

Predicting Effects of Veiling Glare Caused by Instrument Panel Reflections in the Windshields

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ABSTRACT

This paper presents quantitative effects of windshield veiling glare on the visibility of targets based on a two part research project. The first part involved measurement and modeling of luminance of veiling glare caused by the reflection of different instrument panel materials under range of conditions defined by combination of windshield angle, instrument panel angle, and sun angle. In the second part, the veiling glare model was incorporated in a visibility prediction model based on visual contrast threshold data. A critical visibility condition of a driver approaching a tunnel with the sunlight falling on his windshield and attempting to detect a target inside the tunnel was studied by conducting sensitivity analyses. The sensitivity analysis showed that a 2 ft diameter 10% reflectance target illuminated by 5000 lux of lighting inside a tunnel visibility distances can be seen from 0 to 3,000 feet depending upon driver's age, vehicle design parameters and sun illumination levels.

INTRODUCTION

In designing vehicles, especially with more sloping windshields, it is critical that right combination of windshield and instrument panel geometry and materials be selected to avoid the problem of degrading the driver's forward visibility by the veiling glare caused by reflection of the sun illuminated instrument panel into the windshield. The Veiling Glare is defined here as the light that is reflected or scattered from a vehicle windshield into the driver's eyes. It is called the veiling glare because it creates a veil that is superimposed as unwanted luminance on the driver's view, and it reduces the driver's visibility. When the sun light falls on the windshield, it illuminates the top part of the instrument panel and its reflection in the windshield is seen by the driver as the veil. The factors that effect this visual effect are: a) the windshield angle, b) windshield type/material, c) the angle of the instrument panel with respect to the windshield, d) the source of incident light, i.e. the sun during the daytime, e) source or sun angle, f) source illuminance, g) instrument panel material characteristics

such as gloss/reflectance, texture, color, etc., and h) parting line geometry (joints or discontinuities of the top part of the instrument panel) [1].

Figure 1 presents a driving situation in which the effect of veiling glare becomes very critical. The situation involves a driver approaching a darker area such as a tunnel (or a parking structure) and looking for an object in his path inside the tunnel while the sunlight is falling on his windshield. The visibility of target inside the tunnel will be reduced by the veil created by the reflection of the of the sun illuminated instrument panel into his windshield. The visibility of the target will also depend upon other factors such as the size and reflectivity of the target, its location in the tunnel, tunnel lighting and ambient illumination falling on the target, and the driver's age.

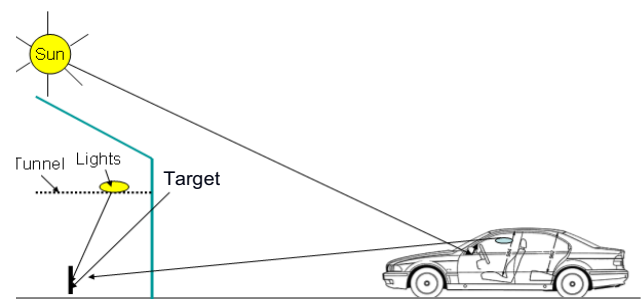


Figure 1. Veiling Glare Encounter Experienced by a Driver Approaching a Target Inside a Darker Tunnel When the Sunlight Falls on the Windshield

Figure 2 presents the ray geometry of the incident sun light as it is reflected into the windshield and viewed by the driver while detecting (observing or looking for) a target. During the early design phases of a vehicle, a vehicle package engineer will generally draw such ray geometry diagrams from various different driver eye points that are defined by using eyellipses [2] to assess the windshield and instrument panel architecture for potential veiling glare effects.

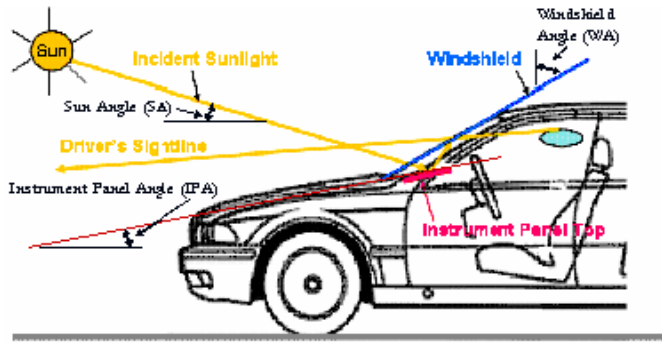


Figure 2. Ray Geometry in the Veiling Glare Encounter

OBJECTIVES

The objectives of this project were to measure veiling glare characteristics of windshield reflections and develop a visibility distance prediction model to evaluate the effects of the veiling reflections on the driver's forward visibility. The visibility model can, thus, be used as a design tool to eliminate the distracting and visibility degradation effects of the veiling glare during the early stages of designing a new vehicle.

APPROACH

The research was conducted in two phases. In the first phase, a miniature veiling glare simulator was developed to simulate and measure the veiling glare on the windshield caused due to reflection of the instrument panel illuminated by simulated sunlight. The measured veiling glare luminance data were statistically analyzed to obtain a model to predict veiling glare coefficient [VGC] in $\text{cd}/(\text{sq. meter} \times \text{lux})$ as a function of the geometric variables associated with the veiling glare situation and the instrument panel material characteristics. The second phase involved developing a model to predict visibility distances to targets in veiling glare situations similar to the tunnel approaching situation shown in Figure 1.

PHASE 1: MINIATURE VEILING GLARE SIMULATOR & MEASUREMENTS

The miniature veiling glare simulator was designed and built at the UM-Dearborn campus. The simulator consists of a wooden fixture to hold and position a 16"x16" flat piece of windshield glass and a 12"x12" flat sample of instrument panel material in any vehicle geometry. The windshield angle could be adjusted from 50 degrees to 70 degrees from the vertical to simulate configuration of windshield angles from pick-up trucks (or SUVs) to very aerodynamic sports cars. The instrument panel angle could be adjusted from -20 degrees to +20 degrees (minus angle indicates the instrument panel sloping down and the positive angle

indicates the instrument panel tilted up and at a smaller included angle with the windshield) with respect to the horizontal. The sunlight was simulated by using a light source with a high color rendering index value of 89. The light source could be positioned to create incident (sun) angles from 10 to 30 degrees from the horizontal. (See Figure 2 for the illustration of the three angles). Figure 3 shows the miniature fixture. The sun illumination was measured by using a Minolta handheld light meter. A spectroradiometer (SpectraScan Model 705, Photo Research Inc.) was placed at the driver's eye location and aimed horizontal to measure luminance, chromaticity coordinates, color rendering index and spectral distribution of the veil created by each instrument panel material.



Figure 3. Miniature Veiling Glare Simulator

Measurements in Veiling Glare Simulator

Sixteen different instrument panel materials were provided by Collins and Aikman to represent a range of types of materials used in various current vehicle models. The veiling glare luminance values for each of the materials was measured in geometric configuration defined by the combination of the following three factors and their levels:

Windshield Angle: 55, 60, 65 and 70 deg.
 Instrument Panel Angles: -20, 0 and +20 deg.
 Sun Angles: 10, 20 and 30 deg.
 Instrument Panel Materials with Gloss Values (G):
 0.80 to 2.7

The gloss value (G) of each material was measured by using a commercially available gloss meter at 60 deg. incident and reflectance angles.

Early pilot measurements made under wider ranges of the combination of the above three variables showed that veiling glare luminance dropped rapidly and was low when the sun angles were larger than 30 degrees.

instrument panels were sloping down (i.e. instrument panel angles were negative), and when the windshields were more vertical (i.e. windshield angles were smaller than 55 deg.).

Data Analysis and Modeling of VGC

The veiling glare coefficient (veiling luminance divided by illumination incident on the windshield) data were analyzed using the Minitab software and analysis of variance (ANOVA) technique to determine effects of the factors and plots of main effects and interactions. Table 1 shows that all the four independent variables and their two variable interactions that were significant at P value less than 0.01.

Table 1. Analysis of Variance Table for Veiling Glare Coefficient

Source	DF	SS	MS	F	P
Windshield Angle	3	0.1060355	0.0353452	560.6	0.000
IP Angle	2	0.0631110	0.0315555	500.5	0.000
Sun Angle	2	0.0399564	0.0199782	316.9	0.000
Gloss	15	0.0100092	0.0006673	10.58	0.000
Windshield Angle*IP Angle	6	0.0275632	0.0045939	72.86	0.000
Windshield Angle*Sun Angle	6	0.0070378	0.0011730	18.6	0.000
IP Angle*Sun Angle	4	0.0069472	0.0017368	27.55	0.000
Error	573	0.0361280	0.0000631		
Total	611	0.2967883			

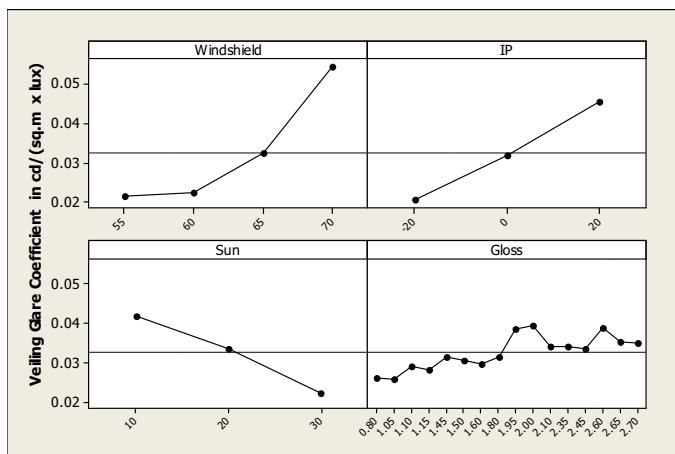


Figure 4. Main Effects Plots of Four Independent Variables

Figure 4 illustrates a main effects plot of veiling glare coefficient (VGC --the veiling luminance measured in cd/sq. meter divided by the illumination in lux falling on the windshield) obtained from the Minitab software for four independent variables, namely: a) windshield angle, b) instrument panel angle, c) sun angle, and d) gloss values of the 16 materials used in the study. The figure shows that the VGC increased with an increase in the windshield angle, an increase in the instrument panel angle, a decrease in the sun angle, and an increase in the gloss value of the instrument panel materials.

Figure 5 shows an interaction plot showing how the combination of windshield angle and instrument panel angle affects the veiling glare coefficient. The effect due to the instrument panel angle increases with an increase in the windshield angle. This effect can be seen in Figure 5 by observing how the separation between the top and the bottom curves increases with increase in the windshield angle.

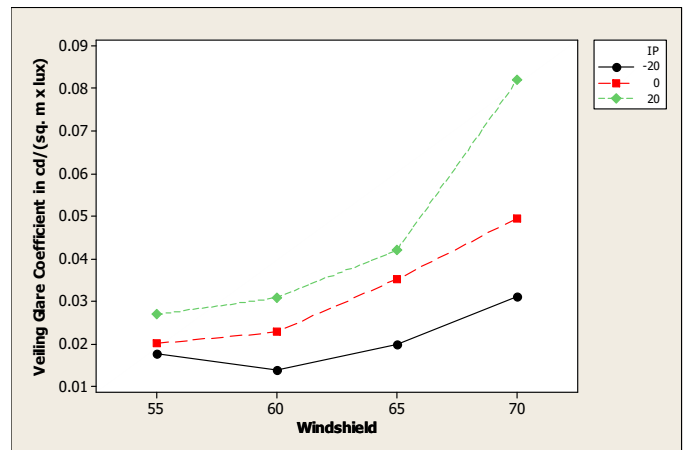


Figure 5. Interaction Plot Showing Effects of Windshield Angle and Instrument Panel Angle on Measured Veiling Glare Coefficient [cd/(sq. meter x lux)]

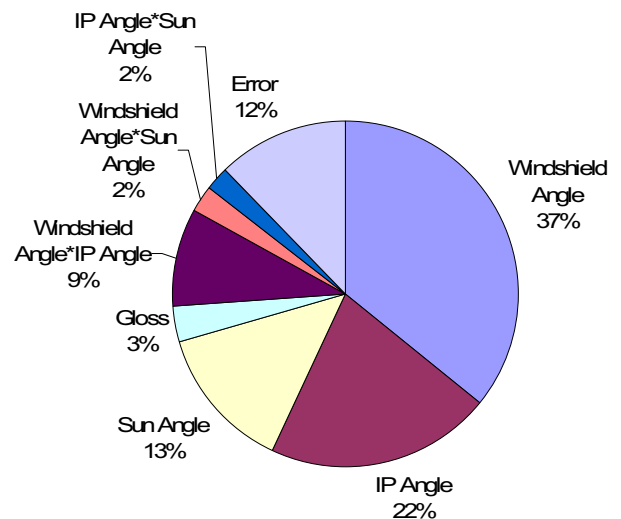


Figure 6. Pie Chart Showing Relative Contribution to the Sources to the Sum of the Squares.

Figure 6 above shows a pie chart to illustrate relative contribution of the eight sources of variations in terms of the sum of the squares (SS) presented in Table 1. The figure shows that largest to smallest important contributors to the veiling glare coefficients are windshield angle, instrument panel angle, sun angle and the interaction between the windshield angle and the instrument panel angle, respectively.