TOTAL DESIGN OF POLYMER COMPOSITE AUTOMOTIVE BUMPER FASCIA

Mohd Nizam Suddin[1], Mohd Sapuan Salit[1], Napsiah Ismail[1], Mohd Abd. Maleque[2] and Syams Zainuddin[1]

Received: Jan 17, 2004; Revised: Oct 12, 2004; Accepted: Nov 2, 2004

Abstract

An automobile bumper fascia is a component, which contributes to vehicle crashworthiness during front or rear collisions. In the past, the fascia was made of plastic materials. The weight reduction in the bumper fascia without sacrificing the safety of the car was extensively studied. In this paper, the bumper fascia made of polymeric based composite material was designed with solid modelling software. The polymeric based composite material was selected because of low weight, high specific stiffness, high specific strength, high-energy absorption and easy to produce in complex shapes. Four conceptual designs of a bumper fascia were developed with a 3-D solid model. To decide the final design of bumper fascia, the matrix evaluation method was used. The weight of the bumper fascia was obtained through weight analysis that had been carried out using Pro/Engineer software. The fascia was successfully designed with less weight compared to the current fascia.

Keywords: Conceptual design, fascia design, bumper design

Introduction

The requirement for energy saving in the automotive industry has risen dramatically over the years. One of the options to reduce energy consumption is weight reduction. However, the designer should be aware that in order to reduce the weight, the safety of the car passenger must not be sacrificed. A new invention in technology material was introduced with polymeric based composite materials, which offer high specific stiffness, low weight, corrosion free, ability to produce complex shapes, high specific strength, and high impact energy absorption. Substitution of polymeric based composite material in car components was successfully implemented in the quest for fuel and weight reduction. Among the components in the automotive industry substituted by polymeric based composite materials are the bumper beam, bumper fascia, spoiler, connecting rod, pedal box system, and door inner panel. The bumper system consists of three main components, namely bumper beam, fascia and energy absorber as shown in Figure 1.

The bumper system is a structural component, which contributes to the crashwor-

---

[1] *Department of Mechanical and Manufacturing Engineering, University Putra Malaysia 43400 Serdang, Selangor, Malaysia*

[2] *Department of Mechanical and Materials Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia*

[*] *Corresponding author*

Suranaree J. Sci. Technol. 12(1):39-45

thiness or occupant's protection during a front or rear collision. There is an interest among the researchers to move from conventional materials such as plastic, aluminium, or steel to materials such as polymeric based composites in the bumper system.

In this study, polymer composite is selected as material for bumper fascia. Polymeric based composite is the most commonly used among all the composite materials. The fibre reinforcement is normally made from glass, carbon, aramid, boron or natural fibres while the matrix is normally thermoplastic or thermosetting materials. It is normally used due to low weight, aesthetically pleasing, comparable strength and stiffness properties compared to more concentional materials and yet generally its manufacturing cost is generally low. It is now being used in a variety of applications ranging from children's toys, furniture industry, marine application, aerospace industry and most commonly in automotive industry.

In this paper the design of polymeric-based composite automotive bumper fascia is carried out using modern total design method. It is the systematic activity necessary, from the identification of the user/market need, to the selling of the succesful product to satisfy that need. It is an activity that encompasses product, process, people and organization (Pugh, 1990).

A composite material bumper system has been made using sheet moulding compound (SMC) with random chopped glass fibre composites (Cheon *et al.,* 1995). Minaudo *et al.* (1997) developed a one piece, injection moulded, thermoplastic rear bumper system with pole impact protection. Clark *et al.* (1991) described their extensive work on bumper beams using continuous glass fibre composites to study the stress contour in the component. Cheon *et al.* (1999) developed the composite bumper beam for a passenger car. The material used was glass fibre epoxy composite material, except for the elbow section. Gilliard *et al.* (1999) developed an I-section beam with 40% chopped glass fibre GMT (glass mat thermoplastic). They found that an I-section bumper design has improved the static load and the dynamic impact performance of mineral filled/chopped glass fibre GMT, in the development.

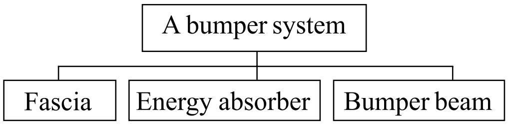


Figure 1. Automotive bumper system component

Rawson (1999) evaluated the performance of polyolefin in comparison with engineering thermoplastics for blow moulded bumper beams for mid size vehicles. Since many researchers are devoted to designing a polymeric based composite bumper beam to reduce weight, this project proposed and developed a polymeric based composite bumper fascia for the Proton Iswara 1.3 Aeroback. The front end of the bumper fascia is the subject of this study.

In this study, the bumper fascia was made of conventional polyurethane (88% by weight) and PRIMGLOS (8% by weight) /K46 glass sphere (4% by weight) materials. In this design the fascia consists of a lot of curvatures and it is a one piece moulded part. To reduce the bumper fascia weight, the lower portion of the bumper fascia material was removed. This design is to allow enough air to enter the engine compartment for cooling purposes. In order to strengthen the bumper fascia, the energy absorber (foam) made of polyurethane was attached on the backside of the fascia. The rib was designed to support the removable portion of bumper. The rib has a 3 mm thickness, 40 mm width and it follows the shape of the removed portion on the fascia. The final design of the bumper fascia showing the dimension of the rib was designed according to the size of the available bumper fascia of the Proton Iswara in the market.

The bumper fascia has a ″C″ profile, where the aerodynamic design of the fascia is to reduce air resistance when the car is moving. In this design the thickness of the fascia was fixed at 3 mm. This thickness was based on the ideal thickness of the fascia of most passenger cars. The bumper fascia was determined with a smooth outer surface. The bumper fascia was mounted to the bumper bracket with bolts and nuts. To ensure the fascia is easy to assemble and disassemble, the number of bolts required to attach the fascia to the car was reduced to two pieces and the design of the mounting bracket was also improved.

The objectives of this paper are to apply total design method in designing bumper fascia made of polymeric-based composite material using solid modelling software and to investigate the weight of bumper fascia made of polymeric-based composite. The scope of this paper is to design automotive front bumper fascia using polymeric-based composite material for Proton Iswara 1.3s Aeroback.

Design Methodlogy of Polymeric Based Composite Fascia

Figure 2 shows the architecture of the research on polymeric-based composite bumper fascia. Market research is the first process in the design techniques. The market investigation was done mainly through books, technical reports, patents, journals and the proceedings of the latest related technologies. The basic issues investigated included legal and policy issues, basic technology, competition, exceptional technology hurdles, target, risk, customer definition, engineering definition, and industry analysis. The output of market analysis was the product design specifications (PDS). The input of PDS for the bumper fascia is shown in Figure 3. A further process in designing the bumper fascia is conceptual design. In this phase, a statement of the problems were taken and broad solutions were generated in the form of schemes. The why? why? why?, brainstorming, mindmapping, analogy method, and a morphology chart were extensively used to generate possible solutions in the fascia design. It is the phase that makes the greatest demands on the designer, and where there is the most scope for striking improvements.

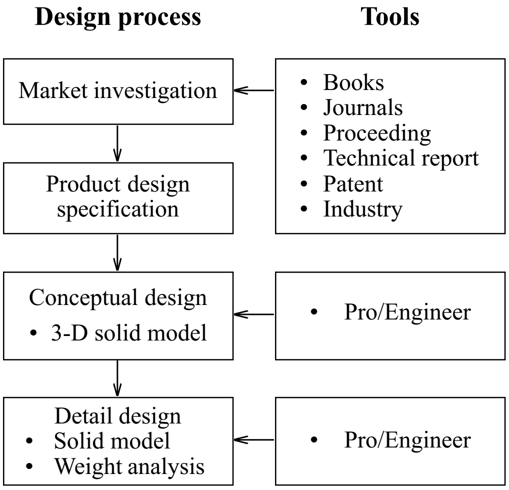


Figure 2. The architecture of the research on polymeric based composite bumper fascia

The final process in this project is the detailed design of the product. The final product was drawn in a 3-D solid model and the evaluation of the final design of the product was simultaneously solved using Pro/Engineer software.

The computer aided design used was Pro/Engineer, developed by the Parametric Technology Inc. (PTC). Pro/Engineer is a parametric, feature-based modelling system for the design, through documentation of the mechanical parts and assemblies. It permits users to write equations to effectively set up a chain of 'constraints', such as parallelisms or load bearing.

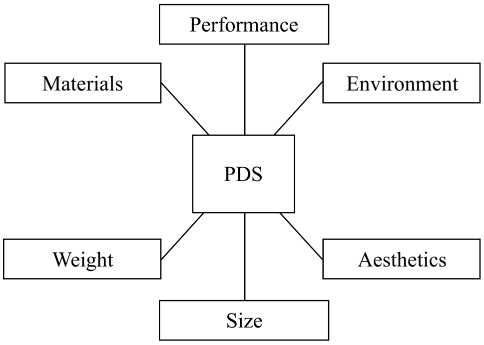


Figure 3. The PDS of bumper fascia

Conceptual Design of Polymeric Based Composite Bumper Fascia

Design concept or conceptualisation is normally the beginning phase of the design process after the recognition of the need. Creativity is related to conceptualisation because it is a means to identify viable solutions by considering alternatives. Creativity is a means to generate alternative solutions (Ertas and Jones, 1996). In this work the conceptual design stage was the third step in the design activities after market analysis, and product design specification. This phase takes the statement of the problem and generates broad solutions to it in the form of schemes. It is the phase that makes the greatest demands on the designer, and where there are many rooms for striking improvements. It is the phase where engineering science, practical knowledge, production methods, and commercial aspects need to be brought together, and where the most important decisions are taken.

Concept Development

There are many methodologies available for initiation of concepts. The following are used in this project:

Mindmapping

A mindmap of the design implications of the conceptual design of the front bumper system is developed in this project. The central 'topic' is expressed as a diagram that identifies those parts of the structure being considered. In addition to the central topic, sub-areas and their critical offshoots are circled to make them stand out. As well as identifying the issues to be dealt with, the map also records questions that the designers needed to address before progress could be made.

Analogy in Fascia Design (Cross, 1994)

A four-step approach to using analogies to generate design concepts is listed here:

- State the need
- Generate the analogies by completing the phrase, "this situation is like……"
- Solve the analogy
- Transfer the analogy to the original problem

Brainstorming in Fascia Design

Brainstorming was used to generate as many analogies as possible and as many solutions to each analogy as possible. In the brainstorming session of producing ideas for the bumper fascia, bunches of ideas were produced but are not reported here. Those ideas were combined and suited to their logical interconnection. From these combinations, several bumper fascias were produced.

Random Input in Fascia Design (Cross, 1994)

This technique can be applied as a deliberate technique, e.g. opening a dictionary or magazines and choosing a word at random and using that to stimulate thought on the problem in hand. Or switch on a television set and use the first visual image as the random input stimulus.

Why? Why? Why? in Fascia Design (Cross, 1994)

Another way of extending the search space is to ask a string of 'why' questions about the problem, such as 'why is this grille necessary?' 'Why can't we eliminate the bracket?' etc. Each answer was followed up, like a persistent child, with another 'why?' until a dead end was reached or an unexpected answer prompts an idea for the solution.

The Morphology Chart (Cross, 1994)

A complete range of alternative design solutions for the product was generated, and thence was widened the search for potential new solutions. In this chart, the features or functions that are essential to the product are listed. For each feature or function the means by which it might be achieved are listed. Finally all the possible solutions were drawn in the chart. This morphology chart represents the total solution space for the product, made up of the combinations of sub-solutions. Figure 4 shows an example of morphology chart for the bumper fascia.

Final Concepts

After much free hand sketching using the combinations of the brainstorming, four new ideas were generated, modified, and then plotted with help of computer-aided drafting as shown in Figures 5 to 8. The four design concepts of the bumper fascia are drawn in 3-D solid modelling software. The computation of mass was self generated and immediately obtained after the density of the material was defined in the solid modelling software. Detail explanation of concepts 1 to 4 is given in Table 1.

Mass Calculation

$$m = \rho V \qquad (1)$$

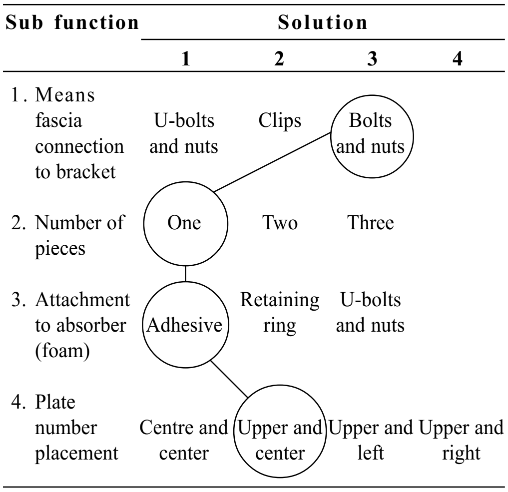
m = mass of the part (kg)

ρ = density of the material (kg/mm^3)

V = volume of the material used (mm^3)

Concepts Evaluation

The evaluation of the bumper fascia conceptual designs was carried out using the weighted objective method. For each concept, the utility score for each objective was multiplied with the weight to give relative values. These values were summed up to get the total values of each concept. The concept with the highest values was selected. As shown in Table 2,



Sub function	Solution			
	1	2	3	4
1. Means fascia connection to bracket	U-bolts and nuts	Clips	[✓ Bolts and nuts]	
2. Number of pieces	[✓ One]	Two	Three	
3. Attachment to absorber (foam)	[✓ Adhesive]	Retaining ring	U-bolts and nuts	
4. Plate number placement	Centre and center	[✓ Upper and center]	Upper and left	Upper and right

Figure 4. An example of morphology chart for the bumper fascia

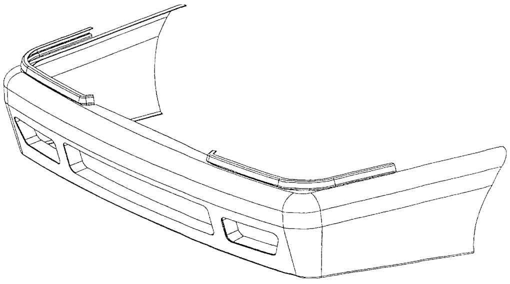


Figure 5. Concept design-1

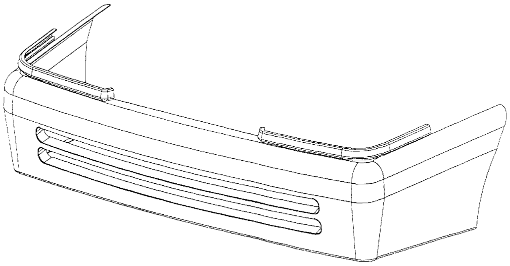


Figure 6. Concept design-2

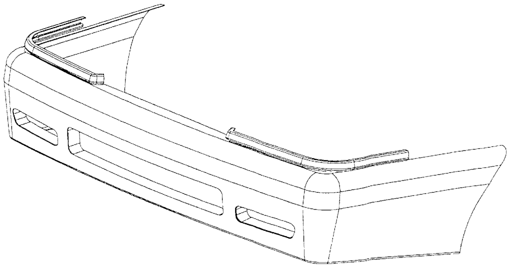


Figure 7. Concept design-3

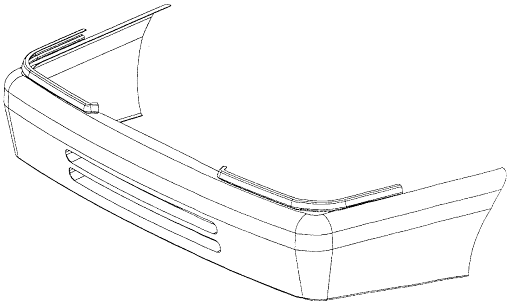


Figure 8. Concept design-4

Table 1. Characteristics of concept design of bumper fascia

Characteristic	Concept-1	Concept-2	Concept-3	Concept-4
Means connection to bracket	bolts and nuts	bolts and nuts one	bolts and nuts one	bolts and nuts one
Number of pieces	one	one	one	one
Attachment to absorber	adhesive	adhesive	adhesive	adhesive
Plate number placement	upper and center portion of fascia	upper and center portion of fascia	upper and center portion of fascia	upper and center portion of fascia
Weight	32.43N	31.98N	30.98N	31.23N
Hole pattern	one hole at the centre position two holes at both sides	two long holes are arranged in series	one hole at the centre position and two small holes at both sides	two short holes are arranged in series

Table 2. Weighted objective method for evaluation of bumper fascia

Objective	Weight	Concept-1		Concept-2		Concept-3		Concept-4	
		Score	Value	Score	Value	Score	Value	Score	Value
Low cost	0.25	8	2.0	7	1.75	8	2.0	6	1.5
Low weight	0.25	8	2.0	7	1.75	8	2.0	6	1.5
Appearence	0.1	5	0.5	7	0.7	8	0.8	7	0.7
Meterial realisation	0.2	7	1.4	6	1.2	8	1.6	6	1.2
Manfacturability	0.2	6	1.2	6	1.2	7	1.4	6	1.2
Overall utility value	7.1	6.6	7.8	5.8					

concept 3 scores the highest values and it was the best candidates.

One important issue to address in this study is on the way to obtain score for each objective in each concept. Is is carried out simply by converting the statements of objectives into parameters that can be measured, or at least estimated with some confidence. Some parameters are not measurable in simple, quantified ways, but it is possible to assign utility scores estimated on a points scale. Finally, the relative utility value of the concepts are calculated and compared. By multiplying each parameter score by its weighted value, the 'best' alternative which has the highest sum value is chosen as the 'best' (Cross, 1994).

Solid Modelling Design for the Bumper Fascia

The solid modelling system (Pro/Engineer) was used to design the components of the bumper system. The typical bumper system consisted of bumper fascia, reinforcing beam, and energy absorber. Figure 9 shows the final design of the 3-D solid model of the composite bumper fascia.

The Weight of the Bumper Fascia

The weight of the bumper fascia was computed according to equation (1), when the density of the bumper fascia material was defined in the solid modelling software. The result of the computations is shown in Table 3.

Table 3. The volume, and mass of proposed bumper fascia

Density (kg/mm^3)	Volume (mm^3)	Mass (kg)
1×10^{-6}	3.098×10^{-6}	3.098

As indicated eralier, the methodology adopted in this study is total design and it ideally should consider and study in detail every aspect of design including energy absorption and strength of bumper fascia. However, for this paper only limited aspects of design as presented above are considered to avoid the publication from being too lengthy and interested readers should refer to more detailed study of other aspects in other publications (Suddin, 2003).

Conclusion

The systematic design approach is able to guide the designer to achieve the set goals. The conceptual design is very important in design activities because it forms the background work of the bumper fascia design. The systematic conceptual design enables the designer to produce a high quality design in the final design stage. 3-D solid modelling software such as Pro/Engineer has been used extensively in conceptual design and the detail design stage. The parametric software is the best because it can provide an opportunity for the designer to optimise the thickness of the bumper fascia. The advantages of a polymeric based composite such as low weight, corrosion free, easier to produce complex shapes, high specific strength, and high specific stiffness make it suitable material for the bumper fascia.

References

Cheon, S.S., Choi, J.H., and Lee, D.G. (1995). Development of the composite bumper beam for passenger cars. Composite Structures, 32:491-499.

Cheon, S.S., Lim, T.S., and Lee, D.G., (1999). Impact energy absorption characteristics of glass fibre hybrid composites. Composite Structures, 46:267-278.

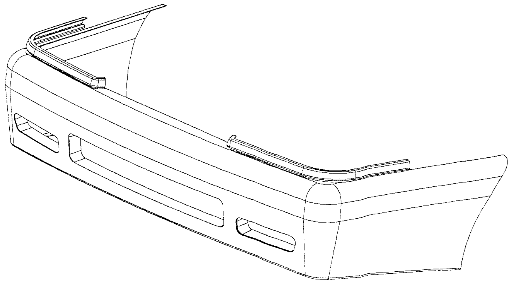


Figure 9. The final design of 3-D solid model of composite bumper fascia

Clark, C.L., Bals, C.K., and Layson, M.A. (1991). Effects of fibre and property orientation 'C' shaped cross sections. SAE Technical Paper 910049.

Cross, N. (1994). Engineering Design Methods, and Strategies for Product Design. 2nd eds. John Wiley & Sons., Chichester, p. 33-47.

Ertas, A., and Jones, J.C. (1996). The Engineering Design Process. 2nd eds. John Wiley & Sons, Inc., New York, p. 3-8.

Gilliard, B., Bassett, W., Haque, E., Lewis, T., Featherman, D., and Johnson, C., (1999). I-section bumper with improved impact performance from new mineral-filled glass mat thermoplastic (GMT) composite. SAE Technical Paper 1999-01-1014.

Minaudo, B.P., Rawson, J., and Montone, M., (1997). Development of a one-piece, injection moulded, thermoplastic rear bumper system with pole impact protection SAE Technical paper 970483.

Pugh, S. (1990). Total Design. Addison-Wesley Publishing Company, Wokingham, England, p. 5-6.

Rawson, J. (1999). Performance evaluation of polyolefins vs. engineering thermoplastic for blow moulded bumper beams for mid–size vehicles-part 11. SA Technical Paper 1999-01-1015.

Suddin, M.N. (2003). Design of polymeric-based composite automotive bumper fascia, [Unpublished M.Sc. thesis], University Putra Malaysia, Malaysia.