Applying Baydur Composite Material in Designing Automotive Door Beams

Lingyue Ma¹, Mingji Liu¹ and Zhiyuan Chen²

¹School of Automotive Studies, Tongji University, Shanghai 201804, P. R. China
²School of Materials Science and Engineering, Tongji University, Shanghai 200092, P. R. China
Email: 1751457@tongji.edu.cn

Abstract. This work studied the application of Baydur pultrusion composite material to the side door anti-collision beams of cars. The beams are currently made of high-strength steel materials and arranged inside the door to meet the requirements of road safety laws and regulations. The Baydur pultrusion composite material has many advantages that metal steel does not have. Based on the characteristics of the composite materials and safety standards for vehicle side collisions, we proposed a design to use Daybur composite material instead of steel as the anti-collision beam material in automobile side doors. The structural design of the beam with the composite material is optimized so that it can effectively improve the safety performance during side collisions and reduce the body weight to save fuel consumption. The feasibility of the design has been investigated from three aspects of technical manufacturing, safety performance and market application. The application of the composite material in the anti-collision beams will provide new options for the safety and energy efficiency of civil vehicles.

1. Introduction

With the rapid development of automotive industry, the demands for reducing energy consumption and increasing body strength required by safety standards have become a major contradiction in contemporary body manufacturing. Material selection in product design is dominated by the tradeoff between technical properties and cost. However, the increasing importance of pollution prevention requires that the environmental impacts of material are already considered at the design stage [1]. Car weight and specific fuel consumption are strongly coupled: a weight reduction of 10% results in a reduction of specific fuel consumption of 3−7% while maintaining the same functionality [2]. The use of high-strength composite materials instead of traditional metal materials to achieve body weight reduction and increase vehicle body strength has become a trend in the development of the current car body industry. Material substitution involves redesign at the component level to optimally utilize the specific properties of the new material and the use of aluminum and high-strength steel (HSS) [3], [4], carbon fiber composites as alternatives for cast iron and steel. Material selection is determined by economic viability at large production volumes, the weight savings potential, safety performance, physical properties such as strength, formability and stiffness, and anticipated environmental benefits [5]. Carbon fiber composite materials are currently the most important composite materials used in car body manufacturing, and are widely used in body parts such as high-end cars and sports cars. However, carbon fiber has a long production cycle and expensive construction. It is still not able to apply widely in mainstream consumer market-level vehicles.

The Baydur polyurethane pultruded composite is a high-performance engineering material, which is composed of about 20% of Baydur resin system and about 80% of the preferred fibers, and is
manufactured by proprietary pultrusion technology. This composite material has the advantages from carbon fiber while its cost is more acceptable. It has lighter weight than steel, better mechanical properties [6], more impact resistant than aluminum alloy, and its performance surpasses glass fiber reinforced plastic comprehensively. In addition, the Baydur pultruded composites as structural materials have thermal insulation properties that exceed conventional thermal insulation materials and are resistant to a variety of chemical corrosion. However, no article has reported the use of this material in automotive materials.

In this work, based on advanced characteristics of the Baydur Pultrusion composite material and ideas of high efficiency, energy saving, environmental protection and the high-strength performance, we proposed a design of using the composite material as a substitute for steel to make automobile side door anti-collision beams, and demonstrated its feasibility. The anti-collision beams are currently made of high-strength steel materials and arranged inside the door to meet the requirements of road safety laws and regulations for side collisions of vehicles. In the event of a collision, the anti-collision beams are very important to prevent effectively side collision, and responsible for maintaining the integrity of the cabin structure, so that it cannot deform too much to protect the passengers in the car from injury.

2. Structures of Side Door Anti-collision Beams in a Car and Car Crash Test Standard

The side door anti-collision beam is a reinforced structure hidden in the door. This structure is a thin steel plate, as shown in Figure 1 (the red part). Nowadays, two types of the beams with different cross sections are commonly used: a cylindrical shape (mainly used in Japan and South Korea) and a cap shape (mainly used in Europe and America), as shown in Figure 2. Regardless of the differences in shapes and forms of the two types of anti-collision beams, the main structure and their connection with the vehicle frame is identical: a molding material with a uniform cross section, and a special shoe-shaped structure at the tip connection, bolts are used to lock the anti-collision beams at the corresponding restraint positions on A, B and C pillars, respectively, as shown in Figure 1. This is mainly due to the deformation characteristics of steel materials under external stress. Referring to the data of the impact test chamber, metallic material will undergo a large deformation in the radial direction of the force before it fractures, which increases its length and decreases the thickness. This change is not allowed in the scene of a collision. Therefore, the tip is designed as a shoe-shaped structure with a small expansion area and a large cross-sectional area, which can minimize the deformation when the steel anti-collision beams subject to large impact forces. When a vehicle is impacted by a side collision force, the anti-collision beam is restrained by the joints of the B-pillar, A-pillar and C-pillar on the side of the body in the plane of the side door to spread and slow down the strong collision force in the vertical direction of the car side and prevent collision objects from invading the seat space in the car.

![Figure 1](image1.jpg) ![Figure 2](image2.jpg)

**Figure 1** (a) Photograph and (b) schematic diagram of the side door anti-collision beam in a car

**Figure 2** schematic diagrams of two structures of the anti-collision beams

In the car crash test, the main test items for the performance of side door anti-collision beams include Side Mobile Barrier and Side Pole. The side impact test will refer to this part contents of the European Impact Test Standard (E-NCAP), which have high requirements for passive safety [7], [8].
3. Design Scheme of the Beam and Feasibility

The optimization scheme proposed in this design is to replace the steel with the Baydur pultruded composite material for side door anti-collision beams. As the Baydur pultruded polyurethane composite material has a greater strength than steel, the alternative design only needs to adjust certain connections of components, and will not bring major changes to the vehicle frame. Meanwhile, it can reduce the car weight while maintaining the body strength. It still meets or exceeds the demand proposed by automotive safety standards. Compared with the existing steel material formed anti-collision beam, the new design scheme mainly changes in the following two aspects to exert the better performance of the new material.

3.1. Design of Section

Because the pultruded composite material can be set with a special cross-section shape, a square through - hole is added to the plane that was originally located in the center based on the existing structure of the cap-shaped beam, as shown in Figure 3. This design combines the advantages of both cylindrical and cap-shaped anti-collision beams, not only achieving high strength, but also effectively controlling its quality. Another advantage of the through-hole structure is that it provides convenience for the connection method described in the next section and provides suitable restraint locations.

![Figure 3](image1)  the shape diagram of designed beam section.  
![Figure 4](image2)  Design diagram of sleeve structure for fixing the beam to the A and B pillars.  
![Figure 5](image3)  Details of the fixing positions for the beam

3.2. Design of Connection Parts

The current steel anti-collision beam is directly bolted to the corresponding restraint positions on the A and B pillars of the vehicle body. The anti-collision beam has a special shoe-shaped structure at the tip, which is mainly due to the deformation characteristics of the steel material when it is subjected to external stress.

Compared to steel materials, the Baydur polyurethane composite materials have a stronger ability to restore their original shape when subjected to large external stresses, so it is unnecessary to tighten and thicken the tip of the beam. The composite materials exhibit high strength only when the fiber maintains integrity. If bolts are used to lock the composite material beam by drilling holes directly at both ends of the board, the overall strength of the material will be greatly reduced, which will not reach the level required by vehicle safety. In order to solve this problem, we propose an improved solution that uses a sleeve to constrain the entire profile and fasten it to the A and B pillars of the car frame. The sleeve is mainly composed of two interconnected parts, which respectively connect the main body of the side door anti-collision beam and the B pillar, as shown in Figures 4 and 5. This can maintain the structural integrity of the composite material and its high strength. Because the anti-collision beam is restrained from the B-pillar, A-pillar and C-pillar, there is no problem that the locked components do not shift in the side plane of the vehicle body during a collision, and do not need to bear a large impact force when a collision occurs.

3.3. Feasibility Analysis

Firstly, we analyze its feasibility of technical manufacturing. The pultrusion process requires the profile to be shaped uniformly, and the design for the main structure of the side door anti-collision beam can meet this requirement. Therefore, the design solutions are easy to implement on a large scale.
in automotive industry.

Secondly, the most important requirement for the beam material is high tensile strength. Compared with the 22MnB5 high-strength steel plate currently used for side door anti-collision beams, Baydur Material is close to it in strength, and its density is much lower than steel materials. The comparison of these characteristics with the Baydur composites has been listed in Table 1. According to the standards for automobile anti-crash beams, the materials for manufacturing side door anti-collision beams generally have a tensile strength of not less than 1400 MPa. 22MnB5 special steel can meet this requirement. Carbon fiber reinforced polyurethane pultruded composites have exceeded this standard, while glass fiber reinforced polyurethane has slightly lower strength than this. However, after optimizing its structure, its mechanical properties can fully meet or exceed the standards for crash tests.

Table 1. Properties of Baydur pultruded composites and metals.

| property                | Baydur composites | pultruded Aluminu m alloy | steel 22MnB5 |
|-------------------------|-------------------|----------------------------|--------------|
| model                   | Glass fiber       | Carbon fiber               | Type 6063-T5 | 7.80 |
| Density(g/cm³)          | 2.09              | 1.60                       | 2.70         | 7.80 |
| Tensile modulus (GPa)   | 52                | 157                        | 68.9         | 210  |
| Tensile Strength (MPa)  | 1290              | 1786                       | 145          | 1500 |

Finally, analyzing market feasibility. Due to the higher strength of the composite materials, the safety performance of the vehicle can be guaranteed in the event of a collision; at the same time, because the composite materials have lower density than alloyed steel such as the 22MnB5, the body weight can be reduced. This contributes to reducing energy consumption in future long-term use. The contradiction between safety needs and body weight reduction has been resolved by replacing steel with composite materials, so the application of the composite material in side door anti-collision beams has a great significance and market development value in the long run.

4. Conclusion

This paper proposed a design to use Daybur composite material instead of steel commonly used by current car companies as the anti-collision beam material in automobile side doors. The feasibility of manufacturing anti-collision beams with the Baydur pultrusion composite material has been investigated in the following aspects. Firstly, getting the detailed requirements from the on-road safety rules and regulations in relation with side door beams, and optimizing the design of the anti-collision beam structure using new materials. Secondly, comparing the safety performance of the anti-collision beam after the replacement with the Baydur material against high-strength steel. Then, analyzing the benefits brought by this substitution. In the market advocated by green energy conservation and environmental protection in the future, our design can be used for more green civilian vehicles, and have outstanding performance in the market. The use of new material anti-collision beams will provide new options for the safety and energy efficiency of civil vehicles.

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6. References

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