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Performance evaluation for various braking systems of street motorcycles

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Introduction

This report covers a series of motorcycle braking tests aimed at measuring the performance of the front brake and of the rear brake compared with using the two brakes simultaneously during intensive braking in a straight line.

Research method

Six experienced riders performed a total of 349 braking tests on 10 different motorcycles in two separate sessions, August 9

and 27, 2002.

Experimental apparatus

Data acquisition was performed with the aid of a Toshiba Satellite 3000 portable computer coupled to a Stalker ATS radar gun.

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Experimental apparatus

Deceleration performance demanded of the riders called for intense and stable braking from 100 km/h to 0. Riders were instructed to initiate their braking at a speed above 100 km/h to ensure that the measurements recorded only the stabilized portion of their stop.

No crashes were experienced.

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Experimental apparatus

Before each block of tests, riders were instructed as to the type of usage of the brakes they were to perform, whether of both brakes simultaneously or of the front or rear exclusively. Assignment of the three types of braking was made on a rotating basis to compensate for the familiarity and confidence levels of the riders.

Riders were free to choose how they applied the brakes, whether in covered mode or not. Riders also had the latitude to decide to actuate the front brake lever with the number of fingers they chose.

The standard unit of measure for these tests was the G (1G) which equates to an acceleration of 9.8 metres per second per second. Since it was a braking manoeuvre, all the measurements taken were negative.

Results

Control(s) actuated	System(s) actuated	f	Mean Acceleration(-G)	Standard Deviation (-G)	Braking capacity %
Dry surface, Solo, independent system, non-ABS					
Lever and pedal	front and rear	82	0.774	0.144	100
Lever	front	68	0.711	0.107	92
Pedal	rear	72	0.425	0.029	55
Dry surface, Solo, independent system, with ABS					
Lever and pedal	front and rear	26	0.869	0.155	100
Lever	front	17	0.725	0.093	83
Pedal	rear	20	0.424	0.032	49
Dry surface, Solo, integrated system, non-ABS					
Lever and pedal	front and rear	6	0.74	0.075	100
Lever	front	5	0.474	0.023	64
Pedal	rear	6	0.583	0.022	79
Dry surface, Solo, integrated system, with ABS					
Lever and pedal	front and rear	10	0.853	0.103	100
Lever	front	8	0.756	0.028	89
Pedal	rear	3	0.805	0.015	94
Dry surface, Passenger, independent system, non-ABS					
Lever and pedal	front and rear	5	0.745	0.076	100
Wet surface, Solo, independent system, non-ABS					
Lever and pedal	front and rear	3	0.685	0.073	100
Lever	front	2	0.483	0.075	71
Pedal	rear	2	0.41	0.022	60

f = Number of tests

Part two

Task analysis for intensive braking of a motorcycle in a straight line

ELEMENTS OF EMERGENCY BRAKING

Straight-line emergency braking of a motorcycle depends not just on the intensity of braking itself but also on the choice of manoeuvres, the rapidity and the sequence of operations which preceded it.

ABS AND INTEGRAL SYSTEMS

Although anti-lock braking systems (ABS) that make it impossible to lock the wheels while braking in a straight line have been available for motorcycles for several years, the great majority of motorcycles presently in use are not so equipped.

DIFFICULTY OF APPLICATION IN A CONVENTIONAL SYSTEM

If with an automobile there is little risking in stamping on the brake pedal, maximum braking of a motorcycle poses greater risks and demands greater expertise since the rider must simultaneously manage two independent braking systems in parallel. The fact that the front brake and the rear brake must be operated and modulated in a separate and optimal manner, the front by the right hand and the rear by the right foot, without causing a locked wheel underlines the difficulty the rider must face.

Also, during deceleration, such as in the case of emergency braking, load is transferred progressively to the front wheel. This phenomenon, which is more pronounced on a motorcycle than on an automobile, implies that the available braking force diminishes progressively on the rear wheel and increases progressively on the front wheel during braking. This is another variable for which the rider must compensate and which increases the difficulty of execution.

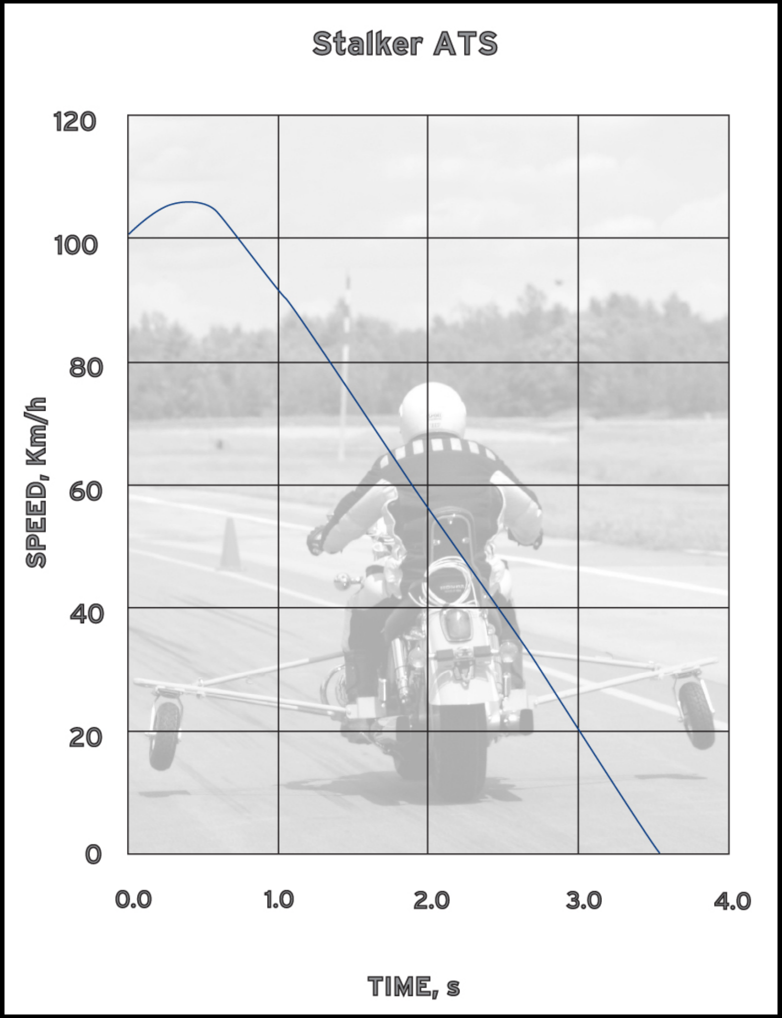
RISKS ARISING FROM A LOCKED FRONT WHEEL

Locking of the front wheel must be avoided at all costs during hard braking because it leads almost automatically to a loss of directional control and a sideways crash if it persists longer than a tenth of a second. Fear engendered by this physical reality means that the majority of motorcyclists under-utilize the capacity of their front brake, especially at the start of braking. Thus it is of paramount importance to become proficient at the start of braking because the distance travelled is relatively greater than at the end of braking.

TEST CONDITIONS

We retained the services of eight experienced riders. Two motorcycles were used, one sport machine and one custom cruiser, both equipped with outriggers to allow the riders to reach or surpass the braking limits of the motorcycles. For the compilation of the preliminary results, more than 820 tests were recorded. From this data pool, 298 tests corresponding to the selection criteria were retained for compilation of the final report. In order to be selected, a test had to post intensive and continuous braking beginning from a speed equal or superior to 100 km/h preceded immediately by a period of acceleration.

TEST CONDITIONS



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POSTULATE ON USAGE OF THE REAR BRAKE

Emergency braking on a motorcycle equipped with a conventional braking system must involve use of the rear brake, even though it has a less important role than the front brake. It plays a role in the first instants of braking before the

rear wheel becomes unloaded through weight transfer.

FREE BRAKING PROCEDURE

Riders were required to brake as hard as possible while using the controls in a sequence with which they felt most at ease.

Riders were free to choose how to apply the brakes, whether covered or not. Riders also had the latitude to squeeze the front brake lever with the number of fingers they wanted.

This freedom of choice meant that some of the recorded tests were done by one rider who did not use the rear brake and by another who pulled in the clutch lever just before reaching a complete standstill of the motorcycle. These tests were not

included in the tables employed for recommendations.

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JUSTIFICATION FOR A STANDARD PROCEDURE

The two motorcycles used for these experiments were of different types: a 2001 sport model Honda CBR929RR and a 1999 custom style Honda GL1500 Valkyrie. In terms of braking performance there was no significant difference between them. The mean stopping distance in 214 tests of the sport model was 41.67 metres from 100 km/h compared with a mean of 41.83 metres in 84 passes of the custom machine. These results convince us that a standard emergency braking procedure is possible and valuable despite the weight differences among motorcycles.

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EFFECTS OF DECELERATION FORCE

The mean deceleration for the group of 298 passes braking from 100 km/h to zero wa -0.898 g in a mean time of 3.18 seconds. During these more than 3 seconds, the rider had to manage his braking while subjected to a considerable deceleration force against his arms and hands which must in large measure support his upper body. A simulator designed to recreate this force would have to incline the motorcycle on its front wheel at an angle of 64 degrees.

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THE EQUILIBRIUM STAGE

Each emergency braking manoeuvre is preceded by a stage of stabilizing the motorcycle. Although it may be very short, it is no less important despite the fact that it is little covered in the literature. Even when the motorcycle gives the impression of rolling in a straight line, the rider makes constant adjustments to maintain equilibrium among different forces and the chosen trajectory. At the moment of emergency braking, this equilibrium must be perfect and be maintained for the length of the braking manoeuvre.

PRISONER OF POSTURE

Once the emergency braking procedure is started, because of the forces engendered by deceleration on the arms and hands, the rider is a prisoner of his choice of the number of fingers employed on the front brake lever. During the course of intensive braking he must not modify the position of his fingers.

DISTANCE VERSUS TIME

The objective of emergency braking must be to reduce as much as possible his speed in the shortest distance possible and not in the least elapsed time. Although there is a correlation between braking distance and time, it is not absolute. Thus the quickest stop from 100 km/h recorded during these tests lasted only 2.70 seconds but covered 37.68 metres. The shortest stopping distance recorded was 36.95 metres in an elapsed time of 2.75 seconds. This slight difference highlights the importance of an effective start to the braking procedure at the moment when the distances travelled are greatest.

USE OF THE CLUTCH

Downshifting: Should one downshift during emergency braking?

We devoted an entire day (June 20, 2003) to this variable during which we recorded 77 tests with two different riders on the same motorcycle.

The mean stopping distance for 31 tests during which the riders were instructed to downshift was 43.17 metres compared with the general average of 41.71 metres for the group of 298 tests.

USE OF THE CLUTCH

		Deceleration	Distance	Time	Distance	Time
			100 km/h to 0		80 km/h to 0	
Variable	N	(G)	metres (m)	secondes (s)	metres (m)	secondes (s)
With downshifting	31	-0.891	43.17	3.21	24.97	1.81
Clutch engaged	35	-0.889	41.51	3.21	24.50	1.78
Clutch disengaged	11	-0.929	39.95	3.08	23.41	1.72
	77					

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SUMMARY OF 298 TESTS

Number of tests (N)	**298**
Chronology	**Seconds**
Time to completely close the throttle	0.0000
Time to apply rear brake	0.2217
Time to apply front brake	0.2278
Time to declutch	1.0679
Time to compress front suspension to half-travel	0.6237
Mean deceleration	**G**
Mean deceleration from 100 km/h to 0	-0.8982
Distance travelled	**Metres**
Total distance 100 km/h to 0 in metres (m)	41.7072
Total distance 80 to 20 km/h in metres (m)	24.3237
Elapsed time	**Seconds**
Total time from 100 km/h to 0 in seconds (s)	3.1830
Total time from 80 to 20 km/h in seconds (s)	1.7694
Reaction time (seconds)	**Seconds**
Accelerator - rear brake	0.2217
Rear brake - front brake	0.0061
Front brake - declutch	0.8401
Total delay	1.0769

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SUMMARY OF TESTS INVOLVING REAR BRAKING AND DECLUTCHING

Summary of tests
- with omission of tests recording an elapsed time for declutching of more than 1 second
- with omission of tests recording an elapsed time for application of rear brake of more than 1 second

Number of tests (N)	**172**
Chronology	**Seconds**
Time to completely close throttle	0.0000
Time to apply rear brake	0.0710
To to declutch	0.1396
Time to apply front brake	0.1454
Time to compress front suspension to half-travel	0.4986
Mean deceleration	**g**
Mean deceleration from 100 km/h to 0	-0.8941
Distance travelled	**Metres**
Total distance 100 km/h to 0 in metres (m)	41.8129
Total distance 80 to 20 km/h in metres (m)	24.3149
Elapsed time	**Seconds**
Total time from 100 km/h to 0 in seconds (s)	3.1967
Total time from 80 to 20 km/h in seconds (s)	1.7670
Reaction time (seconds)	**Seconds**
Accelerator - rear brake	0.0710
Rear brake - declutch	0.0686
Declutch - front brake	0.0058
Total delay	**0.1454**

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SUMMARY OF THE 30 BEST TESTS INVOLVING REAR BRAKING AND DECLUTCHING

Summary of the 30 best tests
- with omission of tests recording an elapsed time for declutching of more than 1 second
- with omission of tests recording an elapsed time for application of rear brake of more than 1 second

Number of tests (N)	**30**
Chronology	**Seconds**
Time to completely close throttle	0.0000
Time to apply rear brake	0.0712
Time to apply front brake	0.1567
Time to declutch	0.2090
Time to compress front suspension to half-travel	0.3401
Mean deceleration	**g**
Mean deceleration from 100 km/h to 0	-0.9713
Distance travelled	**Metres**
Total distance 100 km/h to 0 in metres (m)	38.3510
Total distance 80 to 20 km/h in metres (m)	22.4167
Elapsed time	**Seconds**
Total time from 100 km/h to 0 in seconds (s)	2.9287
Total time from 80 to 20 km/h in seconds (s)	1.6307
Reaction time (seconds)	**Seconds**
Accelerator - rear brake	0.0712
Rear brake - front brake	0.0855
Front brake - declutch	0.0523
Total delay	**0.2090**

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IDEAL SEQUENCE

These figures indicate that the ideal sequence for the most effective emergency braking possible is to successively close the throttle, apply the rear brake, apply the front brake and declutch completely.

A FEW SECONDS OF AUTOMATISM

We quickly realized during these tests that the load imposed on the rider during hard braking is immense. An emergency stop from 100 km/h lasts more or less four seconds; basically, one second for reaction and stabilization and three seconds of braking. During these four seconds the rider undergoing considerable physical stress acts in a conditioned manner.
In an emergency, the rider performs unconsciously but more quickly and less well what he does habitually in more normal situations.

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DEBA SEQUENCE

1 Deceleration

- Completely close the throttle
- Apply the rear brake

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DEBA SEQUENCE

2 Equilibrium

- Place the bike vertical
- Brace arms and legs
- Straighten torso
- Position fingers and feet

DEBA SEQUENCE

3 Braking

- Apply appropriate pressure of the front brake
- Declutch completely

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DEBA SEQUENCE

4 Adjustment

- Adjust front brake pressure
- Adjust rear brake pressure

DEBA SEQUENCE

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