Motorcycle Crash Testing and Reconstruction:
Selected Exponent Publications

In its normal course of business, Exponent conducts many accident investigations and crash tests related to motorcycles for a range of clients. The knowledge gained from these investigations, as well as internally funded research, is used to continually improve testing methods and accident reconstruction techniques for the analysis and investigation of motorcycle design issues and accidents. Four publications described below provide examples of Exponent’s continuing interest in motorcycle testing and crash and safety analysis.

**Full-Scale Moving Motorcycle into Moving Car Crash Testing for Use in Safety Design and Accident Reconstruction**
Exponent’s Contributing Engineers: J. Smith, T. Frank, G. Fowler
Reprinted with permission from SAE paper 2012-01-0103 © 2012 SAE International

Published data indicate that prior studies of motorcycle accidents and the advancements in motorcycle safety designs have been based, in large part, on single-moving-vehicle crash tests. However, as described in this paper, the accuracy of the post-impact motion of the motorcycle and automobile is important for evaluating the kinematics of the motorcycle rider. For two-moving-vehicle accidents, the rotation of the motorcycle front wheel and the resulting asymmetric compression and deformation of the front forks affects the post-impact motion of the motorcycle rider and the crash damage observed on the motorcycle and the other vehicle. Consequently, it is preferable to conduct two-moving-vehicle crash tests when the post-impact kinematics are important to an analysis.

Exponent’s Test and Engineering Center has been conducting crash tests of moving motorcycles into moving cars for many years and has developed reliable methods for conducting such tests across a wide variety of speeds and impact orientations (Fig. 1).

Conducting such tests has rendered a broad understanding of the post-impact motion of the motorcycle, the kinematics of the rider, and the post-crash damage available for analysis when a motorcycle is involved in a two-moving-vehicle impact. This paper presents the test methods used and a selection of the results derived from a series of crash tests involving moving motorcycles colliding with moving cars (e.g., Figs. 2 and 3). The featured tests were conducted at speeds representing both urban and highway travel and provide data that is useful in evaluating crash events with variations in the impact angle and initial point of contact between vehicles.
Pitch-over events are common in motorcycle accidents and can be caused by impact to the front wheel and occasionally by hard brake application. In either case, the rider of the motorcycle can be propelled over the handlebars as the motorcycle pitches rear-end up. In accidents caused by pitch-over braking, the accident investigator may be faced with limited evidence and then must rely on analyzing the throw distance of the rider in attempting to reconstruct the pre-accident speed of the motorcycle. This analysis can be complicated by the presence of a second rider (the passenger) on the motorcycle. Pitch-over caused by front wheel impact can be similarly complex (Fig. 4). Although motorcycle deformation as a result of front wheel impact has been studied, circumstances surrounding the nature of the deformation, or the impact itself, may require that the trajectory of the rider be analyzed to determine the pre-impact motorcycle speed.

A series of sled tests were conducted by Exponent to analyze rider and passenger motion during pitch-over events, to develop a more complete understanding of how deceleration and initial speed affect the occupant trajectory and velocity. Brake stops were simulated on the sled, as well as front-wheel impacts. High-speed video footage was analyzed to develop an understanding of the pitch-over dynamics and rider/passenger trajectories and velocities (Fig. 5). A full-scale crash test was also conducted and compared against the results of the sled simulations. This paper presents the results of this study and offers a method for accident reconstructionists to employ as they examine motorcycle accidents that involve pitch-over events.
Motorcycle accident reconstruction is traditionally challenging. Accident reconstructionists often use conservation of linear and rotational momentum when determining the impact speed of two vehicles. However, with the weight disparity between a motorcycle and what is often a passenger vehicle (or larger), this method may result in such a wide range of impact speeds that the analysis provides the reconstructionist with little useful information. To complicate the calculations, the reconstructionist must also account for the uncoupled mass of the motorcycle rider. Another method often used in accident reconstruction is conservation of energy. However, due to the lack of information regarding motorcycle crush energies, this method by itself also may not provide accurate information. Finally, the reconstructionist can turn to crash simulation software. As simulation programs improve their functionality and ease of use, more practitioners are approaching motorcycle crash reconstructions with simulation in mind. However, the fidelity with which the available crash simulation packages recreate the actual conditions of a motorcycle crash remains a topic of discussion.

This paper investigates the ability of two crash simulation tools—EDSMAC4 (Engineering Dynamics Simulation Model of Automobile Collisions, 4th Revision) and SIMON (Simulation MOdel Nonlinear)—to simulate four full-scale moving-motorcycle-to-moving-automobile crash tests. The simulation tools used in this study were not specifically designed to simulate motorcycle collisions of any type. With this in mind, the methods and assumptions used to develop the simulations in the present study are discussed in detail (e.g., Figs. 6 and 7).

The capability of the simulation packages to accurately re-create crashes was examined by comparing the post-impact responses of the passenger car with the data and video from each of the four crash tests. (The model is not designed to simulate the post-collision motion of the motorcycle.) Based on this study, it was concluded that EDSMAC4 and SIMON provide a reasonable match to the immediate post-collision motion of the passenger car when compared to the crash test and thus provide a useful tool for estimating the impact speeds and orientations of the motorcycle and other vehicle. SIMON appeared to better model the post-impact motion of the passenger car to the point of rest (Fig. 8).
Condition of the Motorcycle Steering Head Assembly after Crash Testing

SAE 2012-01-0619

Exponent’s Contributing Engineers:
T. Frank

Reprinted with permission from SAE 2012-01-0619 © 2012 SAE International

Through the use of two different motorcycle crash test series (Figs. 9 and 10), data were collected for the purpose of studying the post-impact condition of the motorcycle steering-head assembly after a frontal impact. The steering-head research investigated the damage patterns created by known impact configurations and speeds, as well as determining whether any relationship existed between pre- and post-impact fastener torques of the steering head. Relevant fastener torques were initially adjusted according to manufacturer’s specifications and then were remeasured after the collision tests. The motorcycle steering assemblies were also photographically documented before and after the tests.

Relevant fastener torques and condition of tested steering assemblies are presented. The results are discussed in the context of accident reconstruction and information provided about the accident conditions, as well as the condition of the steeringhead assembly and relevant fastener torques prior to an accident. An example of the post-impact damage to the steeringhead components is shown in Figure 11.

Exponent’s wide array of expertise, ranging from motorcycle accident reconstruction and crash testing to biomechanical analysis of rider injury, give Exponent a unique perspective to fully understand and analyze motorcycle-related issues. When it comes to motorcycle-related research, full-scale crash tests, and in-depth accident reconstructions, Exponent’s scientists and engineers are among the industry leaders.

For more information or to discuss a specific matter of concern, please contact one of the following individuals.

James Smith, P.E., Principal Engineer
jsmith@exponent.com

Todd Frank, P.E., Managing Engineer
tfrank@exponent.com

Graeme Fowler, Ph.D., P.E., Principal Engineer
gfowler@exponent.com

Stephen M. Werner, Ph.D., P.E., Principal Engineer
swerner@exponent.com

Copies of these research publications can be obtained through the Society of Automotive Engineers website, www.sae.org. For more information, please visit our website at www.exponent.com