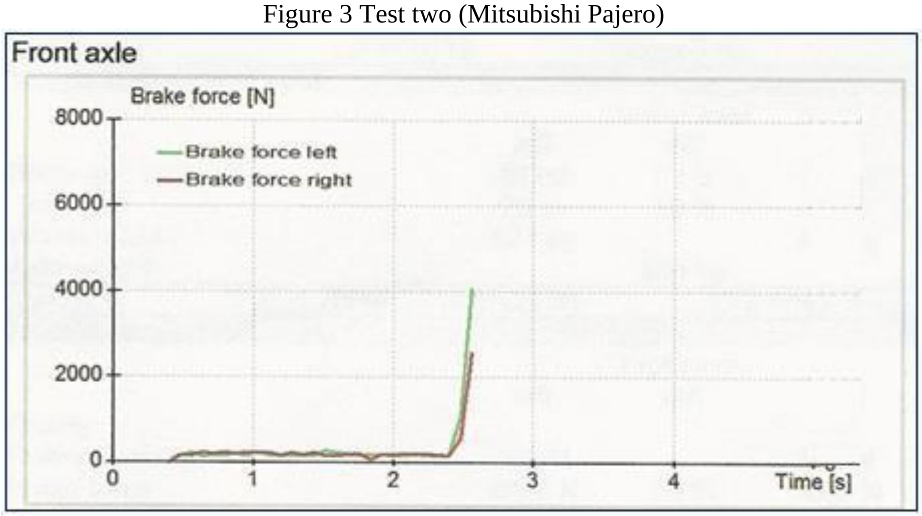

Figure 4 Test Three (Mitsubishi Pajero)

Table 4: GMC Yukon difference-Service front brake tests

Test one			
	Left	Diff	Right
Rolling resistance	125 N		125 N
Brake force	4631 N	2 %	4533 N
Test two			
	Left	Diff	Right
Rolling resistance	144 N		134 N
Brake force	5247 N	9 %	4754 N
Test three			
	Left	Diff	Right
Rolling resistance	144 N		154 N
Brake force	4814 N	23 %	3697 N

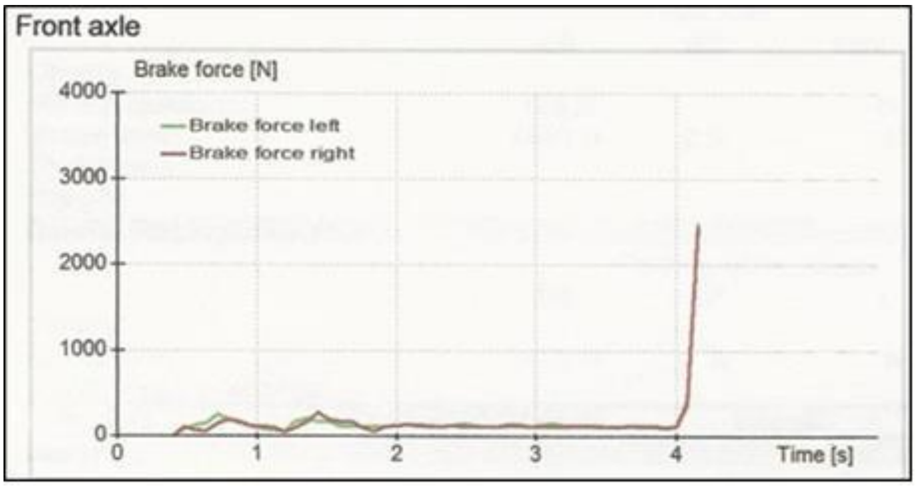

Figure 5: Test one GMC Yukon

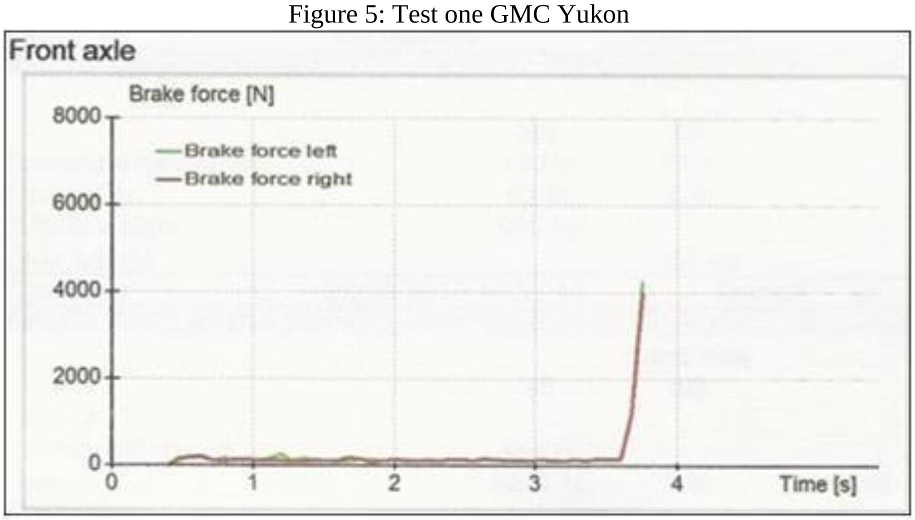

Figure 6: Test two GMC Yukon

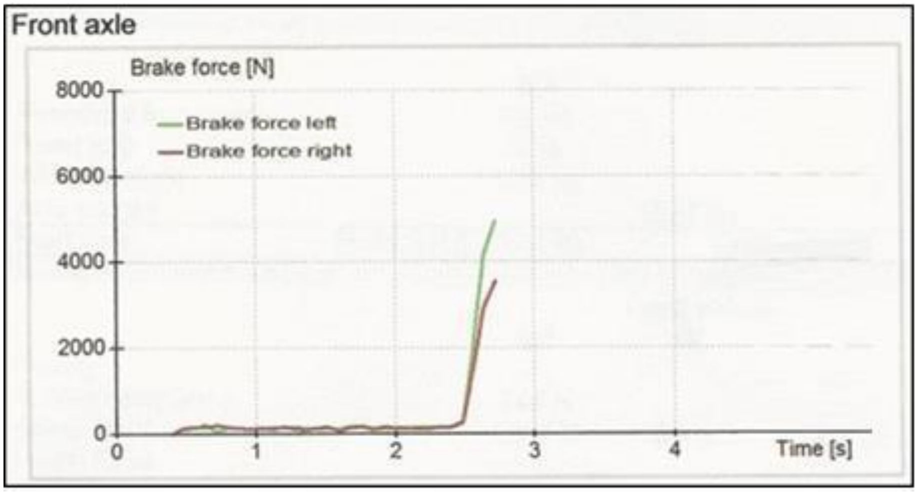

Figure 7: Test three (GMC Yukon)

Table 5: Dodge Durango difference-Service front brake tests

Test one			
	Left	Diff	Right
Rolling resistance	164 N		182 N
Brake force	5151 N	3 %	4974 N
Test two			
	Left	Diff	Right
Rolling resistance	154 N		163 N
Brake force	3283 N	11 %	2910 N
Test three			
	Left	Diff	Right
Rolling resistance	164 N		125 N
Brake force	3322 N	28 %	4600 N

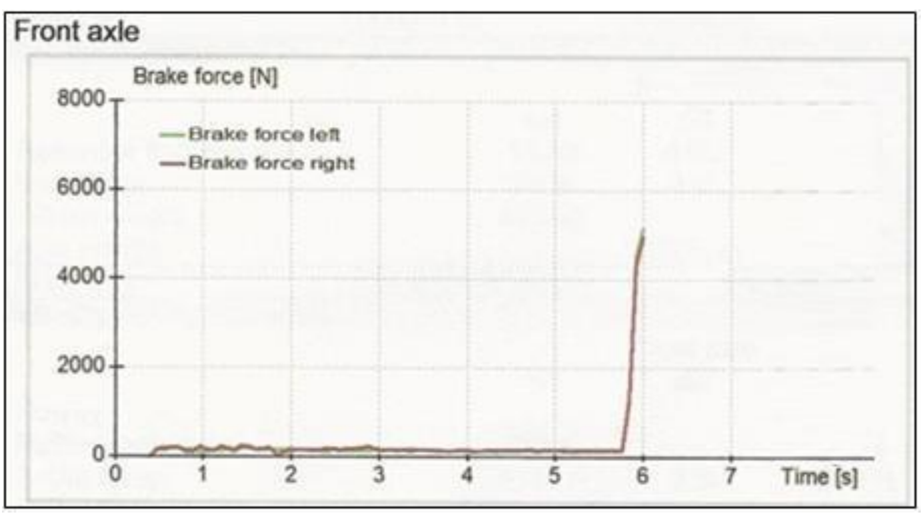

Figure 8: Test one (Dodge Durango)

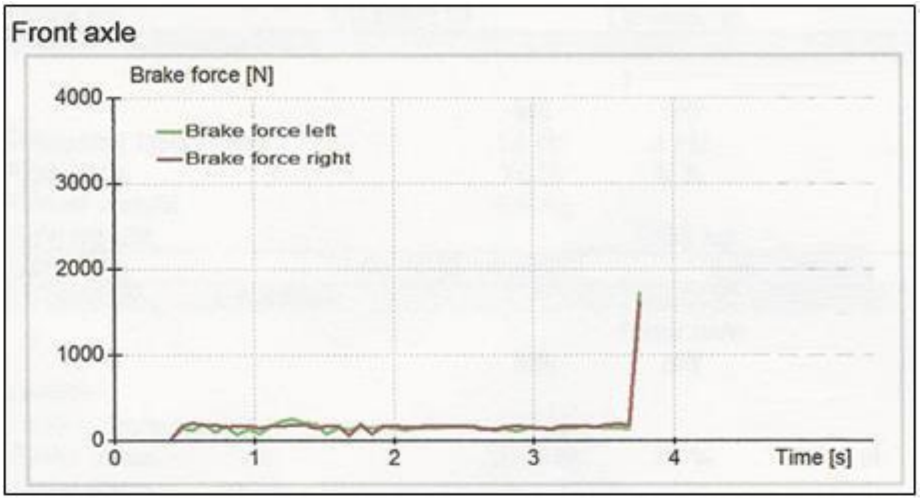

Figure 1: Test two (Dodge Durango)

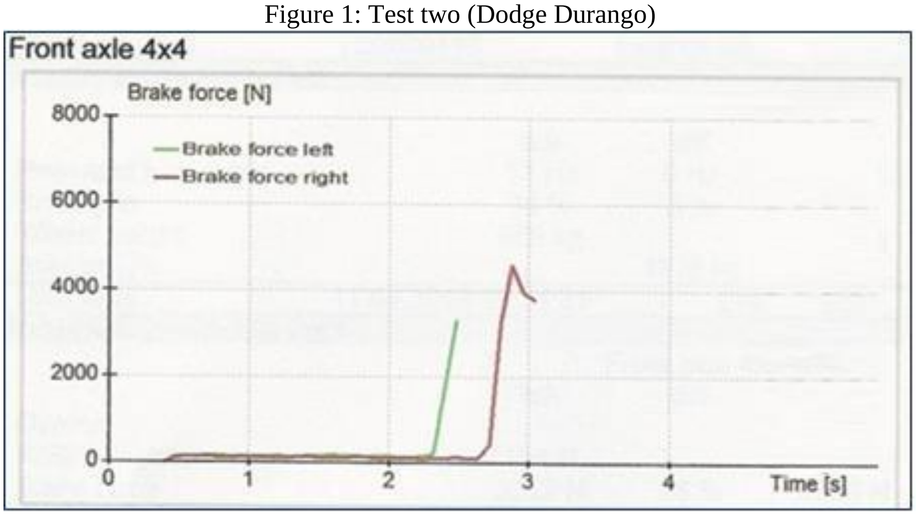

Figure 2: Test three (Dodge Durango)

Through the above results and from Tables: 5,6 and 7 a good condition original brake pads is fitted for the 3 cars generate less than 3% for the Pajero and Yukon and 3% for the Durango , difference in brake force between left and right axles. And it’s clear from the chart results for each car the brake force that bring the vehicles to complete stop were nearly the same in the right and left wheels, that results make the vehicles achieved successful braking and balanced.

Test (2) A new commercial brake pads is fitted in brake test for front axles of each car shown in Figure 5, This test is done to simulate the difference in brake force between the original and the commercial brake pads.

Through the above results and from Tables: 8,9 and 10 a new commercial brake pads fitted for the 3 cars generate 15% for the Pajero, 10% Yukon and 11% for the Durango , difference in brake force between left and right axles, however the difference-service brake (Δ) test for each car didn’t exceed the allowed limits of 25% . And it’s clear from the chart results for each car the brake force that bring the vehicles to complete stop for the Pajero is nearly 3100 N on the left brake side and nearly 2600 N on the right brake side, and for the Yukon is nearly 4300 N on the left brake side and nearly 4000 N on the right brake side and for the Durango is nearly 1800 N on the left brake side and nearly 1650 N on the right brake side. Within this test condition, the cars was balanced and successful braking was achieved.

Test (3) Different brake pads coefficient of friction, once the new commercial pads is fitted on the right hand side front axle, and the original brake pads is fitted on the left hand side axles, the tests carried out showed the difference in the coefficient of friction between the original brake pads and commercial brake pads during the brake test.

Following the modification that was made to simulate fault in coefficient of friction values caused by different of friction brake pads materials. The results showed that the brake force difference-service brake (Δ) test was carried out difference in brake force between left and right axles for Pajero and Yukon (25% , 23%) Which is nearly to exceed the allowed limits of 25% and Durango (28%) which is exceed the allowed limits of 25 %. Also it’s clear from the chart results for each car the brake force that bring the vehicles to complete stop for the Pajero is nearly 4100 N on the left brake side and nearly 2800 N on the right brake side, and for the Yukon is nearly 5000 N on the left brake side and nearly 3600 N on the right brake side and for the Durango is nearly 4800 N on the left brake side and nearly 3300 N on the right brake side. Which is clear from the obtained chart a peak brake forces achieved to bring the vehicles to complete stop. All of these results indicate big difference that could lead to unbalanced Brake system.

5. Conclusions

The brake pads have a great impact on performance of the brake system. When the brake pad has a different coefficient of friction comparing to the other brake pad on the other side of the vehicle, an unequal brake force between the right hand-side and the left hand-side axle will be produced. In this case, the brakes will grab harder on one side. Unbalanced force can cause the brake to pull to one side and the car will spin out of control or skid and shifted from the road when the driver depress the brake pedal to stop the car. This brake failure may lead to accidents, property damage, physical injuries or even death of an individual

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