Motorcycle Sliding Coefficient of Friction Tests

Bruce F. McNally, ACTAR
Northeast Collision Analysis, Inc.

Wade Bartlett, PE, ACTAR
Mechanical Forensic Engineering Services, LLP

Introduction

Three motorcycle drop tests were performed in a manner designed to simulate a motorcycle falling to the pavement under real-world conditions. The tests were performed on a gridded test surface, so that a video analysis of the entire trajectory of the motorcycle could be completed. Using this technique, we were able to establish the significance of the deceleration associated with the initial contact between the falling motorcycle and the roadway surface. The test results suggest that a higher sliding coefficient is warranted for motorcycles that slide for short distances prior to striking another vehicle, versus using the lower average coefficient of friction associated with longer sliding trajectories.

Background

Since the mid 1980's, several groups have endeavored to perform tests to measure the coefficient of friction of various types of motorcycles sliding on differing roadway surfaces. The manner in which these tests were conducted vary to some degree, but most have either dropped motorcycles from a moving vehicle or have placed the motorcycles onto the roadway surface in artificial manners.[1,2,3] Other tests have been performed where the motorcycle was simply dragged while attached to a scale, to measure the resistive force of the motorcycle sliding on the roadway surface.[4,5] A few have measured the coefficient of friction under more realistic conditions, where the motorcycle was released from an upright position and allowed to fall onto the roadway on its own or by preventing the front wheel from rotating.[6,7]

In 1991, Lambourn reported that in tests he performed while allowing the motorcycle to fall from an upright position, higher average coefficient of friction levels were found than in tests where the motorcycle was released from a low-platform trailer position onto the roadway.[8] He reasoned that the higher levels of friction seen on some of the lower speed upright-launch tests were likely associated with the motorcycle *"digging-in"* upon initial contact with the roadway. This is likely the reason that many have performed their friction tests from low drop heights.

Upon analysis of a video clip of a motorcycle incident that occurred at highway speeds under real-world conditions, we found that the motorcycle experienced a higher deceleration during the initial contact with the pavement than it did during the remainder of the slide. This observation prompted us to conclude that the higher normal forces associated with the initial interaction between the motorcycle and the roadway produced the higher deceleration seen when the motorcycle struck the roadway. To further evaluate this phenomenon, we performed three successful tests under controlled conditions to measure the deceleration during intervals of the motorcycle's trajectory.

Test Methodology

For these tests we used two motorcycles, a Suzuki GSX 750 Katana and a Honda CBR 360. The Suzuki was equipped with standard plastic bodywork, with no aftermarket alternations that would be expected to alter the outcome of these tests. The Honda was equipped with crash bars and was missing its handlebars. Both of these alterations would be expected to lower the average drag factor of a factory model motorcycle absent these alterations.

Prior to testing, a custom carrier was designed and fabricated. The carrier was designed to hold the front wheel of the upright motorcycle a short distance off the roadway surface while the motorcycle was being towed to the desired launch speed. This carrier device was attached to a platform motorcycle trailer. The front wheels of the motorcycles were rigged to lock shortly after release from the carrier, simulating a front-wheel-only braking action. The front wheel lockup caused the motorcycles to quickly fall to the pavement and slide freely to their final rest position.

The test area was pre-lined in five-foot intervals with colored tape. In addition to the high-visibility lines on the pavement, traffic cones were placed at specific intervals on the test area to facilitate post-test orientation on the video taken of the tests. Two video cameras were used to document each test. One video was placed on the trailer platform facing the motorcycle and the other was placed in an elevated man-lift.

The trailer unit was towed to test speed by a sport-utility vehicle, which was equipped with a MacInnis Engineering 5th wheel speed measurement device. The 5th wheel documented the speed of the tow vehicle during the ten seconds prior to and the five seconds after release of the motorcycle from the carrier. The 5th wheel data was used in

conjunction with videotape analysis to determine the speed of the test motorcycle at various intervals during its trajectory. Following each successful test, the roadway evidence was documented and photographs were taken from multiple angles.
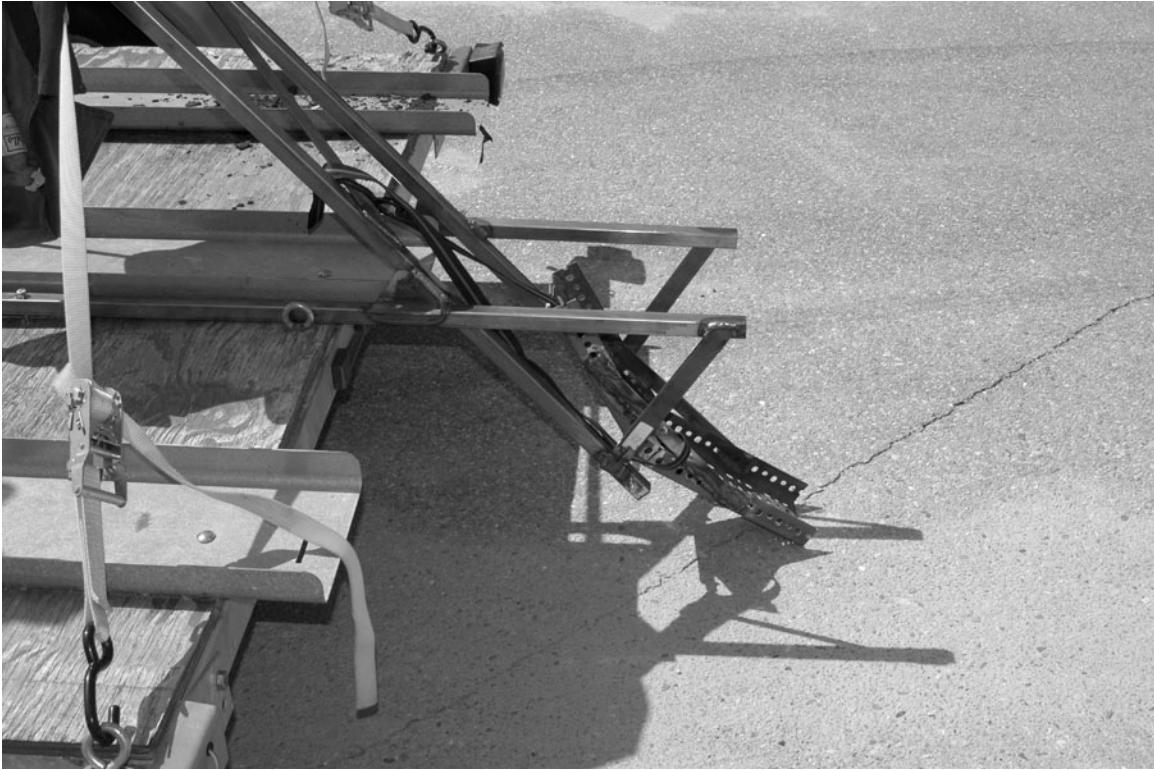

Photo One – *The test rig used to carry the front wheel of the test motorcycles*

Results

Four different tests were attempted. During the first test we were unsuccessful in launching the motorcycle from the trailer. Two successful tests were performed with the Honda motorcycle and one was performed with the Suzuki. One test resulted in the Honda sliding each of its sides, while the Suzuki test resulted in the motorcycle sliding on its right side. The first test produced no useable data and is excluded from further discussion.

Each test was videotaped with a digital video recorder from an elevated position. The position of the video allowed us to analyze the trajectory of the motorcycle during its deceleration. To enhance the videotape analysis, digital video editing software was used to "split" the video into half-frames. Normally, standard video is recorded at a frequency of 29.98 frames per second. Using the half-frame video, we were able to visualize twice the number video frames for the same time period. Once the video was split into half-frames, each frame was numbered for easy-reference during the analysis.

The video was played back frame-by-frame so that an accurate time vs. distance relationship could be established. Using this time vs. distance relationship in a spreadsheet program, we were able to easily calculate the average velocity of the motorcycle over short displacement distances. The difference between sequential velocity measurements over the individual elapsed times were then used to numerically differentiate the velocity curve to generate the average accelerations during these short time periods.

The results of each of the tests indicate that the test motorcycle tended to experience a higher deceleration during the initial portion of its slide, and then slide at a lower average deceleration rate over the remainder of the slide. The following graphs display the acceleration plots for the video analysis for each of the tests.

Test 2 Acceleration
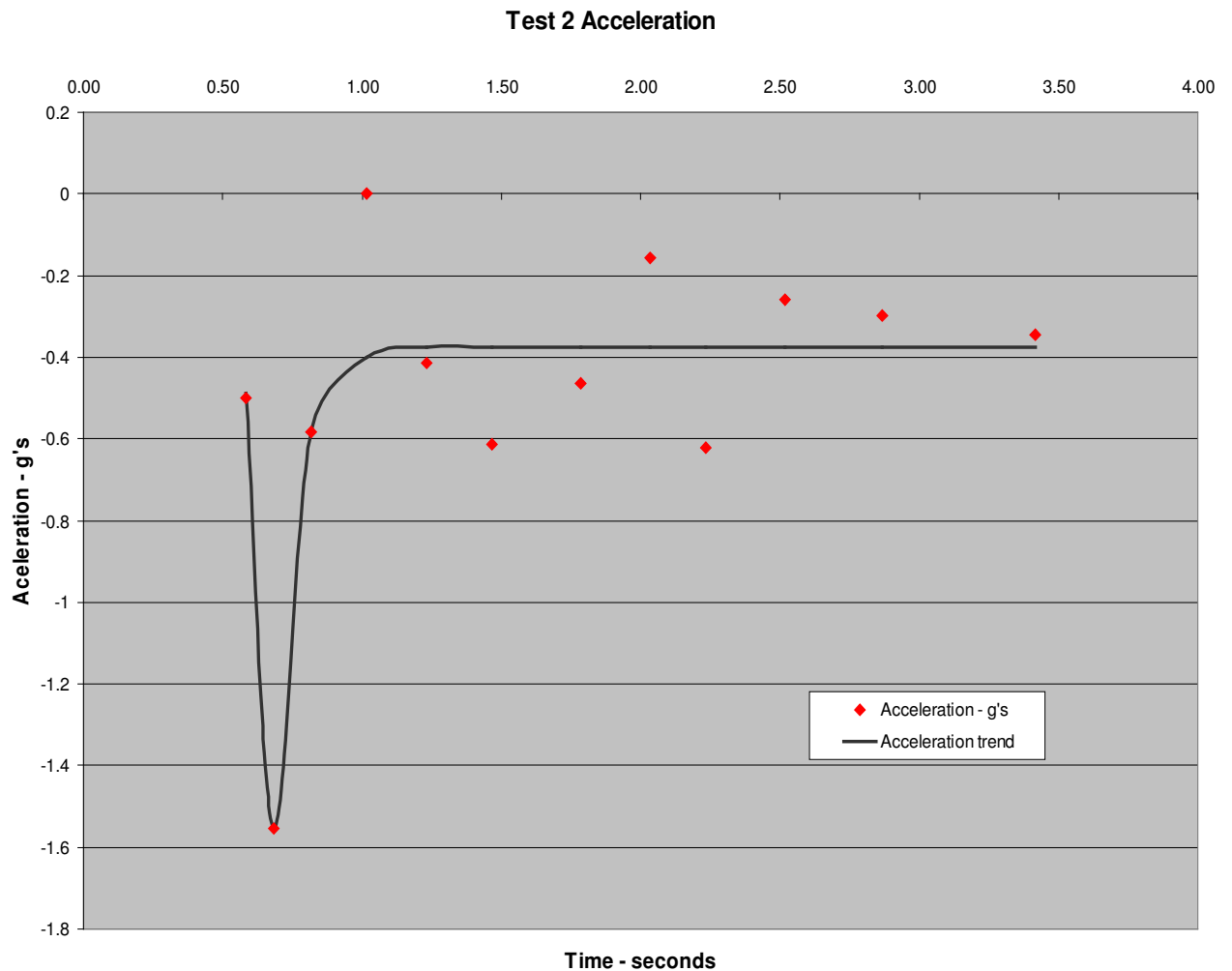
Test 3 Acceleration
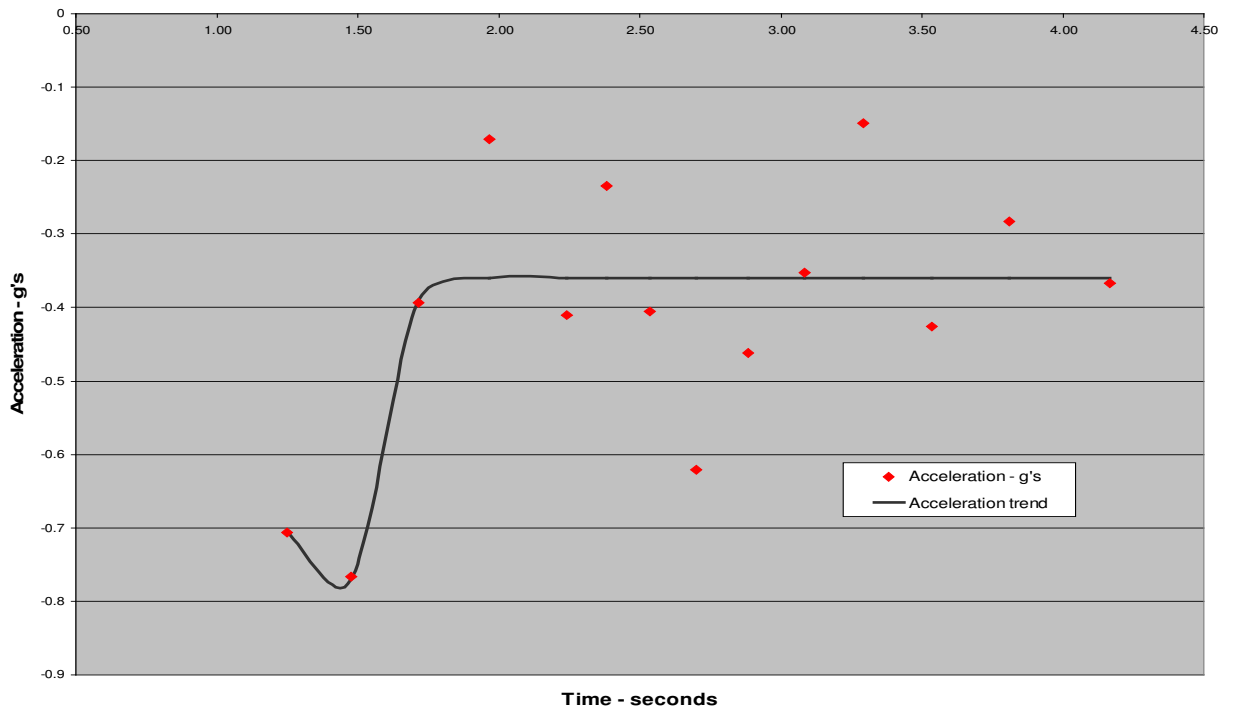
Test 4 Acceleration
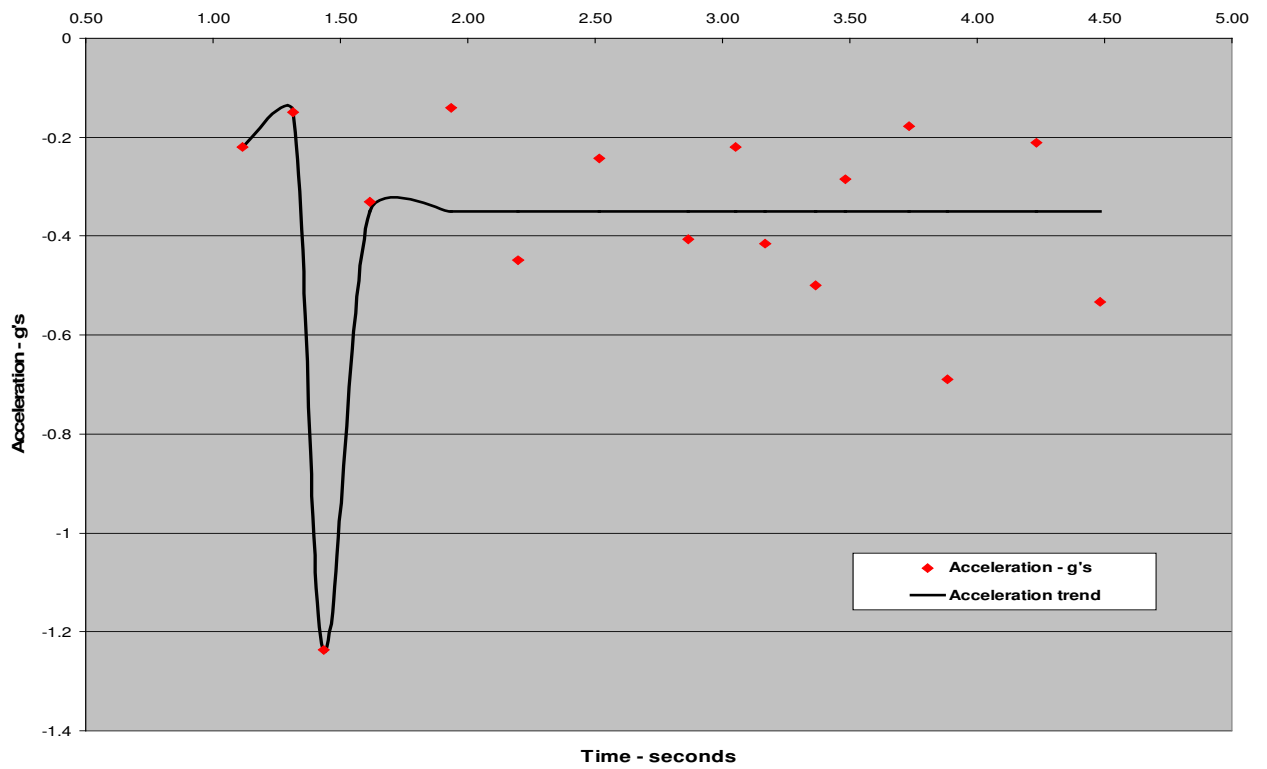
The data gathered through review of the video was compared to the field data in order to use two independent methods to measure the average drag factor of the motorcycle sliding across the pavement. By knowing the speed the motorcycle was traveling when it initially made contact with the pavement and the overall distance that it slid on the roadway, we calculated the average coefficient of friction during the slide. Alternatively, using the video data, we took the average of the acceleration points that occurred during the slide portion of the trajectory. These two different calculation methods were found to be reasonably consistent with one another. The field data from the tests and the average drag factors calculated with the two methodologies are noted in **Table 1.**

Test Number	Motorcycle	Speed at Onset of Slide	Overall Slide Distance	Ave f from Field Data	Ave f from Video Data
2	Honda	40 fps	52.6 feet	0.47	0.48
3	Honda	57 fps	131.0 feet	0.39	0.41
4	Suzuki	47 fps	88.0 feet	0.39	0.42

Table 1

It should be noted that the video data in Test 3 did not include the very first portions of the motorcycle slide, as the motorcycle was prematurely released and fell to the pavement just prior to reaching the gridded portion of the test area. Because of the angle of view afforded by the video and the uncertainty associated with the absence of grid references in this initial portion of the slide, we chose to analyze only the portion of the slide that occurred within the gridded area. The acceleration shown in acceleration graph for Test 2 indicates that the motorcycle was still decelerating at a higher rate during the time period we chose to first analyze, but the peak acceleration is much lower than that seen in the other two tests. Although the peak deceleration was not likely accounted for in the video analysis, the values calculated for the average coefficient of friction appear to be unaffected by the incomplete data in this test.

Discussion

The data from the three tests clearly indicate that the motorcycle decelerates more quickly in the moments shortly after making contact with the pavement than it does during later portions of its slide. Lambourn noted that the higher average coefficient of friction was speed relative and was likely caused by the motorcycle digging into the pavement during the initial contact phase of the trajectory. Recalling that drag force is found by multiplying the drag factor by the normal force (which is often equal to the weight of the object), we can conclude that the high normal forces associated with impact with the ground produced the higher deceleration.

Although the two explanations seem parallel to one another, we note that the gouge marks on the pavement in our tests were not particularly deep near the area of impact, yet the motorcycle was clearly decelerating at a higher rate during this initial interaction with the roadway. The likely reason that Lambourn noted higher overall coefficients of friction during the lower speed tests that he performed is that the initial impact with the roadway would tend to more significantly affect the overall average of the friction during shorter slides than in longer slides. During longer slides, the relatively short duration of the initial impact phase would have a lesser effect on the overall average deceleration during the slide.

Test Number	Motorcycle	Average f after stabilizing	Ave drag factor in first 15 feet	Ave overall f from Field Data	Ave overall f from Video Data
2	Honda	0.38	0.88	0.47	0.48
3	Honda	0.36	0.74	0.39	0.41
4	Suzuki	0.35	0.78	0.39	0.42

Table 2

The significance of this phenomenon becomes apparent when attempting to reconstruct a collision where the motorcycle has fallen to the pavement and slid for a relatively short distance before colliding with another vehicle. In these circumstances, it is appropriate to use a higher coefficient of friction for the slide distance than one would typically use for the same type motorcycle sliding over long distances. **(See Table 2)** It is clear that using the average coefficient of friction under these particular circumstances would produce an underestimate of the amount of energy lost during the pre-impact slide of the motorcycle.

The two motorcycles used in these tests were equipped with either crash bars or full body covers, allowing them to slide relatively easily across the pavement surface. More tests should be performed with a wider variety of motorcycles, using techniques such as those used in this study, so that the significance of the initial impact with the pavement can be evaluated further. The test techniques used in this study allowed us to both measure the overall average friction and the friction levels during various phases of the trajectory. Further refinement of this technique may allow us to develop appropriate friction levels to use during the impact phase of short duration slides. The initial data suggests using friction coefficients of as high as .75 to 1.0, depending upon the duration of the pre-impact slide.

Conclusions

A total of three successful motorcycle sliding friction tests were performed in order to evaluate the significance of the deceleration experienced by the motorcycle during the early stages of the sliding trajectory. The results of the tests indicate that the motorcycle tends to decelerate at much higher rates during the initial impact between the motorcycle and the pavement, due in large part to the increased normal forces associated with the downward movement of the motorcycle as it impacts the pavement.

The results indicate that it is appropriate to use a higher coefficient of friction in circumstances where the motorcycle slides a relatively short distance prior to colliding with another vehicle. Although the data is limited due to the number of tests performed, the tests results suggest that a coefficient of friction of as high as .75 to 1.0 is appropriate under the above described conditions.

More testing should be performed with larger variety of motorcycles to evaluate the significance of motorcycle style on the peak acceleration values associated with the initial interaction with the roadway. More tests would also increase levels of confidence in the appropriate range of coefficient of friction under short pre-impact motorcycle slides.

Acknowledgements

References

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