

Glass Debris in Rollover Accidents

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ABSTRACT

Vehicles involved in rollover accidents almost always leave a debris trail. This debris trail is useful for the accident reconstructionist; it assists with identifying the vehicle path during the rollover and the location and orientation of the vehicle at various vehicle to ground contacts. Often it is helpful to know when and where various vehicle windows fractured. This is possible by comparing glass obtained from the accident site with glass samples still attached to the accident vehicle. The limit of this analysis is controlled by the manufacturing tolerance of the vehicle glass and the specified pane thickness. This paper presents a series of measurements made on various automotive tempered windows and presents: 1) the thickness range in individual panes, and 2) the thickness variation seen from pane to pane in the same vehicle.

INTRODUCTION

Rollover accidents constitute approximately 8% of the total accidents in the United States and approximately one third of all fatal accidents [1, 2]. The accident reconstructionist is often asked to analyze such events to determine the vehicle kinematics. The path of the vehicle is generally evident from vehicle to ground contacts and debris from both the interior and exterior of the vehicle. The debris can consist of components broken off of the vehicle during the roll sequence or ejected cargo. Rollovers occurring on the paved portion of a roadway will often create gouges in the pavement, but any debris which was deposited is generally removed shortly after the accident. Rollovers which occur off the paved portion of the roadway will also create gouges in the dirt, but over time may become less apparent due to foliage or normal weathering. Often the debris deposited off-road is undisturbed post accident and is still available for discovery at a later time. Experience has indicated that large pieces of debris are often gathered at the time of the accident, but the smaller pieces are not. Fractured tempered glazing is one type of debris which is seldom gathered immediately post accident in off-road rollover accidents and is available for subsequent discovery.

When reconstructing a rollover sequence, it is often important to determine where various windows of the accident vehicle fractured during the rollover. Some simple analysis may be applied to narrow down the candidate windows; for example, the rear windows of most vehicles contain metal strips for window defrosting, and often the window tinting is different for various positions. The specified nominal thickness of the tempered glass in the various positions often is different. For example, in an SUV the rear quarter glass may be specified to be 4.0 millimeters (mm) while the adjustable door windows may be 3.5 mm. The question becomes, "If all the tempered glass in the vehicle is nominally 3.5 mm, is it possible to determine which window the glass came from?" To answer this question it is necessary to see the variation (range) in glass thickness within a single pane versus the differences seen pane to pane. The following study is a survey of various vehicles to examine these variations.

BACKGROUND

Historically the forensic analysis of glass has been used to help solve crimes against society. Generally the samples obtained are few in number and minute in size. Finding a sample with both parallel surfaces intact is rare. The matching of glass, therefore, has to move beyond simple thickness measurements to more sophisticated techniques. Most literature reporting on the forensics of glass uses either chemical composition or refractive properties to identify glass samples. Renshaw and Clarke found the thickness standard deviation for five float glass samples as ranging from 0.004 mm to 0.013 mm in an early study conducted in 1974 [3].

Automotive tempered glass typically ranges in nominal thickness from 3.0 to 6.5 millimeters. The manufacturing tolerance is generally published at ± 0.1 mm [4].

MEASUREMENT TECHNIQUES

To measure window thickness range requires measurements of the entire surface of the pane. This requires fracturing many windows or using an accurate nondestructive technique to measure the glass over the whole surface. Accurate direct measurements are easi-

ly available using a micrometer, but only around the perimeter of the glass. Ultrasonic techniques can be used to accurately measure a window over the entire surface.

Ultrasonic methods have been used a number of years to measure the thickness of materials. Ultrasonics use the simple principle of $V=d/t$. Where V is the velocity, d is the distance (or thickness in this case) and t is time. The ultrasonic gage measures the time for a sound wave to travel through a solid material. The sonic velocity of the solid material is then used to compute the thickness of the measured solid. Three modes are commonly used to measure thickness when using a sonic gage. In Mode 1, measurement is made between an excitation pulse and the first backwall echo from the test piece. It is a general purpose test mode. In Mode 2, measurement is made between an interface echo representing the near surface of the test piece and the first backwall echo. Mode 2 is most often used for measurements on sharp concave or convex radiuses or in confined spaces, and for high-temperature measurements. In Mode 3, measurement is made between two successive backwall echoes. It may be employed only when clean multiple backwall echoes appear which typically limits its use to materials of relatively low attenuation and high acoustic impedance such as fine-grained metals, glass, and ceramics. Mode 3 typically offers the highest measurement accuracy and the best minimum thickness resolution in a given application, at the expense of penetration, and it is used when accuracy and/or resolution requirements cannot be met in Mode 1 or 2. Automotive tempered glass is an ideal material to use with Mode 3 offering the highest possible accuracy [5].

In this study, an Olympus Parametrics NDT 35DL Ultrasonic Precision Thickness Gage (35DL) was used in Mode 3 in conjunction with a delay line transducer model number M202-RM. Mode 3 offers a rated measurement accuracy of ± 0.002 millimeters. Reference measurements were made with a Mitutoyo micrometer model number 293-348 with a rated resolution of 0.001 mm and an accuracy of ± 0.0013 mm.

SURVEY

For this study the windows were measured as follows:

1. Photographs were taken of the sample vehicle, the vehicle VIN plate, each measured window, and the window's glass manufacturer decal.
2. For most windows the micrometer was used to make a reference measurement on the sample window. The reference measurement was recorded. For those windows with a black coating along the perimeter of the glass, an SPI Electronic Deep Throat Micrometer model number 13-821-4 with a rated resolution of 0.001 mm and an accuracy of ± 0.004 mm was used to make the reference measurement.

3. An ultrasonic measurement at the same location was made with the 35DL. The reference thickness measured with the micrometer was used to calibrate the 35DL and establish the sonic velocity of the glass. The sonic velocity was then recorded.
4. Up to 24 measurements were made around the perimeter and throughout the center of each window using the 35DL.
5. The total range in thickness within a window was computed.

Some windows did not have an exposed edge to allow for a micrometer reference measurement. This was true of many of the fixed rear quarter windows on many SUV's and minivans. In this case the sonic velocity of one of the other windows of the same sample vehicle was used; the window with the most similar tinting was selected. Later a comparison of sonic velocity of the various sample windows was analyzed to determine the validity of these measurements.

RESULTS

A survey of 108 panes of glass were measured in 18 vehicles which ranged in model year from 1987-2006. Vehicle types included 2-door hatchbacks, 4-door sedans, sport-utility vehicles, vans, and pickups. A summary of all vehicles included in the survey is provided in Appendix A. All tempered window glass was measured in each vehicle, except those windows with aftermarket window tinting film.

Glass thickness was found to range from 3.124 mm (0.1230 in.) to 5.070 mm (0.1996 in.) (Figure 1). Generally, it was observed that the rear window glass was the thickest window in a vehicle.

The sonic velocity of all windows measured ranged from 5.7521 to 5.8187 mm/ μ s and had a mean of 5.7735 mm/ μ s. Because this range only varied by 1.2%, the effect on accuracy is negligible and, therefore, measurements are valid when using the sonic velocity from another similar window in the same sample vehicle. Automotive tempered glass appears to maintain a very high consistency in sonic velocity.

The minimum thickness range within a single pane was found to be 0.003 mm (0.0001 in.) and the maximum within a single pane was 0.067 mm (0.0026 in.). Generally, it was observed that the rear window glass tended to have the largest range seen in a vehicle. Figure 2 shows the distribution of thickness range by model year. The data show a trend toward less variation with newer model-year vehicles. They also show that all of the panes surveyed were well below the SAE recommended thickness tolerance of ± 0.1 mm for automotive glazing. In fact, the average range was found to be 0.017mm (0.0007 in.). It was observed that the variation distribution within a single pane was not necessarily random; rather it often gradually transitioned from one side to another.