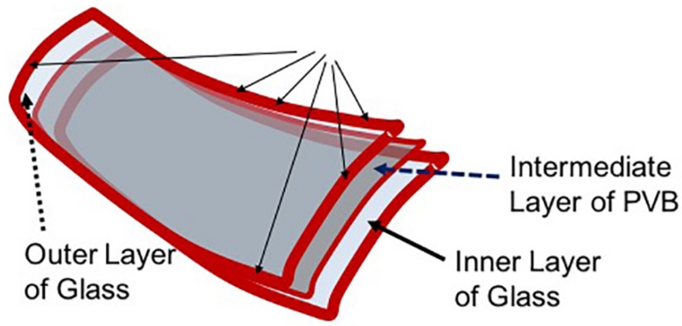
WINDSHIELD GLASS – APPLICATIONS IN AUTOMOBILE ACCIDENT FORENSICS

Many automobile accidents are complex cases with multiple events during a single accident. The aim of forensic investigations of such (and all other) accidents is to reconstruct the sequence and the severity of events during the accident and then to establish cause-and-effect relationships between the injuries (or damages) and the probable factors - vehicle design (e.g. brakes, structure, airbags); vehicle operator (e.g. distracted driver, alcohol impairment, reduced vision); and operating conditions (e.g. fog, failed traffic sign, excessive speed, icy road).

Most often, the traditional practice of accident reconstruction involves using empirical algorithms (generally 'lumped mass-and-spring models') with some measurements from the accident site and from the car's exterior damage to estimate the crash parameters. In accidents involving multiple impacts, such methods may not be adequate and it becomes necessary to develop new techniques for obtaining reliable information regarding the accident.

This article describes such a technique developed by the author, using the ‘stored information’ in a windshield when it is damaged from impacts in an accident. As illustrated below, analysis of high-resolution and properly-detailed photographs of the windshield can provide significant additional information for accident reconstruction and for injury causation evaluation.

Laminated Windshield Construction enables vehicles to meet the requirements of the Federal Motor Vehicle Safety Standards for protection of vehicles’ occupants in certain types of crashes. The ‘laminated safety glass’ in these windshields consists of three layers – (i) an outermost glass layer, (ii) a thin laminate of plastic material known as ‘Polyvinyl Butyral’ (or ‘PVB’), and (iii) an innermost glass layer. Typically, each glass layer may be 2.5 millimeters thick and the intermediate PVB laminate may be 0.75 millimeter in thickness. All three layers are bonded together and the entire assembly is encased in the vehicle's windshield frame which is a part of the vehicle's structure. The above thicknesses may vary from one manufacturer to another and from one model to another. When subjected to severe impacts, the inner and the outer glass layers will fracture at relatively low values of stress. The intermediate PVB layer is a 'hyperelastic' material and it can withstand large amounts of deformation and strain without rupture.



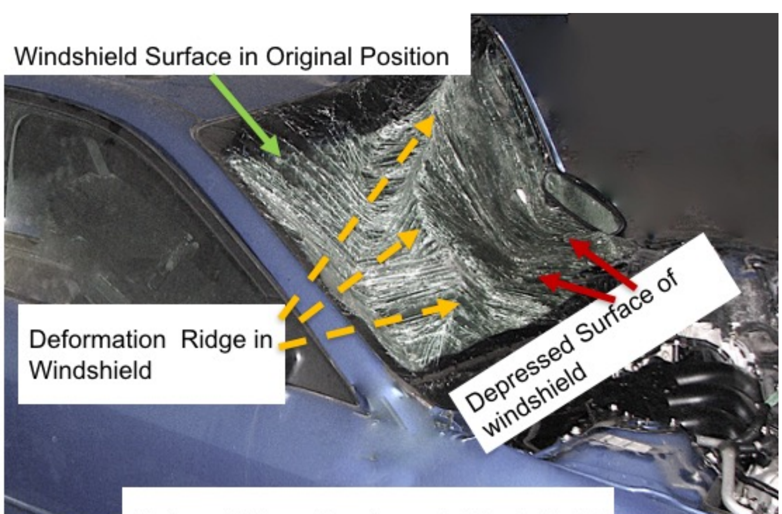
All layers bonded together

This laminated construction allows the windshield to 'store' information about the impact in the form of lines of fracture in the glass layers and as deformations in the windshield's surface as follows. In an impact, the glass in the two layers will fracture and the shape and density of these fractures depends on the type and the severity of impact. Since the glass layers are bonded to the hyperelastic PVB layer which remains attached to the vehicle frame, the fractured pieces of glass are retained by this layer and are observed as fracture lines or 'patterns' after the impact. Any second impact would result in additional distortions in shape and additional fracture lines in glass, superimposed on the previous patterns. The appropriate analyses of high-res photographs of these 'patterns' can then be carried out to obtain accident-related information of interest. Of course, this method may not apply in cases where the PVB layer itself has been broken off by intrusion of a large object or when most of the windshield is separated from its frame. However, in a large number of actual cases, the windshield retains much of the 'impact information'. Such techniques based on high-res photography ('photogrammetry') are used in several branches of science and engineering. The specific methodology and analysis process applied to the photographs in each case depends on the field of application and the desired results.

Analysis of High-Res Photographs in the examples below was done to convert the ‘damage information’ in the windshield into data such as severity and sequence of impacts (external and internal), and then to establish relationships between injuries and the causation factors.

EXAMPLE 1 is from investigation of an accident that consisted of several impacts, e.g. car-to-car crash, vehicle rotations, impact with roadside structure(s) and impact with ground (or another hard surface). Three photographs from the study are shown below. The first photograph is from a high viewpoint outside the vehicle and in front of the vehicle on the passenger-side. Some detail is lost in the picture seen here due to the image size limitations in publication. However, many findings are still visible and will be briefly discussed.

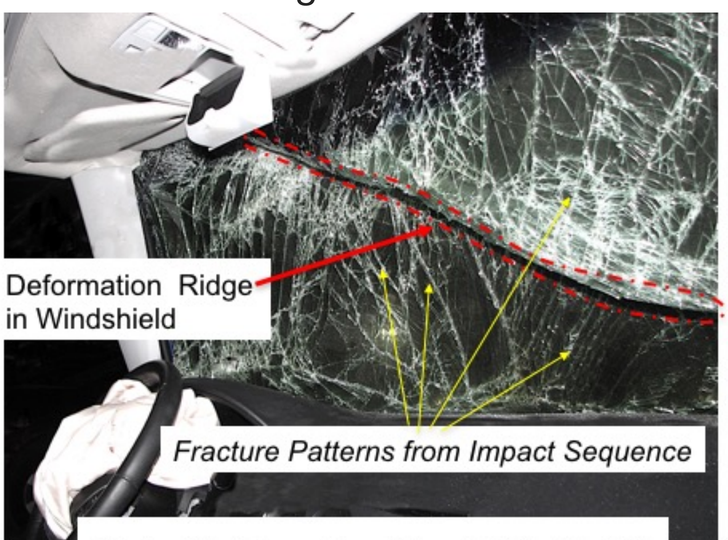
The prominent ('global') damage in the post-crash windshield is observed to be a diagonal 'ridge' extending from the bottom of the passenger-side A-pillar to the top of the driver-side A-pillar. This ridge deviates from an almost straight line shape in the vicinity of the passenger-side pillar. Multiple fracture lines are observed on each side of the ridge. Several other observations can also be made: (a) the surface of the windshield near the top of the passenger-side pillar remains undisturbed; and (b) the severe deformation of the windshield in the vicinity of the bottom of



External View: Post-crash Windshield

driver-side pillar makes its surface parallel to the dashboard surface. The multiple impacts to the windshield in this case divide it into ‘segments’, each segment containing some information about the parameters of the accident. Highly detailed photographs of each segment were evaluated for variables such as: the density and orientations of fracture lines; the change in the shape of these lines as they cross the ‘ridge’; slopes and dimensions of various segments, etc. One example conclusion is that the impact leading to the ‘ridge’ was preceded by fracture lines formed in one segment.

Shown below is the second photograph ‘P2’ from this example, taken from a view point in the vehicle’s interior and on the right side of the rear seat. Although there are some visual similarities between this photograph and the one shown above, this photograph P2 contains additional details of the windshield’s fracture patterns and these were analyzed from suitably enlarged views of each section of the windshield.

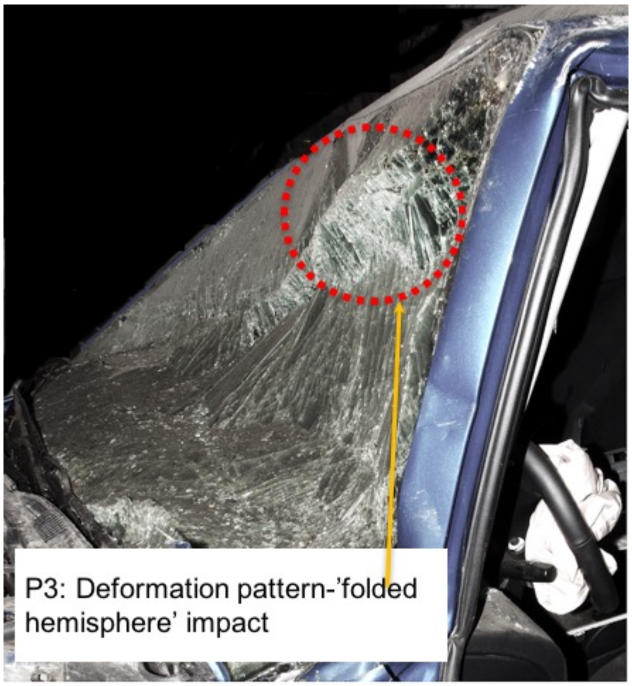


P2: Inside View: Post-Crash Windshield

Details of the geometry of fracture lines and the change in direction from one segment of the windshield to another are related to the various parameters of the accident. In some cases, it becomes necessary to visually ‘straighten’ the deformed windshield since to better analyze the superimposed patterns and determine the timing sequence in the accident.

When examined closely with proper magnification, the photograph ‘P2’ also shows an impact to the inner surface of the windshield. For the actual case, each part of the damaged windshield was photographed separately in high resolution. This technique established that the fracture pattern from impact on the inner layer of glass corresponded to the driver's head hitting the windshield. It also established the timing of this impact in the multi-impact sequence.

As another illustration, the photograph P3 shown here also provides many details of the accident. A visual observation shows the 'bulge' in the windshield from the inside of the car in the outward direction. Analysis of the superimposed damage patterns sequences this interior impact as following the formation of the diagonal ridge but preceding some of the other damage segments in the windshield.



P3: Deformation pattern-'folded hemisphere' impact

Analysis of the superimposed damage patterns sequences this interior impact as following the formation of the diagonal ridge but preceding some of the other damage segments in the windshield.

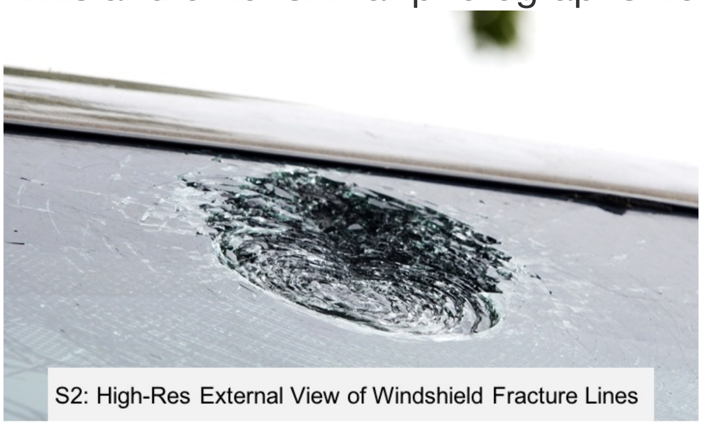
<u>EXAMPLE 2</u> involved a car driving on a city street during nighttime hours and being struck by an object thrown from outside the vehicle. This caused a momentary distraction to the driver, leading to the driver losing control of the vehicle and striking other roadside objects.

The issues in this example case involved the determination of the direction of the projectile and of the location from which it may have been thrown.

The overall view of the vehicle in the photograph 'S1' here shows the impact to be near the top surface and in the center of the windshield but does not provide any other details. Using high-res photographs and appropriate analysis techniques, it is possible to obtain much more relevant information.

S1: External View of Car’s Windshield

The photograph ‘S2’ is a high-res exterior view of the impact 'crater'. This and other similar photographs from different angles and viewpoints were analyzed for the relative depths of various points in the crater. This information, combined with the known shape of the impacting object helped determine the orientation of the projectile when it hit the windshield. Since the broken glass fragments were retained by the PVB layer of the windshield, it was also possible to evaluate the orientation of the glass fragments inside the indentation, thus providing more information to help determine the direction of impact.


S2: High-Res External View of Windshield Fracture Lines

Similarly, photographs taken from other viewpoints, e.g. from inside the vehicle as in ‘S3’, show fracture propagation patterns in the laminated glass. Analyses of the shape, density and dimensions of these fractures (or 'cracks in glass') also help determine, to some extent, the direction of the force at the moment of impact.


S3: Inside View of Windshield Fracture Lines

This methodology of using of high-res photography-based analysis for accident forensics requires detailed knowledge of the impact behavior of all the involved components – the glass layers and the laminate in the windshield, and the vehicle's structure, as well as the structural behavior of the impacting objects. In addition, information obtained from other measurements of the vehicle's deformation (exterior and interior) help complement and support the capabilities described above.