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Further Research on Camouflaging A-pillar of Sedan

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Abstract Three main factors, dip angle, thickness, and the separation between pillar and driver's eye, directly impact the invisible effect and mechanical strength of support frame. Some solutions to solve problems while using a camouflaging technology for vehicles were suggested. One typical tricky difficulty for the design of an invisible pillar is how to let drivers with different stature to achieve the same stealth effect. One solution is to employ a triangular prism to change the image location from the light blocked by A-pillar so that drivers of various heights can get the same invisibility rate. Hopefully, the trickiest problem for designing an invisible A-pillar can be solved with ease.

Keywords: *stealth technology, camouflage technology, automobile industry, A-pillar of vehicle, quadrangular prism, quadrilateral prism*

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1. Introduction

Currently, the application of stealth technology has been used almost exclusively in military industry [1,2,3]. Having been invented and developed for more than one hundred years, vehicles are essential and necessary for our daily lives. Without them we almost cannot make a living. Compared with automobile batteries and self-driving systems, camouflaging technology for A-pillar, cannot be regarded as something essential and urgent. All the pillars (A, B, C and D) serve as support frames for the windshield, side windows and roof of the vehicle. Nevertheless, all pillars have a positive and negative effect; they brace the roof and windshield, but also, to some extent, block the driver's view to cause blind spots. The existence of blind spot not only makes driving less safe, but also makes driving more uncomfortable. Therefore, automobiles designers have been considering how to redesign traditional pillars. Many innovative construction ideas for pillars have been suggested [4]. However, the blind spots caused by the pillars, particularly the two A-pillars, remain. This case is similar to the attempt to use rechargeable batteries to replace the engine. Although in principle, rechargeable batteries can be utilized for all sorts of vehicles, there is a long way to go before this improvement is widely implemented.

Aiming at making a stealth support frame system, an invisible prism of self invisibility, was first designed in 2017 [5] and since then, some relevant research has been reported [6,7]. Afterwards in 2018, a more general prism, the quadrilateral prism of self-invisibility was introduced [8]. Then, the problems arising from making use of this invisible prism in the construction of the A-pillar of vehicles was investigated. The trickiest obstacle of all is how to accommodate for the change of the observation point for drivers of various heights in order to get the same invisibility rate. Among all the support frame pillars of a vehicle causing blind spots, the two A-pillars are more critical than the B, C or D pillars. Compared with the right A-pillar, the left one is much more difficult to camouflage while keeping mechanical strength unchanged. Unfortunately, the area of the blind spot caused by the left A-pillar is the largest. Therefore, once the left A-pillar can be camouflaged, the blind spot problem can be considered solved.

In this paper, some factors that influence the invisibility rate and mechanical strength of pillars are summarized and solutions to settle tricky problems to exploit a practical use of camouflaging technology are suggested.

2. Factors Impacting the Invisibility Rate

2.1. Factor One: Inclination Angle

As shown in Figure 1, in the light of the principle of invisible prism [4], only the part of the width BD from the incident beam CE can go through. Suppose F and G represent two invisibile prisms and their thicknesses, the summation of $d_1 + d_2$ is the space that the incident beam can go through and reach the observation point A. Analysing, further, we find that the invisibility rate roughly equates $\frac{d_1 + d_2}{d}$. It is easy to imagine that when θ gets smaller, for fixed point A and invisible prisms F and G, the ratio of $\frac{d_1 + d_2}{d}$ goes down gradually. Furthermore, the overlapping ratio of F and G also decreases. Therefore, the mechanical strength gets smaller. In a word, when θ goes down, both the invisibility rate and mechanical strength go down simultaneously. On the other hand, for fixed θ, the overlapping rate between F and G will go up if the thickness of the invisible prism shrinks, and the invisibility rate goes up linearly. It seems as if this strategy is not bad. Unfortunately, this causes the observation point to be quite narrow. In practice, both the vehicle and the observation point, the driver's eyes, remain in motion.

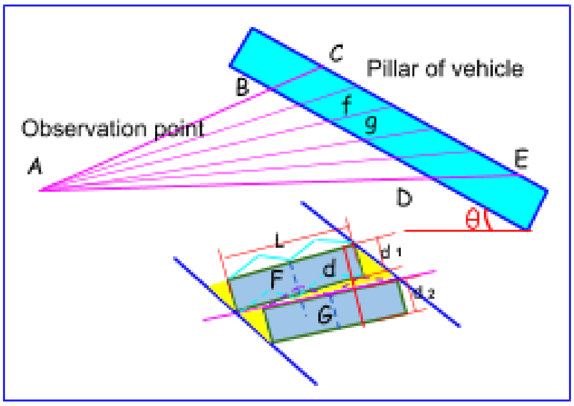

Figure 1. Illustration of the relative position between the pillar and observation point

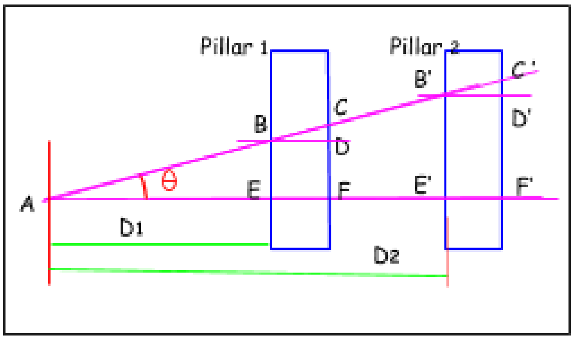

Figure 2. Illustration of distance vs invisibility rate

2.2. 2. Factor Two: Distance

Figure 2 illustrates the distances between the pillars and observation point A. Suppose two pillars are parallel parting from A with a separation D_1 and D_2. Although D_2 is larger than D_1, CD remains to equate to C'D'. In the light of the definition of invisibility rate [5], for pillar 1, only an incident beam with roughly the width BE can reach A. Therefore, the invisibility rate roughly equates $\frac{BE}{CF}$. Similarly for pillar 2, the invisibility rate equates to $\frac{B'E'}{C'F'}$. Obviously, $\frac{B'E'}{C'F'}$ is larger than $\frac{BE}{CF}$. Therefore, the larger the separation between A and the pillar, the bigger the invisibility rate.

2.3. Factor Three: Size of Pillar

Again, as shown in Figure 2, shortening B'D' and letting A be still, based on the invisibility rate formula $\frac{B'E'}{C'F'}$ increases linearly. Therefore, keeping all other parameters fixed, the smaller the size, the larger the invisibility rate. Of course, the mechanical strength of the pillar must be considered so that the size of pillar should be in some suitable range.

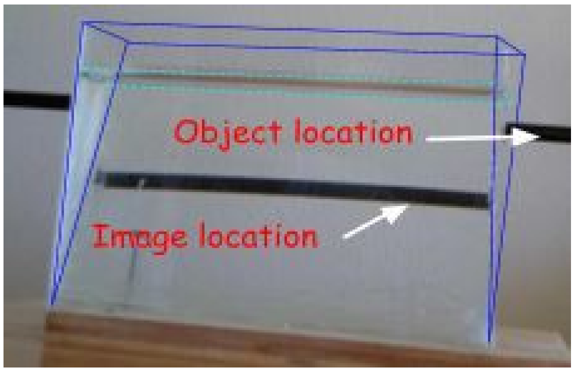

Figure 3. V-like triangular prism image formation

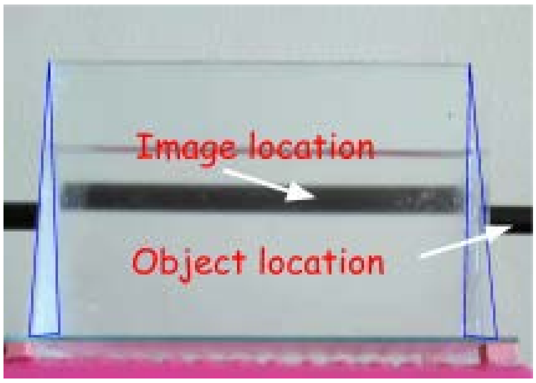

Figure 4. Δ - like triangular prism and image formation

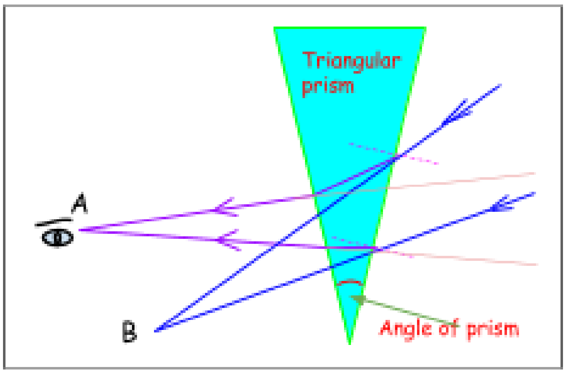

Figure 5. Refractive light path of Figure 3

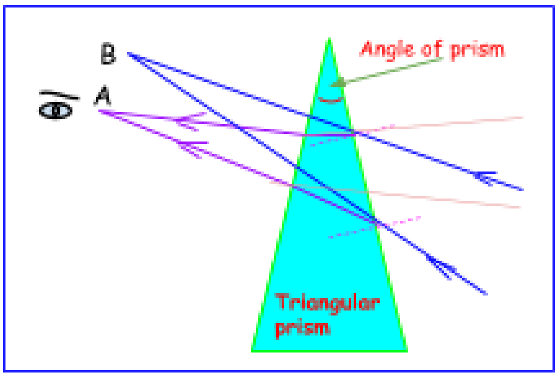

Figure 6. Refractive light path of Figure 4

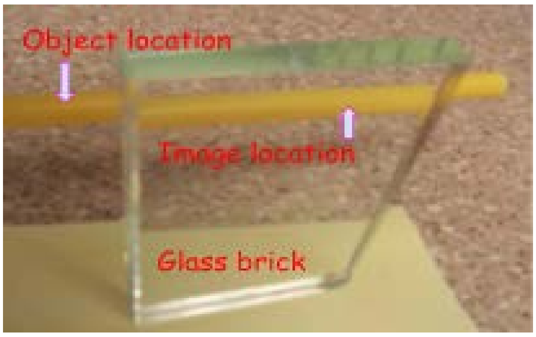

Figure 7. Glass chunk to refract light

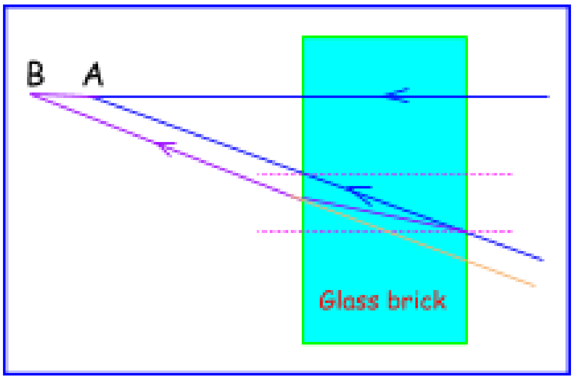

Figure 8. Refractive light path of Figure 7

Figure 9. Material object and triangular prism

Figure 10. Image formation from Figure 9

3. How to Change Image Location for Various Heights of Drivers

Given the above three main factors that impact the invisibility rate and mechanical strength of pillars, we learned that the left A-pillar is more difficult to design for a good invisible effect than the right one, because it is much closer to the driver's eye. The smaller distance causes both the invisibility rate and mechanical strength to go down linearly if the thickness of invisible prism remains constant. As has been pointed out, the smaller thickness of invisible prism means the allowed range of change of observation point to be more narrow.

In the assembly line process of manufacturing vehicles, all the same parts of the same vehicle type must be identical, no matter what the stature of drivers would be. This means for the same pillar, the image location should lay at the same point in space. However, the eye's position of various drivers of different stature is divergent. For example, if the invisible pillar is designed for a driver who is 1.7 meters tall, another driver of 1.8 meters cannot get the same invisible effect for the same pillar. How can this problem be solved?

One possible promising strategy to settle such a tricky problem is to use a triangular prism as shown in Figure 3 and Figure 4. Evidently the image location can be shifted after the accident beam is refracted by a triangular prism. Their light paths are shown by Figure 5 and Figure 6, respectively. Also the usage of a glass chunk, as shown in Figure 7 and Figure 8, can shift the formed image. If the pillar is designed for a driver of average height, say 1.7 meters, but the car is used by a driver who is 1.8 meters tall, then a triangular prism suitable to the difference of 0.1 meter can be placed so that the image location can be shifted for the driver of 1.8 meters. The invisible effect can remain approximately the same. Figure 9 and Figure 10 show the material object and its shifted image formed by a triangular prism.

In the light of the principle of image formation, shifting the image location means the observer sees the image deviating from the real position a little bit. The deviation degree depends on the magnitude of the shift. A small shift does not influence the invisible effect as a whole.

4. Discussion and Conclusions

Strictly speaking, designing a good invisible support frame of vehicle relates closely to many branches of learning: mechanics, materials science, optics, and even physiology. Support frames of vehicles will always block some of the driver's view unless they are made with ideal transparent material or removed. The typical difficulties faced by the designer are invisibility rate, mechanical strength of pillar and the observation point shift due to various drivers' stature. Usually, the vehicle manufactured by assembly work line has a fixed placement of all parts. Therefore the angle of triangular prism needs to be changeable so that the image location can be shifted to meet the demands of various drivers' eyes. The triangular prism made of glass is a solid object, not continuously deformable. One easy way to change the angle of the prism is to use a liquid triangular prism, containing liquid within a solid shell. Lay such a triangular prism near invisible pillar and then change the angle of prism according to the stature of drivers. Change the angle of the prism until the driver gets the best invisible effect. However, based on the principle of image formation, the image formed by refraction through a triangular prism will displace from its real position as shown in Figure 9 and Figure 10. Therefore the invisible prism design should be designed to fit the most probable value of drivers' stature so that the amount of image shift can be minimal.

Based on the above analyses and discussions, a definite conclusion can be drawn: the use of a triangular prism with the possibility of changing the angle of prism allows for the image location forming from the light through the invisible prism to be changed to adapt to various drivers' stature. Further research and experimentation is in progress.

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