



A Comparative Study on Automotive Brake Testing Standards

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Abstract Performance testing of automotive brakes involves determination of stopping time, distance and deceleration level. Braking performance of an automobile is required to be ensured for various surfaces like dry, wet, concrete, bitumen etc. as well as for prolonged applications. Various brake testing standards are used worldwide to assure vehicle and pedestrian safety. This article presents methodologies used for automotive service brake testing for two wheelers. The main contribution of this work lies in comparative study of three main brake testing standards; viz. Indian Standards, Federal Motor Vehicle Safety Standards and European Economic Commission Standards. This study shall help the policy makers to choose the best criteria out of these three while formulating newer edition of testing standards.

Keywords Brake testing · Brake performance · ECE standards · FMVSS · IS

Introduction

Performance of automotive brakes is very important from vehicle and pedestrian safety perspective. Automotive brakes are required to be effective on various road surfaces. Since the brakes work on principle of friction, the effect of heat on brake performance should also be dealt with. Wet

surface or the presence of water adversely affects the brake performance. Stringent standards involving various types of tests have been devised world over to ensure safe application of automotive brakes. The vehicle is supposed to meet the requirements of these standards in order to be eligible for roadworthiness [1].

This article presents the brake methodology used in general and the theoretical background of brake testing. Performance parameters of automotive brakes have been elaborated. Overview of various types of brake tests along with required instrumentation has been provided so as to be able to appreciate the rigor involved in brake testing. However, the main contribution of this article is a comparative study among three brake testing standards for two wheelers, namely Indian Standards (IS) 14664:1999, Federal Motor Vehicle Safety Standards (FMVSS) 122 and European Economy Community (ECE) Standards R78 [2–4]. This study shall be useful while formulating new editions or revising the existing brake standards in India. The scope of the brake testing discussion made here is limited to the service brakes of two wheelers only.

Brake Performance Testing Parameters

1. Following are the main parameters used to characterize the brake performance.
 - (a) Stopping Time: The time elapsed between the moment the brake force is applied to the pedal and the vehicle stops (considering full stop) [1].
 - (b) Stopping Distance: The distance covered by vehicle from the moment when driver begins to

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actuate the brake control(s) until the moment the vehicle stops [2].

The mathematical expressions for these parameters are as shown in Eqs. (1) and (2):

$$\text{Stopping time} = V_o/D_x \quad (1)$$

$$\text{and Stopping distance} = V_o^2/2D_x \quad (2)$$

where, V_o is the initial velocity and D_x is deceleration due to brake application. It has been assumed that the final velocity of the vehicle is zero (full stop) and other forces on the vehicle remain constant during brake application.

The influencing parameters on the brake performance are initial velocity and deceleration of the vehicle [5, 6].

Various Brake Tests

Brake testing is a procedure for periodical checking that a vehicle's brakes are maintained (working) at a level of performance that does not put people at risk [2, 7].

According to IS 14664:1999, following are the tests conducted to assess braking performance of a vehicle.

- (i) Type P Test (Dynamic Performance)
- (ii) Type F Test (Heat Fade)
- (iii) Type W Test (Water Fade)

Type P Test

The test is conducted at initial speeds and load conditions as specified in the standard. The vehicle is started and speed is picked up slightly above the specified initial test speed. As the vehicle nears the test area, vehicle speed is maintained slightly above the specified initial speed, the throttle is closed fully and the drive is disengaged where possible by declutching or otherwise. If recording devices of distance, speed or deceleration are not automatic, the devices are started. When the speed of the vehicle drops within the allowable range of the initial speed, the brake control is applied rapidly, continuously and smoothly so as to bring the vehicle to a halt.

The test is repeated as described above, increasing the control force, if wheel(s) have not locked and reducing the control force, if wheel(s) have locked till the control force is established where the best performance is achieved during the stop without wheel locking. After establishing the correct control force, the tests are repeated sufficient number of times such that four (4) valid readings are available. If stopper for limiting the control travel or valves for limiting the hydraulic pressure is used, the control force is recorded [2].

Type F Test (Heat Fade Test)

This test is performed so as to assess the brake behaviour after repetitive use since the effectiveness of brake decreases with rise in temperature. The initial speed, control force and use of gear and clutch control are maintained as per the standard. After each stop the vehicle is immediately accelerated to reach the initial speed and maintained at that speed till the initiation of the next stop. The distance between successive stops is 1000 m. The throttle shall be fully closed during the braking. Immediately after the 10 repeated stops, Type P performance test, as mentioned above using the same control force as per the standard is carried out and the stopping distance/mean fully developed deceleration is recorded. This test is carried out only once [2].

Type W Test (Water Fade Test)

This test evaluates the braking performance on wet surfaces. While performing this test, the track is required to be dry, but the brakes to be tested are made wet, preferably by tap water at a temperature not exceeding 30 °C. Water is applied using a procedure as mentioned in the standard.

The vehicle is run at initial speed appropriate to the test for a distance not <500 m prior to the point at which the test is to commence without operation of the brake(s) to be tested. The vehicle is braked after wetting of the brakes, from the initial speed with control force as has been mentioned in the standard. The test consists of 15 stoppages, with an interval of 120 s between two stoppages. During each stoppage, the mean deceleration value is calculated. The deceleration achieved at the first stoppage shall not be <60 % of the value maintained during the base line check. At the end of fifteenth stop, at least 90 % of the value of the base line check should be achieved. In case 90 % of recovery has been achieved before the fifteenth stop, further recovery stoppages need not be carried out [2].

Preparations and Instrumentation for Tests [2]

This section provides some general details about the requirements to be fulfilled before the tests and the instrumentation required for the same.

Preparations

The manufacturer needs to prepare the vehicle before presenting for brake testing. The vehicle is run-in and the brakes are properly bedded-in. Adjustment of the free play of levers and pedals is to be made.

Actual weight during testing should not exceed specified laden or unladen weights by more than 25 kg. The distribution of weight between axles should be as close as possible to the values recommended by the manufacturer. Tolerance of $\pm 5\%$ of specified speed on initial speed is allowed. The test is required to be conducted on a dry level test track with a coefficient of adhesion not < 0.8 . The test is conducted when wind speed is < 3 m/s in any direction. The ambient temperature should be preferably between 15 and 40 °C and relative humidity should be $< 75\%$.

Instrumentation for Tests

Contactless electronic speed and distance measuring instruments (commonly known as ‘Correxit’) or speed measuring system using an additional wheel (commonly known as fifth wheel) is used and should meet least count and accuracy requirements as presented in Table 1.

Instrument for Deceleration

Decelerometers are recommended to be secured on test vehicle properly such that its position is not likely to be disturbed during tests. This is required to be fitted as close to the center of gravity of the vehicle as possible in longitudinal and lateral plane. Before commencement of each run, leveling of instrument within the limits prescribed by the instrument manufacturer is ensured.

Instrument for Speed

While measuring deceleration, a speedometer can be used. Marking is required to be made on the dial of speedometer in such a way that the actual speed of the vehicle, when the indicated speed is as per the marking, established as per the procedure given in IS 11827 is within ± 1 km/h of the specified initial speed. Suitable markings are required to be made for all the necessary test speeds.

Instrument for Control Force

Suitable load cells are to be used for this and the recommended least count and accuracy are 10 N (1 kg) and 20 N (2 kg) respectively [6].

Table 1 Instrumentation least count and accuracy requirement

Parameter	Least count	Accuracy
Speed	0.1 km/h	0.1 km/h
Distance	0.1 m	0.1 m
Time	0.01 s	0.1 km/h

Brake Testing Standards

Various automotive brake standards are being used world over to assess the brake performance of vehicles. Few of them are FMVSS in USA, EEC Standards, IS, J 12-61 (Japan Safety Standard) and Australian Design Rule 33/00. These have various sections detailing the requirements and procedures for different types of vehicles, though the approach and methodology in general remain common. This study focuses on IS 14664:1999, FMVSS 122 and ECE R78 for comparative study limited to braking standards of two wheelers.

Comparison Among Brake Standards

This section presents the comparison between three brake standards used in two wheelers, namely, IS 14664:1999, FMVSS 122 and ECE R78.

Measurement Parameters

The ECE R78 test methods allow brake performance to be measured through the use of either deceleration or stopping distance, whereas FMVSS 122 evaluates the performance through stopping distance only. IS prescribes either i.e. either deceleration or stopping distance as is the case with ECE.

Test Surface

FMVSS 122 currently requires that the road tests be conducted on an 8-foot-wide level roadway with a skid number of 81. The ECE R78 do not specify the coefficient of friction for the test surface, but describe that the test surface must be level, dry, and affording good adhesion. The test lane width is also specified, as 2.5 m (8 feet).

According to IS, the test requires, dry level test track with a coefficient of adhesion not < 0.8 which is equivalent to skid number of 81.

Sequence of Tests

There is no specified test order in the ECE R78. FMVSS 122 requires that all tests be conducted in a specific sequence, ending with the wet brake test. IS also doesn’t specify a sequence of tests, however, for heat fade and water fade tests, the base line check refers the performance level during the dynamic performance test.

Brake Actuation Forces

Table 2 summarizes the brake actuation forces for these standards.

Brake Temperature Measurement

FMVSS 122 includes a specification for plug type thermocouples, including detailed schematics addressing their installation on disc or drum type brakes. Although ECE R78 requires brake temperature measurement, doesn't make reference to specific measurement equipment or installation methods. IS doesn't warrant measurement of temperature during heat fade test.

The ECE R78 specify that the IBT (initial brake temperature) must be ≤ 100 °C (212 °F), whereas FMVSS 122 specifies an IBT between 55 and 65 °C (130 °F and 150 °F).

Burnishing

FMVSS 122 mentions a burnishing procedure, whereas ECE R78 does not include any burnishing procedure for brake testing. IS also doesn't require burnishing of brakes during their testing.

Dry Stop Test

The ECE R78 regulations require that the braking performance be evaluated separately for each brake control, with the motorcycle in the laden condition and at test speeds of 40 or 60 km/h depending on the vehicle category. The main FMVSS performance requirements are quite different, tested in the lightly-loaded condition and with all brake controls applied simultaneously. The FMVSS also requires testing from 30 mph (48.3 km/h), 60 mph (96.6 km/h) and 80 mph (128.8 km/h). IS specifies the test in laden as well as unladen condition; with separate as well as simultaneous brake applications and at 30 and 40 kmph or 60 % of maximum speed, whichever is lower.

Table 2 Brake actuation forces

Regulation	Foot control F_P (N)	Hand control F_L (N)
FMVSS 122	$25 < F_P < 400$	$10 < F_L < 245$
ECE R78	$F_P < 350$	$F_L < 200$
IS 14664:1999	$F_P < 330$	$F_L < 260$

High Speed Test

The ECE R78 test is performed from a speed of 160 km/h or 0.8 of the vehicle's maximum speed (V_{max}), whichever is less. The high speed effectiveness test of FMVSS 122 is conducted from a test speed that is based on the speed capability of the motorcycle, not exceeding 193.2 km/h (120 mph). When tested at the maximum speed of 120 mph, the required stopping distance is 861 feet (262.5 m), equivalent to an average deceleration of 5.5 m/s². IS recommends the dynamic test at 30 kmph (single brake) or 40 kmph (both brakes together) or 60 % of maximum speed, whichever is lower.

Wet Brake Test

In order to simulate heavy rain conditions, the ECE R78 test requires a brake performance test with a wetted brake. This is achieved by spraying water directly onto the brakes during the test. The ECE R78 wet brake performance evaluation begins with a baseline test where each brake is tested separately and is required to decelerate a laden motorcycle at a specified rate, using the conditions of the Dry Stop Test—single brake control activated. For comparison, the same test is then repeated, but with a constant spray of water to wet the brakes. FMVSS test is based on brake performance recovery following the motorcycle crossing an area of standing water. As such, the wetting procedure consists of immersing the front and rear brakes in the water, separately, for 2 min each.

Performance is evaluated with all brakes applied simultaneously and the wet brake recovery performance is based on the fifth stop after having immersed the brakes. As per IS provisions, wetting equipment is used to make the brakes wet. The test consists of 15 stoppages and the deceleration achieved at the first stoppage should not be < 60 % of the value maintained during the base line check. At the end of fifteenth stop, at least 90 % of the value in the base line check should be achieved.

Conclusion

This article makes an effort to provide an overview of the automotive brake testing methodology followed in general. Along with the types of brake tests. It provides some details about the general requirements as well as the instrumentation required. The comparative study presented to help gain insights into the three brake testing standards, viz. IS, ECE and FMVSS. This comparative study, the authors

believe, shall be useful for the policy makers, industry experts while drafting revised brake testing standards. Two main issues, i.e. the sequence of brake tests and temperature measurement during heat fade tests are worth pondering during future revisions. Brake performance testing of burnished brakes as in case of FMVSS may also be given consideration so that the minimum acceptable performance of worn brakes is guaranteed. Similar studies on brake testing standards with regard to various categories of vehicles may provide some useful insights for future revisions.

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