Design and Experimentation of Test Rig for measuring Effectiveness of Brake Pad

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Abstract— Design and experimentation of test rig for measuring the effectiveness of brake pad aimed at estimating the performance of brake pad of a bike under numerous braking conditions and there by assist in the disc project and analysis. The test rig is equipped with several measuring instruments, and data acquisition systems [DAQ], which are necessary for performing the tests. Two sets of brake pads are tested. Optimized brake pads with hatched surface are suggested as it will dissipate more heat and increase its effectiveness. An analysis into practice of new materials is essential which improve braking efficiency and provide better stability to vehicle. We used two alternate materials fly ash and c-c composites. This investigation is done using ANSYS software along with the modeling software CATIA V5.Analysis done on real model of disc brake rotor of Bajaj pulsar 180 and rotor of different materials. Therefore, it gives optimize stress, deformation & weight of the improved disc brake rotor & also good heat dissipation.

Key words: Brake disc, Rotor, Thermal analysis, PRO-E, ANSYS software

I. INTRODUCTION

In design optimization problem there are aims and limitations that must be met. With mechanical design, size, weight, strength, and cost are a few of the many restraints that may need to be taken into concern when designing for a set of objectives. Two sets of brake pads are tested. Optimized brake pads with hatched surface are suggested as it will dissipate more heat and increase its effectiveness. Hatched pads are hatched in inclined way. Hatch pads increase the friction and are more efficient than the existing brake pads. Temperature is reduced due to hatching as it provides ventilation between the brake pads, and gives us the better results.

Altered materials fly ash and c-c composites for disc rotor are compared with the current material. These materials are compared and analyzed using present model, from which the best solution is chosen. The best material is then enhanced upon iteratively. These iterations are in essence series of trial and error that can regularly need many cycles, each of which can be expensive and time consuming. With finite element analysis and optimization, other difficult problems can be solved more rapidly, reducing the amount of physical testing for a new material. This helps address the cases whereon-optimal projects might carry on to be used to cut the time, cost, and danger of trying to find a better design. FEA methods are used to make disc brake rotor with material which is lighter and gives good results than the current rotor. The analyses will be taken with the help of sensors which are more accurate than manually taken results.

II. LITERATURE SURVEY

An Experimental Brake Pad Test Rig was designed and constructed using readily available materials. The equipment was designed to test automobile disc brake pad wear and effectiveness at various speeds and braking forces. To determine its functionality a wear test was conducted on a commercial brake pad at various speeds and brake forces. This prototype test rig can be used in testing the brake pad of different vehicle such as Toyota, Mitsubishi, Volvo, Peugeot, and other brands of interest. [1]

This study describes an inertial dynamometer system (test rig) which has been applied to the testing of disc brake pads at different operating conditions. The test rig is equipped with several measuring instruments, and data acquisition systems [DAQ], which are necessary for performing the tests. Two sets of brake pads are tested. This study explains the temperature distribution obtained by experiments on two different shapes of brake discs pads affected by the types of shapes of brake discs pads, disc geometry and operating conditions. The test results also showed that the friction with hatched pad better fades resistance than the others. [2]

Transient Thermal and Structural Analysis of the Rotor of Disc Brake is aimed at evaluating the performance of disc brake rotor of a bike under severe braking conditions and there by assist in disc rotor design and analysis. An investigation into usage of new materials is required which improve braking efficiency and provide greater stability to vehicle. [3]

This work is presented with "Design modification & optimization in stress, deformation & weight of Disc brake rotor" which studies about on disc brake rotor by modeling & analysis of different shapes of slots of different vehicle's disc brake rotor with same outer diameter & inner mounting position of holes on wheel hub as like Bajaj Pulsar 150.Analysis done on real model of disc brake rotor of Bajaj pulsar 150 and disc brake Rotor of different shapes of slots of different vehicle's in one Disc brake rotor [4]

This study incorporates the FEA and EMA analysis of squeal which is disc brake rotor of Cast steel material, the different parameters which are responsible for squeal in the braking system have been analyzed with the help of experimental modal analysis for Free-free condition and FEA is done with their boundary conditions. "Brake squeal" means noise occurs when the speed of the vehicle is below 30km/h and braking pressure is below 2Mpa, which radiates the noise in 1 kHz to 16 kHz audible frequency range. [5]

By applying brake, shoe pad is grip the disc of disc brake due to that stopping of their rotation and altering kinetic energy in to Heat energy due to speedily apply handbrake there is thermal stress produce of disc. [6]

In this project the investigation is done by modeling & analysis of different shapes of slots of different vehicle's disc brake rotor with same outer diameter & inner mounting position of holes on wheel hub as like Bajaj Pulsar 220cc.. The shape optimization technique is used to find the optimum design solutions. The outer diameter, inner diameter, mounting position of holes on wheel hub is considered as the constraints for design. The goal was to design a rotor with minimum stress level and that maintains similar structural performance as rotors that are currently commercially available. [7]

Friction-induced vibration of disc brakes is a topic of major interest and concern for the automotive industry. Customer complaints result in significant warranty costs yearly. In the present paper, a detailed experimental study of the disc brake vibration is performed on a simplified brake dynamometer.[8]

In this paper carbon ceramic matrix disc brake material use for computing normal force, shear force and piston force and also calculating the brake distance of disc brake. The typical disc brake two wheelers model using in Ansys and done the Thermal analysis and Modal analysis also calculate the deflection and Heat flux, Temperature of disc brake model. This is important to know action force and friction force on the disc brake of new material, how disc brake works more well, which can help to decrease the accident. [9]

In this study, the temperature distributions and stress situations of four different pad materials during 300 s occurring as a result of permanently braking were examined using Solid Works Simulation Solutions packet program with finite element method. In the study, in order to consider the impact of pad's wear, two pads of different thicknesses were examined as well. [10]

In this work, an alternative material has been proposed for the brake pad and rotor to achieve effective braking conditions and stability of the vehicle by increasing coefficient of friction and good wear resistance. Two different materials, S2 Glass Fiber and Carbon fiber are selected as thepad materials and Aluminum alloy and Gray Cast iron is selected for the rotor material. Static and thermal analysis was performed on solid disc and ventilated discs for different pad materials and rotor materials using ANSYS 15[11]

This work investigates the thermal properties of polyvinyl chloride and asbestos ceiling sheet. We have studied the thermal properties of these materials in terms of the thermal conductivity (TC), thermal resistivity (TR), thermal diffusivity, thermal absorptivity, and specific heat capacity (SHC). The result showed that thermal conductivity, thermal resistivity, thermal absorptivity, thermal diffusivity and specific heat capacity values of PVC and asbestos ceiling sheets falls within the range of good insulating materials like pine fibre-board and oak wood.[12]

III. PROBLEM STATEMENT

The effectiveness of the brake pad depends upon the material of disc and the shape of brake pads which is used. The material used for brake pads is asbestos and suggesting any alternate material for the brake pads is quite a costlier thing. So alternatively, to increase the effectiveness of brake pads we used alternate materials for the disc rotor. After using the alternate materials for disc the wear rate is less than the existing brake pad our goal is achieved. To increase the effectiveness of brake pads we have changed the shapes of the brake pads. After using the alternate shape for brake pad, the wear rate is less than the existing brake pad and the heat dissipation is also less and our goal is achieved.

In the present work we aimed is to find optimize brake pads and the disc rotor solution which should be efficient than the existing model brake disc rotor of Bajaj 180 cc. The structural shape optimization technique is used to optimize the brake pads and alternate material disc rotor then validate it in vibrational and thermal analysis.

IV. METHOD OF ANALYSIS

The CAD model is prepared in CATIA. The CAE Analysis is done in ANSYS 15. The analysis is done to determine the thermal and modal analysis for brake pads and rotor materials. The best optimized is found out in Comparison with the existing model and other samples. The thermal analysis is done to check the thermal behavior with change in the surface area. The modal analysis is done and found out the mode shape for the material. The experimental analysis is done with the prepared set for both the thermal analysis and for the modal analysis. The Comparison of two brake pads and the three disc rotor is done to validate the results.

V. EXPERIMENTAL SETUP

The experimental setup consists of

- 3-Phase, 2 HP, 1440 Rpm Motor.
- Shaft
- Caliper
- Hydraulic Brake Assembly
- Frame
- Variable frequency device and
- Sensors to measure temperature,

Frequency, noise and acceleration.

Fig. 5: Experimental Setup

A. Input Parameter for Disc brake of Bajaj Pulsar 180 cc

Rotor disc dimension = 260 mm. (260×10^{-3} m)
Rotor disc material = Cast Steel
Pad brake area = 1692 mm^2 (1692×10^{-6} m^2)
Pad brake material = Asbestos

Permissible temperature = 250 ºC
Maximum pressure = 1 MPa
Vehicle speed = 100 Km/hr. [3]
Mass of vehicle =150 Kg.

Fig. 5: A Actual brake pads for Bajaj pulsar 180cc

Hatched pads are hatched in inclined way. Hatch pads increase the friction and are more efficient than the existing brake pads. Temperature is reduced due to hatching as it provides ventilation between the brake pads, and gives better results.

Fig 5: B Modified hatched brake pad for Bajaj 180cc

Different materials are considered for selecting the optimized design and the properties are detailed in Table 1

Material	Cast Steel	Aluminum Fly ash	CC-Composite
Density (kg/m^3)	7850	2633	1700
Thermal conductivity (W/mK)	60.5	110.5	40
Thermal expansion (10^{-6}/k)	12	16	0.4

Table 1: Technical specification of different materials

B. Coupled Field Analysis with Different Materials

The results shown below are the comparison between hatched brake pads and original brake pads the thermal analysis is done on original brake pads and are compared with the experimental results. The disc results are compared with ventilated disc brakes made up of cast steel, Aluminum Fly ash, CC-Composite. These results are obtained after applying thermal and modal conditions. The maximum values of temperatures, total heat flux, total deformation are interpreted in the form of colors such as blue s minimum, green is intermediate and red is maximum temperature.

VI. RESULTS & DISCUSSION

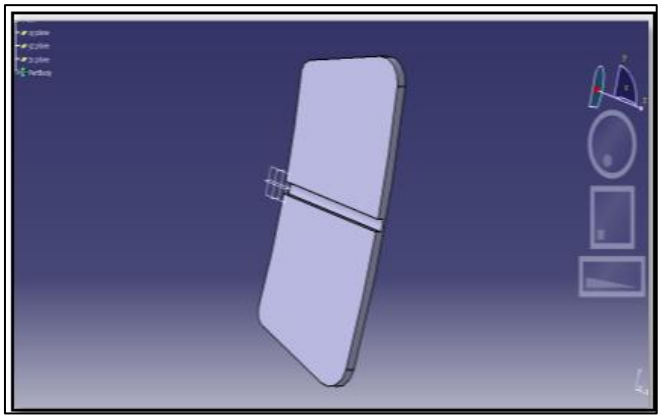


Fig 6: A CAD model for Bajaj pulsar 180cc front brake pad

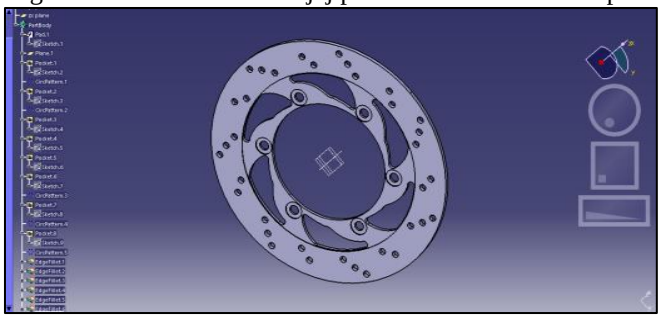


Fig 6: B Modeling of Original disc brake ofPulsar in CATIA

A. Thermal Analysis

The Experimental thermal analysis will be done on brake pads. Brake is applied periodically to reduce or to stop the disc. While put on the break the friction is generated between the disc and brake pad. These friction forces oppose the motion of disc, due to the friction between the disc and brake pad heat is produced in the disc and it dispense over the disc. Heat produced in the brake pads is dissipated by the conduction and convection mode of heat transfer.

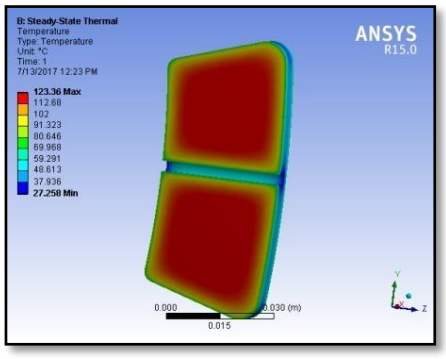
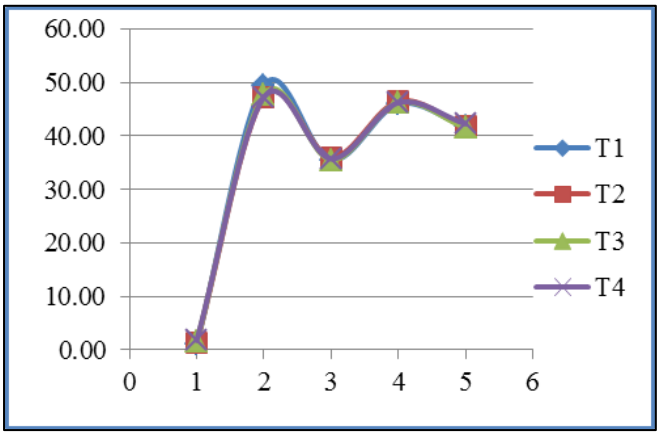
Pad material	Temperature
Asbestos	

Fig. 6.2: Temperature distribution on brake pads

VII. THERMAL ANALYSIS RESULTS AND DISCUSSION

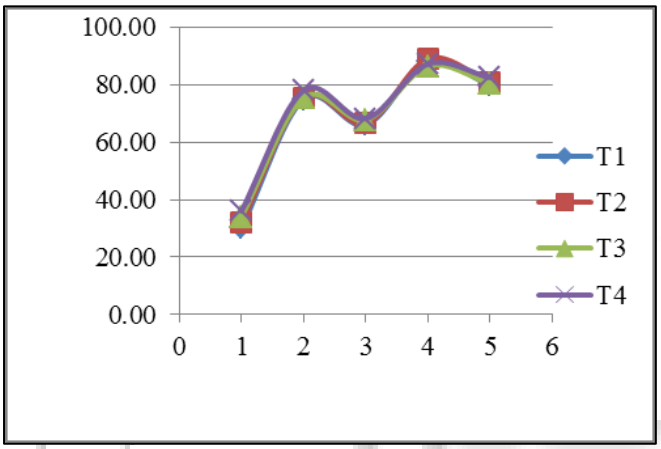
For checking the temperature of the brake pads we have drilled the brake pads putting 4 sensors in the brake pads and we get different temperatures at different speeds. So, we calculated the temperature at the constant speeds.



Graph

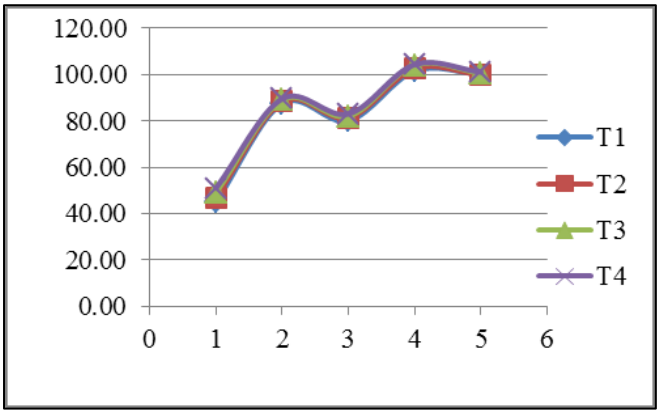
A. Speed 1150 RPM

At constant speed 1150 RPM we observed that the temperature is in the range of 22 ^{0}C to 54 ^{0}C for all the four sensors.



B. Speed 1440 RPM

At constant speed 1440 RPM we observed that the temperature is in the range of 30 ^{0}C to 88 ^{0}C for all the four sensors.



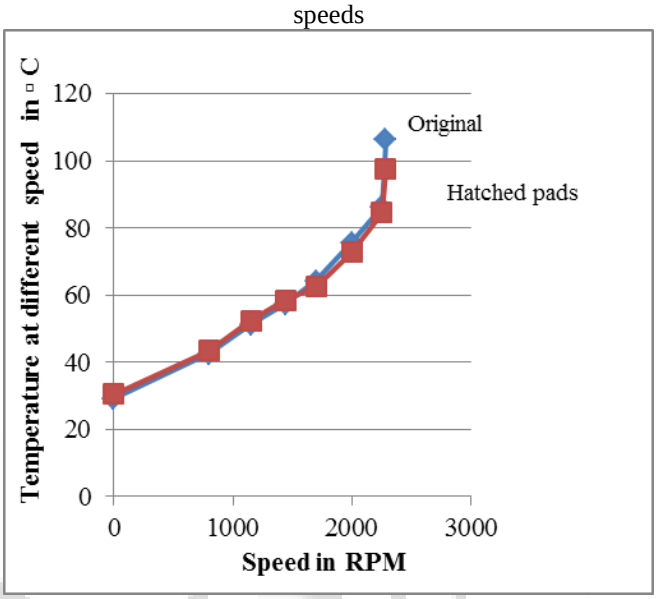
C. Speed 1700 RPM

At constant speed 1700 RPM we observed that the temperature is in the range of 40 ^{0}C to 103 ^{0}C for all the four sensors.

The temperatures for hatch pads are calculated and we observed that after hatching we get temperature less than the original pads. After having the combined results of 4 sensor a we compared it with the hatched pads and we got the following result mentioned in the table below:

Speed in RPM	Temperature in ^{0}C	
	Original pads	Hatched pads
0	33	31.25
800	42.5	43.5
1150	51.25	52.75
1440	57.25	58.5
1700	64.25	62.5
2000	75.5	72.75
2250	86.25	84.5
2282	103.5	97.5

Table 2: Observation table for temperature at different speeds



Graph 2: Experimental results for the original brake pads and hatched brake pads

After comparing the results we get that the temperature is reduced for the hatched pads as it provides ventilation. At speeds 0, 800, 1150RPM we get almost equal results but at the speed of 1440, 1700, 2000, 2250 RPM we get the results of hatched pads less than the original pads.

VIII. MODAL ANALYSIS

The vibration analysis is done to find the natural frequency of the optimized disc as well as existing disc and to find out which effect of changing the weight and geometry on the natural frequency of the disc brake rotor. There are six mode shapes we taken to study in modal analysis and check its behavior.

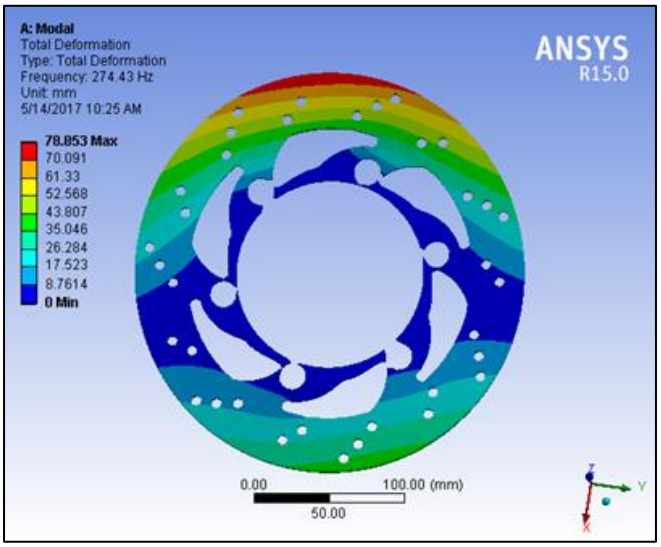


Fig. 8.A: Original Disc at 1st node

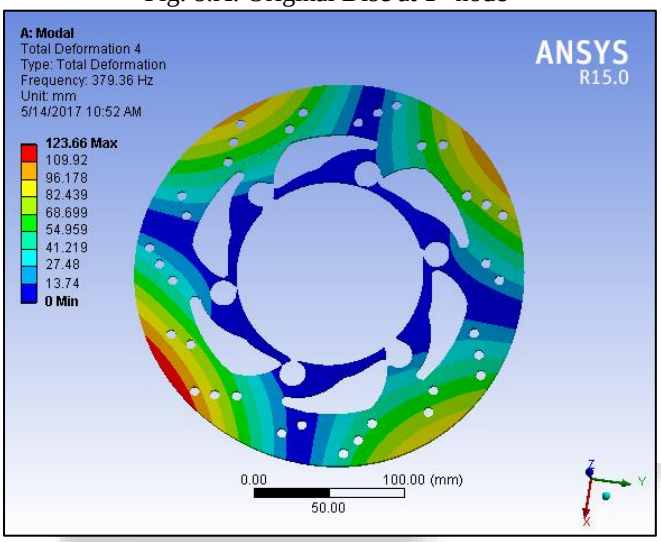


Fig. 8.B: Aluminum Fly ash at 4th node

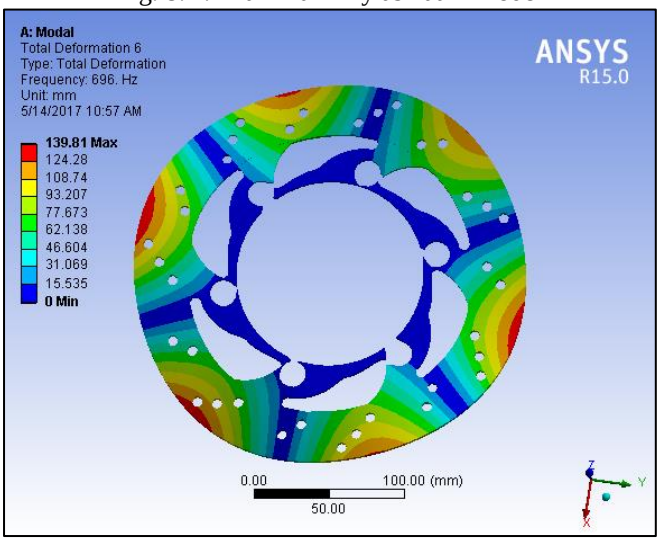
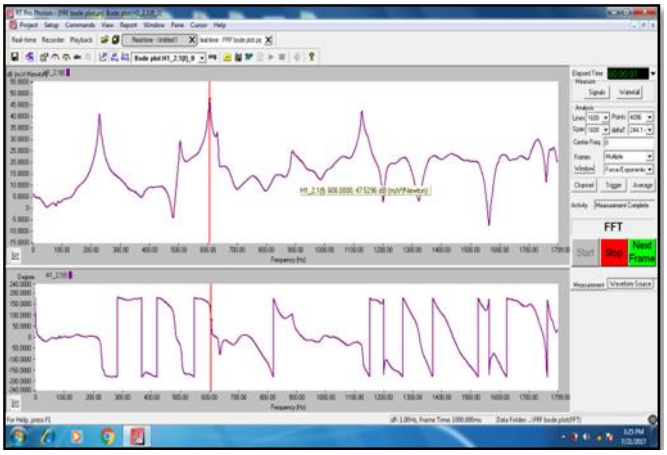


Fig. 8.C: C-Composite at 6th node

IX. VIBRATION MODAL ANALYSIS

To increase the effectiveness of the brake pads the frequency of the disc is measured as it is not possible to increase or decrease the frequency of the asbestos as it is the sand like material. Changing the brake pads is not easy task the alternate material for brake pads is costly so changing the material of disc was easier than changing the material of brake pads. So, the suggested material for the disc brake is Al-Fly ash and cc-composite.

A. Experimental Results using FFT Analyzer for Existing Disc Rotor



B. Observation table

1) Comparison of software and experimental results of modal analysis for existing brake pad modal.

Modal shape No	Frequency of original disc	Experimental natural frequency using FFT	Frequency of Al-Fly Ash	Frequency of CC-Composite
1	229.7	236	226.32	281.9
2	504.53	510	482.71	531.82
3	606.17	616	560.28	689.07
4	631.81	634	703.65	752.62
5	888.9	890	866.57	911.78
6	913.58	1147	954.36	1198.23

From modal analysis of the original disc and the alternate materials it is found that CC-Composite have higher natural frequency.

X. CONCLUSION

1) From the above reading it is observed that frequency for cast steel is 1147 Hz and after using alternate materials the frequency of CC-Composite is more i.e. 1198.23 Hz, higher the frequency less is the wear rate.
2) By doing the thermal analysis we got the temperature range 123 ^{0}C and by doing modification in the brake pads the temperature decreases and it is observed up to 97.5 ^{0}C.
3) Noise is deliberately observed in the range of 20-40 dB when applied pressure at the speed of 30 km/hr.
4) There is also weight reduction after using alternate materials. Less weight leads to less noise while braking.
5) Braking effect is more when the hatched pads are used, and the stopping time is also reduced.

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