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Research Semiquantitatively on Camouflaging Right A-Pillar of Vehicle

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Abstract Various parameters of stealth prisms being adjusted for different A-pillars of vehicles were investigated in detail. The research on camouflaging the right A-pillar of sedans has been done both qualitatively and semiquantitatively. For drivers with different heights, the pupillary distance skillfully compensates for the differences in observation points. Present calculations semiquantitatively of invisible rate and mechanical strength of A-pillar have proved that camouflaging the right A-pillar is feasible.

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

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1. Introduction

Research on camouflaging supporting frames, the pillars of vehicles, has been continued for some time [1,3]. Some factors characterizing the support frames of vehicles, such as dip angle, thickness, and the separation between the pillar and driver's eye influence the invisible effect and the mechanical strength of pillars simultaneously. One tricky difficulty for the design of an invisible pillar is how to accommodate drivers of different stature to achieve the same stealth effect. One promising way, using triangular prisms to settle the problems caused by the different observation points of drivers, has been suggested [3]. The 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.

In order to simplify the description and stress the key points, all the previous reported research regarding the observation point of drivers can be explained by focusing on one point. However, human beings have two eyes, each with the same function. They equally observe objects presented in front of them. If each eye alternatively gets a view, the process of designing invisible pillars of vehicles will be much simpler and easier. In this report, some quantitative and semi-quantitative analyses for the influence caused by the differences in observation points to the invisible pillars were carried out and some positive conclusions were gained. Also, aiming at getting a pillar with a higher invisibility rate and better anti-collision ability, the structure of the invisible prism has been investigated and illustrated by both figures and a table.

2. Designing the Right A-pillar of Sedan for Various Drivers

2.1. The Investigation of Parameters of Invisible Prism

The unique component of invisible pillar is an invisible prism. A real general prism is a hollow quadrilateral prism of self invisibility which has a particular case, namely the hollow quadrangular prism of self invisibility. Also, the quadrangular prism has an ultimate simple case, the rectangular prism which is simple and elegant [2]. In order to highlight the main features and simplify the process of research, we analyzed a rectangular prism quantitatively as in the example of a camouflaging pillar.

As has been investigated before, the width D of a rectangular prism strictly equals $h(1+\tan 2\theta \cot\theta)$ [1]; increasing D makes the invisibility rate more stable to deviations of the observation point. However, a larger interval makes it impossible to form good images in a human being's brain as shown in Figure 1 and 2 unless the separation between the observation point and the invisible prism is far enough apart.

Figure 1. Images of four circular objects vs object distance: (a) Observation point closest to rings, (b) middle interval, (c) largest distance

Table 1. Parameters, width D and length L, to determine a rectangular invisible prism

$\theta°$ / D/ h, L/h	15	20	25	30	35	40	45
1+tan2θcotθ	3.22	3.31	3.56	4.00	4.92	7.76	∞
4cot θ	14.93	10.98	8.58	6.93	5.71	4.77	4

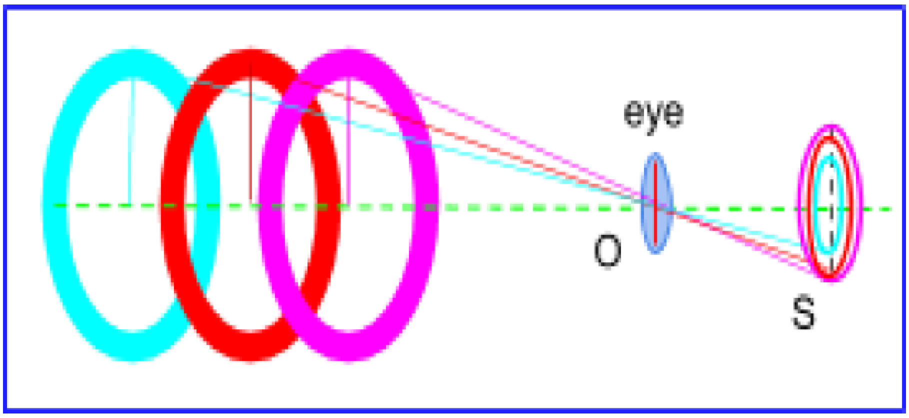

Figure 2. Illustration of the light path of Figure 1

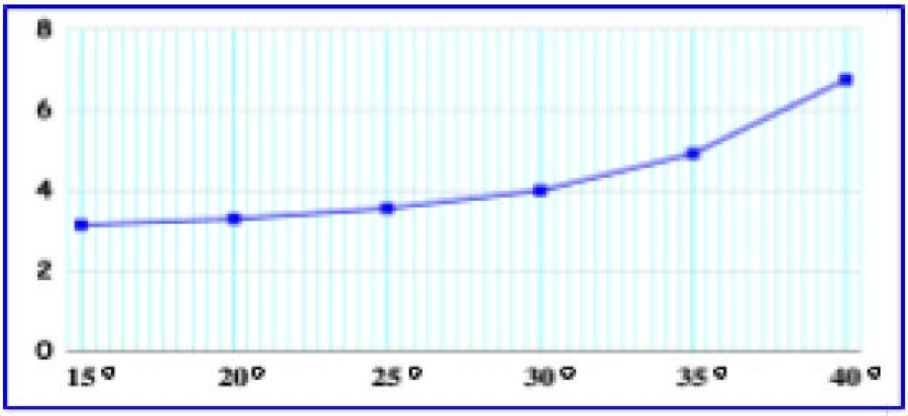

Figure 3. Width of invisible rectangular prism vs base angle of isosceles triangle illustrating Table 1

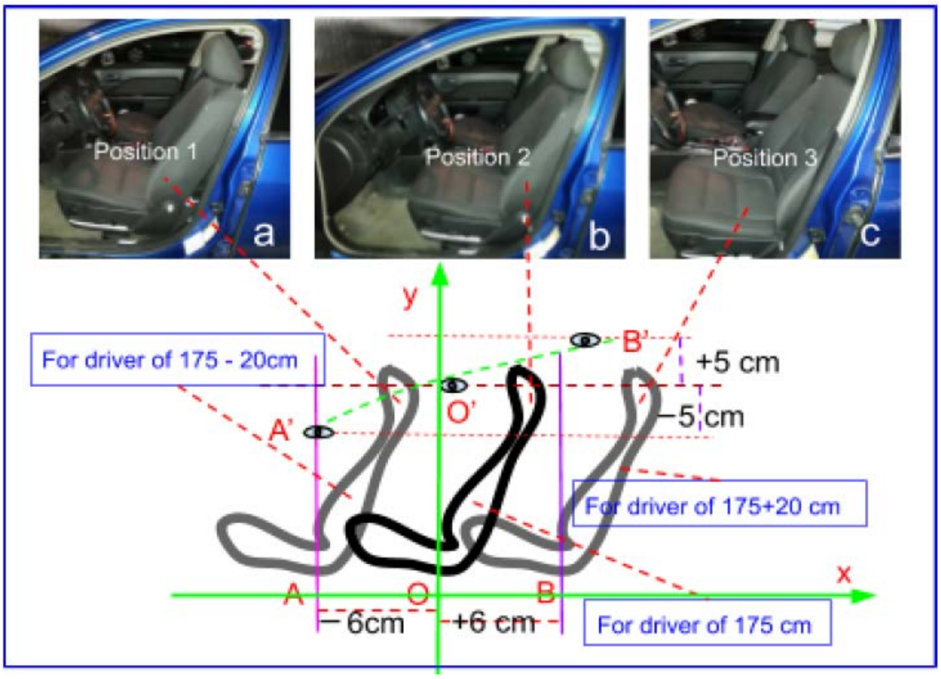

Figure 4. Positions of car seat for drivers of different stature

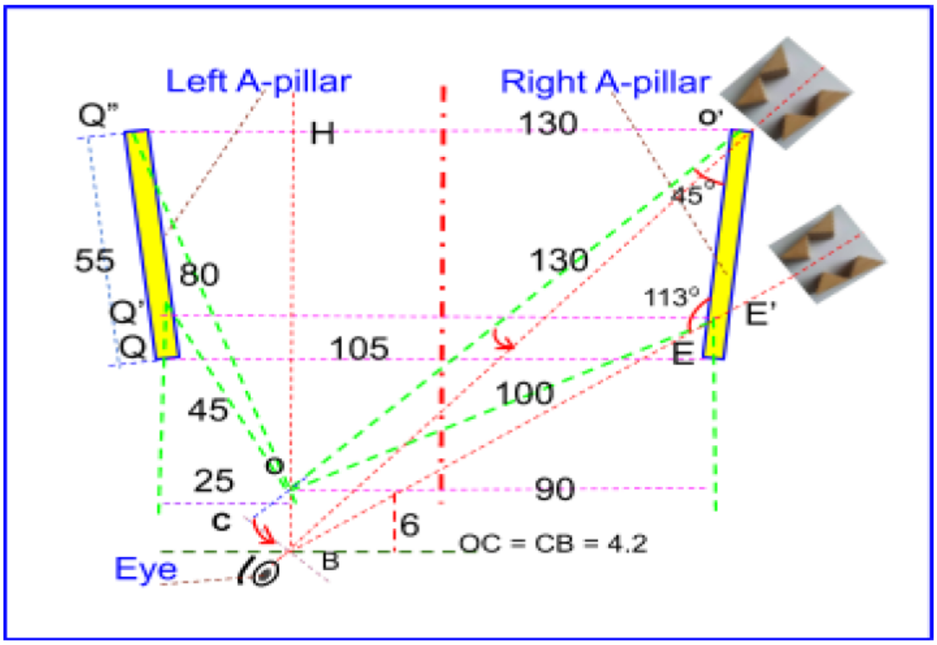

Figure 5. Vertical view of A-pillar and the observation point (data unit: cm)

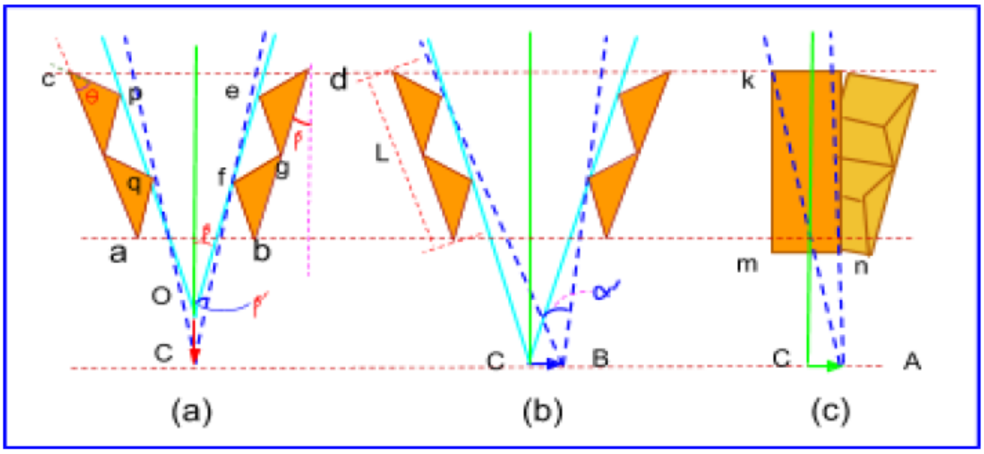

Figure 6. Exploded views of invisible prism vs displacement of observation point

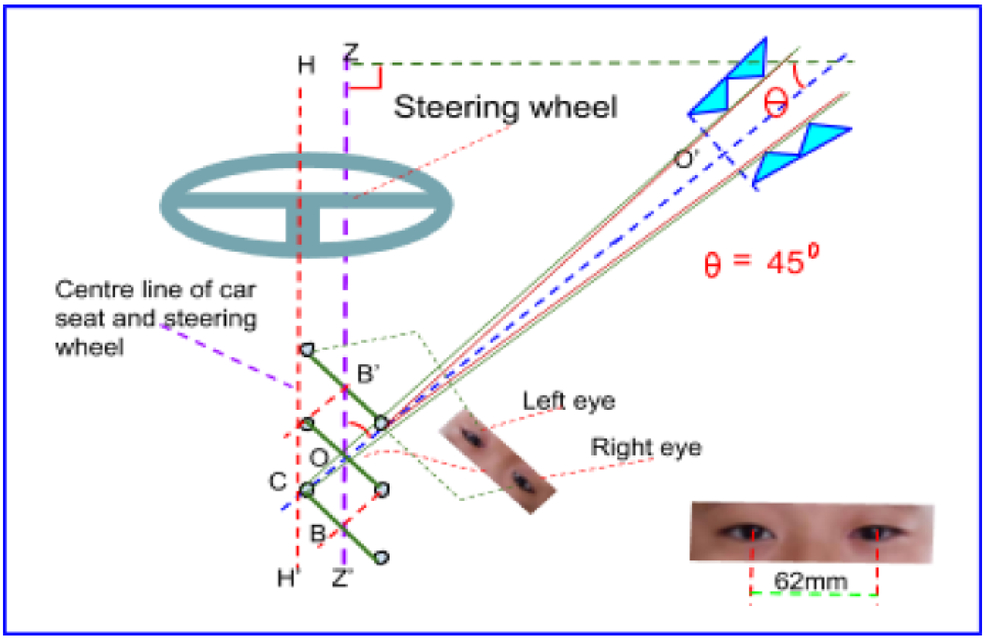

Figure 7. Changes of driver's eyes relative to invisible prism

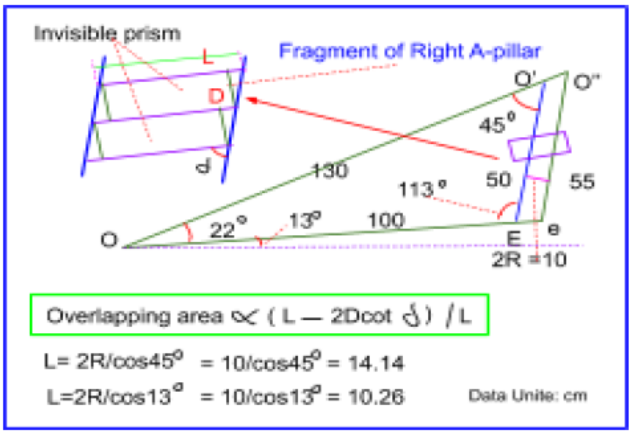

Figure 8. Illustration of calculations of the overlapping area between two invisible prisms

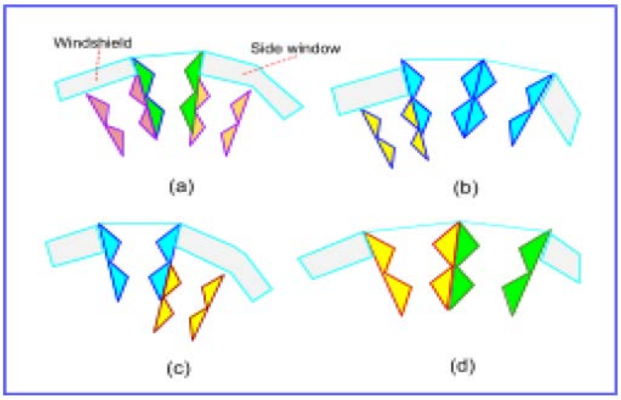

Figure 9. Various combinations of invisible prisms setting up A-pillars suitable to all sorts of vehicles

Figure 1 clearly indicates the images formed of four circular rings. This instructs us that the parameters of the invisible prism depend, to some extent, on the distance from the invisible prism to the observation point. In light of the formula D = h(1+tan2θcotθ), when the incident angle of light to invisible prism $\pi/2-\theta$ (0<θ<$\pi/4$) goes down, D increases, and the length of the prism gets shorter (as shown in Figure 3 and Table 1). Therefore, the size and parameters of the invisible prism can be determined by the incident angle of light. Also, the cross sectional area of a prism can be changed neatly and continuously to meet all kinds of requirements of invisibility rate and mechanical strength.

2.2. Drivers of Different Stature vs the Position of the Car Seat

Three discrete typical heights of drivers are selected here, specifically 155, 175 and 195 cm as shown in Figure 4. Something interesting, but strange is that when comparing the seat position suitable for a 155 cm person to one for a person 195 cm tall, the total distance the seat is moved is only 12 cm horizontally, instead of 20 cm. It is slightly unexpected, but easy to interpret because the height from waist to head bears half of the whole stature and, also the leg is curved, not lying straight. Similarly, the eyes of a 195 cm person are only about 13 cm higher than that of 155 cm person, instead of 20 cm, because the height of springs installed inside the car seat change due to different pressures of drivers of various weights.

2.3. Some Parameters in Steering Room

In order to do concrete calculations, we used a Fusion SE 320 as an example whose vertical view of A-pillar and the observation point are shown in Figure 5. Point O in both Figure 5 and Figure 6, stands for the observation point of drivers who are 175 cm tall. Drivers of 155 and 195 cm height, which equal 175-20 and 175+20 respectively, correspond to the car seat moving O$\pm$6 cm. The displacement of 6 cm can be resolved into OC and CB, equalling 4.2 cm shown in Figure 5. Moving back 6 cm can be resolved into three dimensions as illustrated in Figure 6.

2.4. Brief Calculation on Invisibility Rate vs Displacement of Observation Point

2.4.1. Displacement OC

Drivers moving forwards OB' and backward OB along a centerline relative to the most probable point O produce 6 cm horizontal displacement from O. Obviously OB can be resolved into OC and CB. Because the opening angle of OO' and O'E is 45^o, thus OC= CB= 4.2 cm. In order to give a quantitative conclusion, select a group of data as following from Table 1 which features an invisible prism. As shown in Figure 5, 6 and 7, we can see the following data: D = ab = 4.92 cm, L= ac = 5.71 cm, qf =4.92-2h =4.92-2= 2.92 cm, O'i = 5.71/4 = 1.63 cm. Also let the base angle of triangular prism be $\theta=35^o$. If the observation point is back OB= 6 cm, then O'O=130 cm, OC = CB= 4.2 cm. The invisibility rate β, β' can be calculated as:

$$\beta=\frac{qf}{ic}=\frac{qf}{iO'+O'O}=\frac{2.92}{1.63+130}=0.0222,$$

$$\beta'=\frac{qf}{ic}=\frac{qf}{iO'+O'O+OC}=\frac{2.92}{1.63+130+4.2}=0.0215,$$

$$\frac{\beta'}{\beta}=96.84\%.$$

Similarly for EO: $\beta=\frac{qf}{ic}=\frac{qf}{iO'+O'O}=\frac{2.92}{1.63+100}=$ 0.0287, $\beta'=\frac{qf}{ic}=\frac{qf}{iO'+O'O+OC}=\frac{2.92}{1.63+100+4.2}=$ 0.0276, $\frac{\beta'}{\beta}=$ 96.17%.

These two $\frac{\beta'}{\beta}$ mean the invisibility rate βchanges by the amount $\beta-\beta'$= 3.16% much smaller than β, which is so tiny that it is not easy to be perceived by the naked eye. Therefore, the influence to invisibility rate caused by the displacement OC can almost be ignored.

2.4.2. Displacement CB

CB = 4.2 cm is another component of OB as shown in Figure 6 (b) and 7. It is easy to calculate the change of invisibility rate based on the method reported [4]. It will be a little bit larger than that caused by OC. However, as a pleasant surprise, we found that the displacement CB can be compensated for by the observation function of the left eye. The pupillary distance of human beings is about 6.2 cm which is, coincidentally, equal to OC approximately.

2.4.3. Displacement CA

As has been pointed out [1], the loss of invisibility rate caused by the displacement CA is not easily compensated, although a small part of it can be corrected by the pupillary distance of 6.2 cm. In principle, it can be modified by the triangular prism as reported before [3]. Also, lowering the car seat is a direct and easy way to keep the observation point from changing position too much. Further, the bottom of car seat with springs can keep the observation point of various drivers from moving significantly because taller and heavier drivers will press the springs to produce more contraction lessening the displacement.

2.5. Semiquantitative Valuation on Mechanical Strength

2.5.1. Overlapping Area

For evaluating semiquantitatively the mechanical strength, we refer to the calculation done in [1]. The equivalent radius of A-pillar of Ford (Fusion SE 300) is about 5 cm approximately.

The data given in Figure 8 came from Figure 5. The invisibility rate defined previously [4], the maximum equals O'E/O''e (=50/55=91%) when D goes to zero, the ideal extremity. The overlapping area of two invisible prisms can be approximately calculated by the formula:

$$(L\text{-}2D\cot\delta 1)/L \simeq (14.14\text{-}2\times 2\cot 45^{o})/14.14 = 71.71\ \%.$$

$$(L\text{-}2D\cot\delta 2)/L \simeq (10.26\text{-}2\times 2\cot 67^{o})/10.26 = 83.45\ \%.$$

For simplification, the average of these two is taken as (71.71+83.45)/2 % =77.58%. The larger the overlapping area, the bigger the mechanical strength of the pillar. Evidently, the formula (L-2Dcotδ)/L manifests the larger D, the smaller the overlapping area; also the shorter L, the smaller the overlapping area. However, D determines part of the view space for the drivers. Shrinking D, on the other hand, decreases the view space.

2.5.2. Mechanical Strength Valuation

In order to simplify the process of calculation, we refer to the valuation done in the way reported in literature [1]. The equivalent and average approximate radius of A-pillar for the Ford Fusion SE 300 is about 5 cm. The width of the rectangular prism D = h(1+tan 2θ cot θ), length L=4hcot θ. Therefore, the area of the prism equals: DL= $4h^2$ (1+ $tan2\theta cot\theta$) $cot\theta$. Let h =1cm, and two identical invisible prisms are combined together as shown in Figure 9 (d). Thus the equivalent thickness of the hollow pillar equals 2×0.344= 0.688 cm. Considering the average overlapping area percentage of 77.58%, the valid thickness is 0.688×78.1%=0.537 cm which is roughly close to the traditional thickness of the wall of pillars.

All kinds of vehicles have pillars of different shapes and sizes. Figure 9 shows various combinations of invisible prisms setting up the A-pillar to satisfy the requirements for all sorts of vehicles. Further and thorough research to get stronger anti-collision effects should investigate the internal structure and skeleton of the whole vehicle exhaustively [5,6].

3. Discussion and Conclusion

Among modern devices, the vehicle is almost the most essential tool for human beings' daily life. After more than one hundred years of development, most of the functions of vehicles can satisfy various requirements. Even so, there is no doubt camouflaging pillars is one approach to upgrade the safety for all kinds of vehicles. Consequently, it is worth spending time and energy to research the idea thoroughly.

Although the law of light reflection is absolutely precise, the camouflage work needs to be finally tested by experiment, not by theoretical consideration. Nevertheless, the theoretical investigation is preliminary and necessary for forecasting the possible outcome.

In spite of the fact that most of the calculations done here are quantitative and semiquantitative, it is impossible to make all the data precise because even with the same driver, the seat position changes a little bit from time to time. Therefore, strictly speaking the work done here only can be referred to as the semiquantitative and approximate. For some higher grade sedans such as the Lexus, both the steering wheel and car seat can be adjusted to meet the needs of various drivers. These adjustment functions will surely relieve the pressure of designing invisible pillars. Compared with the left A-pillar, the right one is relatively easier to be camouflaged because it is much farther from the observation point.

One good design factor to emphasize here is the pupillary distance of human beings which compensates for the movement of drivers' eyes. Even if only the right A-pillar is camouflaged, it is significant progress in updating vehicles and making them safer by reducing drivers' blind spots. The design for the left A-pillar and other pillars is under way.

References

[1] Yizong He, Research on the possibility of camouflaged A-pillar by using the quadrangular prism of self invisibility, American Journal of Vehicle Design, 2018, Vol. 4, No 1, 1-10.

[2] Yizong He, A Quadrilateral Prism of Self-Invisibility, American Journal of Vehicle Design, 2018, Vol. 4, No 1, 11-15.

[3] Yizong He, Further Research on Camouflaging A-pillar of Sedan, American Journal of Vehicle Design, 2019, Vol. 5, No. 1, 1-4.

[4] Yizong He, Further research on the quadrangular prism of self-invisibility (I), International Journal of Instrumentation and Control Systems (IJICS), Vol. 7, No. 4, July 2017.

[5] https://carbrain.com/Blog/what-is-frame-damage.

[6] https://www.researchgate.net/figure/Modeling-of-one-side-of-the-vehicle-BIW-using-SSS-simplification_fig5_305701516.

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