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Prospect of Automobile Aerodynamic Drag Reduction External Structure (AADRES) for Electric Car

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Abstract. AADRES has been further optimized over the past hundred years for diminishing fuel consumption, yet there is still a sharp reduction in traditional energy around the world. Recently, the energy structure of automobiles has also been transforming from gasoline power to electric power in order to save energy and reduce the CO2. However, electric cars have one fatal problem which is battery capacity. Therefore, AADRES should be redesigned for electric cars. In order to find an AADRES suitable for electric cars, this paper briefly explains the resistance principle of cars and instances some existing aerodynamic drag reduction methods. By analyzing and identifying those methods, a personal scheme of new style AADRES for electric cars is also presented, which primarily follows the wedge car shape but incorporates a deflector, embedded door handle, and pitted non-smooth surface while removing door mirrors.

Keywords: aerodynamic drag reduction, automobile external design, future car, electric car, rear vortex.

1. Introduction

The development of AADRES has mainly experienced several stages: sedan car, box car, beetle car, boat car, fish car and wedge car. It has developed into a shape suitable for traditional gasoline-powered cars, yet recently, electric cars are coming into the market. It is undeniable that they are very similar in AADRES. However, the question is that electric car has one main problem, the battery capacity [1]. Therefore, it is not a good idea to apply traditional AADRES, which is suitable for gasoline cars, to electric cars without any redesign. In order to find the most suitable AADRES for electric cars, this paper briefly explains the resistance principle of cars to help understand the aerodynamic drag reduction methods mentioned after it. In the end, a personal scheme for new style of AADRES for electric car is proposed. In this paper, some aerodynamic drag reduction methods suitable for electric cars are analyzed and identified. To a certain extent, they could provide references for the AADRES design of future electric cars.

2. Explanation of resistance principle of cars

It has been shown that the air resistance of a car is greatly affected by the rear flow generated at the rear of the car body, especially the rear pulls due to the vortex [2]. Vortex is a group of fluids moving in a circle [3]. Due to their circular motion, fluid particles must gain centripetal force to maintain this motion. This means that the pressure inside the vortex must be less than the pressure outside, so that the pressure difference can produce pressure, which is centripetal force. Therefore, if a rear vortex occurs after a moving car unfortunately, the pressure after the car will become lower than that in front of it, and then, this pressure difference between the front and the rear generates a pressure drag force which has a direction opposite to the direction of car's velocity, hindering the moving. Automobile aerodynamic resistance is closely related to the rear airflow. Because the car's body is similar to a bluff body, the air flowing around the car separates from the body at the rear and generates the rear vortex. As the driving speed increases, the strength of the rear vortex also enhances, leading to a stronger pressure drag to which the car is subject [4].

3. Instances of some aerodynamic drag reduction methods for cars

For cars, air friction drag is related to the air's viscosity and the degree of the car's surface roughness. It is relatively easy to evaluate while pressure drag is not. Pressure drag is relevant to the car's shape. The shape of the car mainly determines the location of boundary layer separation, which also determines the area of the low-pressure area formed by the vortex current behind the car, and it is the area of the low-pressure area that determines the pressure drag on the car. As a result, improving the flow characteristics of the car's rear becomes the focus of aerodynamic drag reduction research.

One of the methods that is most widely used is to install a deflector at the upper edge of the rear window. A deflector can lengthen the curve at the top of the car, so the separation point will also be more in the rear, and the area of the rear vortex will be reduced. Besides, the deflector is also capable of blocking the lower airflow coming up from below, which is also a reason why rear vortices occurs. The reason why deflectors can be used so widely is that they can be designed for any kind of car, especially box cars and boat cars.

There is another method that is practically applied to AADRES designing a door handle embedded in the car door. This kind of design is widely applied to the popular electric car, Tesla. This method aims to diminish the representative area of the car as much as possible by breaking with some traditional ideas.

According to Yang Yi et al.'s research, non-smooth surface can also be used to reduce aerodynamic drag [4]. Their method is to design a rear surface with pits lying on it in a rectangular pattern. And it was experimentally confirmed that the maximum drag reduction rate of this method can reach 7.8%. Zhang Guogeng's research also shows that the maximum drag reduction rate of this kind of design can reach 10.31% if it is applied to the engine cover and car roof cover [5].

Another useful method that can improve the rear vortex is to arrange Air-dam Spoiler under the chassis. Daichi Katoh and Yoshimitsu Hashizume's research introduces a scheme about air-dam spoilers. According to the research, this method can overcome the boundary separation beneath the chassis to some extent [6]. However, this air-dam spoiler is easy to be damaged due to some irregular road surfaces. Therefore, it is conceivable that the car most suitable for this method is ORV (off-road vehicle). Besides, the shape of the taillight also affects the car's aerodynamic performance. According to Yu Jianze et al.'s research, it was confirmed that aerodynamic drag can be reduced by optimizing the shape of the taillight, making it a deflector structure [7].

What is more, Zhu Hui et al. confirmed that horizontal tail contraction can reduce aerodynamic drag effectively [8]. However, there is a disadvantage that it clearly diminishes the capacity of trunks. On the other hand, Gu Zhengqi et al. proposed a new feasible method of reducing air drag by adding air injection devices on the rear of the car in order to break up the trailing vortex (rear vortex) [9]. Research results show that it is very useful. Nevertheless, there is the same disadvantage that the devices occupy space in the truck to some extent.

4. Prospect of AADRES for electric cars

Electric cars have one fatal problem, which is battery capacity. This problem leads to the inability of electric cars to travel a long distance at a time without charging. Under this condition, air resistance further increases battery consumption and reduces the driving distance. Therefore, for electric cars, a suitable AADRES that is good at reducing air resistance becomes much more important.

In order to solve this problem, this part presents a personal scheme of future electric car's AADRES being capable of reducing aerodynamic resistance as much as possible. Figure 1 shows a preliminary sketch of the scheme.

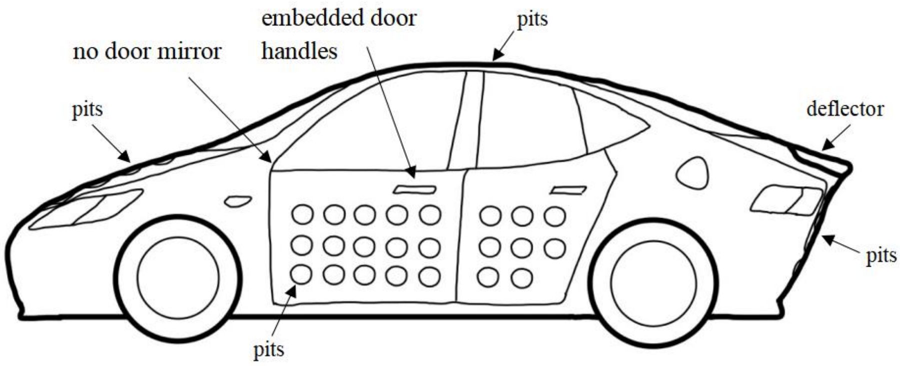

Figure 1. A preliminary sketch of the scheme.

In this personal scheme, the shape of the car mainly follows the wedge car due to its significant characteristics of aerodynamic drag reduction. Next, the curve from the front to the rear is designed gently in order to let the external shape be similar to a streamline body. The height of the chassis is low in order to increase the velocity of the air flowing below the car, leading to a smaller aera of rear vortex beneath the chassis. On the other hand, the air-dam spoiler is not applied in this scheme due to the low chassis. What is more, the pitted non-smooth surface is applied not only to the car's rear surface, but also to the roof cover, engine cover, and side door covers. Furthermore, a deflector is installed at the end of the trunk, and the deflector structure is also considered on the taillights. In addition, according to A. Rinoshika, K. Watanabe and M. Nakano's research, the separated vortex generated from the tip and root of the door mirror has a large effect on the air resistance[10]. Therefore, the door mirrors are thoroughly removed from the car in this scheme. Instead, an electronic display that can project the rear image onto the corner of the windshield will be arranged on the instrument board. The embedded door handles are also applied in order to diminish the car's representative area as much as possible. Moreover, considering the capacity of the trunk, the horizontal tail contraction and the air injection devices are dismissed in this scheme.

Furthermore, considering the development of autonomous driving technology, it is conceivable that the way people travel will change from owning cars to sharing cars. Therefore, in the future, the car shape will be smaller because they only fit only one or two persons. There will be no personal car parks, and people will most likely just call an autonomous driving car when they want to go out, and a car will come to pick them up completely automatically. Fortunately, this personal scheme will still be suitable even if the car becomes smaller, because the air drag reduction methods used in this scheme are suitable for cars of any type and size. However, in the case of this smaller car, the horizontal tail retraction is appropriate because not every passenger has cargo to carry.

5. Conclusion

This paper theoretically presented a suitable scheme for an electric car's AADRES, which primarily follows the wedge car shape but incorporates a deflector, embedded door handle, and pitted non-smooth surface while removing door mirrors, by analyzing and identifying some existing aerodynamic drag reduction methods under the condition that the rear vortex affects the car's aerodynamic performance mainly, yet it is undeniable that there are many other factors that also affect that in various ways. However, while the practical effects of this scheme have yet to be confirmed, it can still be used as a reference for future electric car external design. Therefore, it is expected that there will be experiments and simulations carried out to estimate this scheme practically.

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