

Design and Development of a Composite A-Pillar to Reduce Obstruction Angle in Passenger Cars

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ABSTRACT

In modern passenger vehicles, A-pillar plays an important role in its passive safety by minimizing the deformation of passenger compartment during the crash. To meet various crash requirements, as well as sometimes due to demand of vehicle styling, A-pillar cross section of modern vehicles is generally wider. This wider cross section acts as an increased obstruction to the field of vision of the driver. It is considered detrimental for the safety of road users. The current work proposes an innovative design solution to reduce the obstruction angle due to an A-pillar. It also addresses the weight reduction objective. This is done by utilizing the noble properties of Carbon Fiber Reinforced Polymers (CFRP). Carbon Fiber Reinforced Polymers (CFRP) offer flexibility for complex design. Due to high specific strength and stiffness, CFRP's are suitable candidate for design considerations presented in this study.

Due to the high specific properties, the CFRP's have additional advantages of vehicle light weight body design, which contribute in better fuel efficiency and reduced emissions. The proposed design was analyzed and optimized to meet the stiffness and strength requirements, as well as to further reduce weight of part. The results show good agreement with the stated requirements of reducing the obstruction angle and also aid in the light weight design of the A-pillar.

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INTRODUCTION

With the increase in vehicle qualifying standards, the role of an A-pillar in achieving various vehicle regulatory requirements is vital. These requirements include roof crash, front impact test and front offset impact test by minimizing the deformation of passenger cell. To meet these requirements, A-pillars are designed to resist loads during vehicle crash. Therefore, to cater strength requirements as well as sometimes due to the vehicle styling, A-pillar cross sections of modern vehicles are getting wider than in the older vehicles (1985-2000) [1].

Increase in the cross section of an A-pillar results in increased obstruction to field of vision of driver. Due to this, A-pillar needs to be designed for increased strength without affecting field of vision of the driver [2]. Researchers have explored many different ways to reduce the cross-section of A-pillars while maintaining the strength and stiffness requirements. AION-A-pillar was designed by using

anodized aluminum which is transparent in nature [3]. With the intention of improving visibility, a video camera was used to dynamically capture the outside vision which was displayed on the inner panel of A-pillar [4]. Another attempt of improving visibility of the driver was done by incorporating plurality of openings formed in the A-pillar [5]. To deal with the issue of wider cross section, an expandable A-pillar design was proposed [6]. A means of examining and displaying distances and directions of possible obstacles to the driver was also explored along with the improvements done for visibility and light-weighting [6].

This paper proposes a new design of A-pillar to reduce obstruction angle of A-pillar along with reducing the weight of the part. This is achieved by designing a composite A-pillar with a glass window on exterior as well as interior panel for enhanced visibility.

PROBLEM STATEMENT

Obstruction in the View Due to A-Pillar

A vehicle with a wide A-pillar obscures the driver's line of sight and thereby compromising the field of view of the drive and creating a blind spot. According to a study by University of Minnesota Human Factor Research Lab, with the A-pillar width of approximately 10cm and the line of sight extended out 150m can produce a blind spot of sufficient size to hide a vehicle or several vehicles approaching an intersection from either the left or right of the direction of the vehicle. [8]

Position of driver's eye has been estimated from the study performed by The Department of the Environment, Transport and the Region, United Kingdom [1].

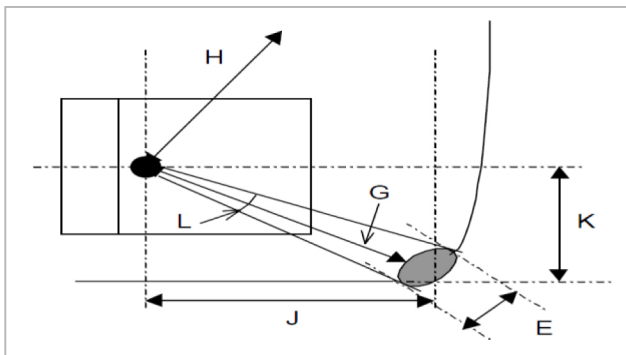


Figure 1. Eye point position from A-pillar. [1]

In the figure 1, J and K represent the longitudinal and lateral distance of eye point from A-pillar center respectively. Mean values of J & K which are 800mm and 290mm respectively, are used to calculate the obstruction of A-pillar in this study.

OBJECTIVE

The paper puts forth a design, in which a glass window will be attached on the exterior as well as interior panel of A-pillar made up of CFRP. CFRP not only offers design flexibility but also possesses good energy absorption capacity which satisfies automotive crash requirements [9].

A general process of designing and optimizing the composite A-pillar structure has been defined in the paper. Proposed design was analyzed and optimized to meet the stiffness and strength requirement as well as to further reduce the weight.

The design has been considered from the dimensional & working specifications of BMW 328i and the scope of analysis is limited to linear static loading. [10]. A comparative study was performed between sheet metal and composite component to evaluate the strength. Non-linear analysis like evaluation of roof crush test is not done but planned for the future work. The production feasibility would be checked to further refine the proposed design after detailed examination of manufacturing and joining techniques.

CONSTRAINTS

Out of all the strength requirement of A-pillar, roof crush is one of the most critical requirement from strength and stiffness perspective.

Federal regulation FMVSS 216 standard currently requires that within 127 mm (5 inches) of load platen travel, a vehicle's roof must be able to withstand a load of 1.5 times UVW and up to a maximum of 22.24 kN (5000 lbs) [11].

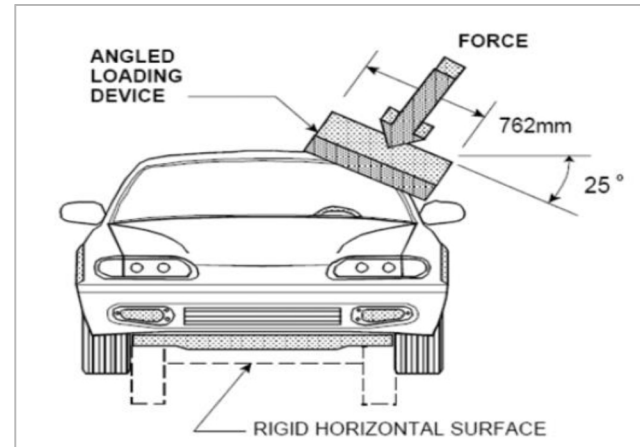


Figure 2. Showing roof crush test setup

CONCEPT - DESIGN & METHODOLOGY

From the case study, the starting point was to use an existing steel construction of the A-pillar, which was further reinforced to achieve required strength criteria. Since it was important to be able to compare the desired new construction with an existing known structure, we chose the outer dimensions for the A-pillar which resembles the existing A-pillar design.

Due to unavailability of the accurate CAD model data of the existing A-pillar design, approximations were taken into consideration while building the baseline model of the metallic A-pillar. These geometric considerations were kept constant with the composite design. It was of key importance to study the feasibility of the design to be competitive with regards to performance, manufacturability, weight and cost.

The relevant load cases for the static roof crush, front impact and front offset impact are considered as seen in the existing A-pillar. The challenge in the definition of load bearing composite components is the combination of the non-linear characteristics of the application with high number of design variables of the material. A simulation and material model for such approach would be non-linear as it involves extensive calculations, precise data and thus will be the future work scope of the work done in this research.

Geometry Considerations for A-Pillar Design

Since it was important to be able to compare the desired new structure with an existing known structure, A-pillar section has been referred from "Fundamentals of Automotive Body Structure Design" by Donald Malen" [12].

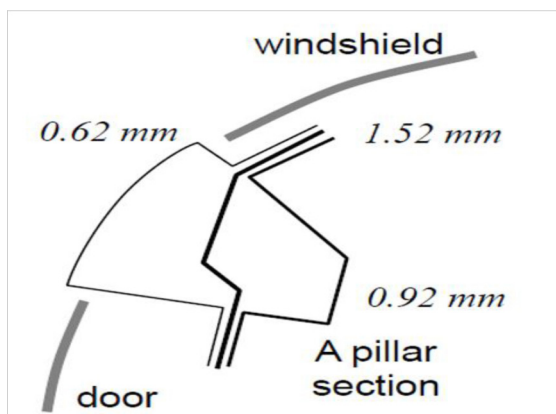


Figure 3. Sheet metal A-pillar section

Engineering Design Calculations

For concept generation of the A-pillar, to meet required standards of roof crush test, the cross section of the A-pillar was changed. Redefined cross section was based on calculated moment of inertia of the existing design of A-pillar versus proposed design of the composite A-pillar. Asymmetrical hat section geometry was selected as a candidate for new design based on the research done by T. Fraser, D. Goldenberg, M. Isa, A. Steinhauser [13]. The analysis on the cross section of the simplified model of the A-pillar was done by first calculating the centroid because the outer and inner panels of the A-pillar are not symmetrical.

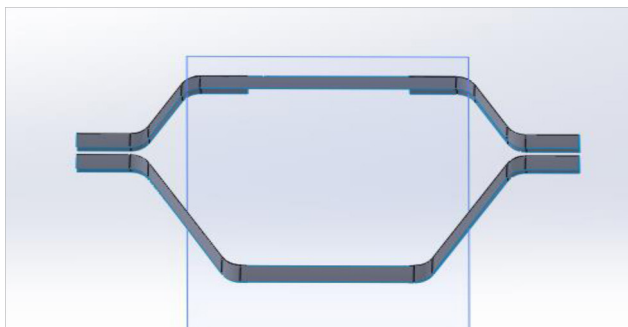


Figure 4. Proposed cross section of A-pillar

Centroid for the surface area of the A-pillar was calculated by dividing the area into six parts followed by calculation of moment of inertia about each of the coordinate axis using parallel axis theorem. Results for moment of inertia for existing cross section and proposed cross sections are summarized in [table 1](#).

Table 1. Moment of Inertia calculation

Cross section	MI in X direction	MI in Y direction
Composite A-pillar	4.72e5 (mm ⁴)	1.44e5 (mm ⁴)
Steel A-pillar	3.51e5 (mm ⁴)	1.33e5 (mm ⁴)

CAD MODELLING

CAD modeling of the existing metal model and proposed design of A-pillar was done in Solidworks. One of the objectives of the study is to reduce the problem caused due to blind spots which will be addressed by providing a glass window in the composite A-pillar.



Figure 5. Sheet metal A-pillar



Figure 6. Composite A-pillar

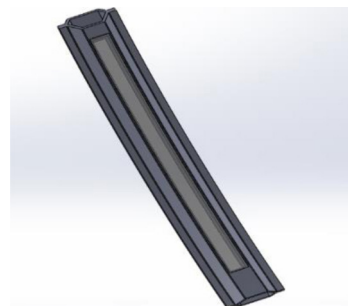


Figure 7. Composite A-pillar with glass

For the initial design, rectangular shape of the glass window was taken into consideration. Composite lay-up will be done to incorporate a rectangular cut section along the length of the pillar. Glass adhering to that shape will be attached on the pillar using adhesives. Future work also includes exploring different shapes of the glass window keeping stress values and manufacturing limitations into consideration. In most of the BIW structures, the A-pillar consists of minimum of three parts namely: Outer panel, Inner panel and Reinforcement. For the composite part design, we have eliminated the need of using reinforcement by using high modulus carbon fiber material. This design has an added advantage of not only simpler structure but also the ease of manufacturing with reduced weight.