Journal of Industrial Technology Vol. 14, (1), 2005, 89-98

COMPOSITE PRODUCT DEVELOPMENT : CASE STUDY IN AUTOMOTIVE BUMPER FASCIA

S.M. Sapuan[1], M.N. Suddin[2], N. Ismail[1] and M.A. Maleque[3]

[1]Department of Mechanical and Manufacturing Engineering
Universiti Putra Malaysia
43400 Serdang, Selangor Darul Ehsan, Malaysia.
(sapuan@eng.upm.edu.my)

[2]Faculty of Engineering
Kolej Universiti Teknikal Kebangsaan Malaysia
Ayer Keroh, Melaka, Malaysia.

[3]Department of Mechanical Engineering
Universiti Multimedia
Jalan Ayer Keroh Lama, Melaka, Malaysia.

ABSTRAK : *Dalam kertas ini satu kajian mengenai reka bentuk menyeluruh bagi fascia bamper komposit berasaskan polimer dipersembahkan. Kaedah reka bentuk menyeluruh terdiri daripada aktiviti-aktiviti berikut : kajian pasaran, spesifikasi reka bentuk produk, reka bentuk terperinci dan reka bentuk konsep. Setiap aktiviti telah dilaksanakan dengan jayanya dalam kajian ini. Pada peringkat reka bentuk terperinci, satu sistem pemilihan bahan telah dibangunkan bagi mendapatkan bahan yang terbaik untuk komponen.*

ABSTRACT : In this paper a study of total design of polymeric-based composite automotive bumper fascia is presented. The total design method consists of the following activities : market investigation, product design specifications, details and conceptual design. Each activity was performed successfully in this study. During the detail design stage, a material selection system was developed to come up with the best material for the component.

KEYWORDS : Total design, composite bumper fascia, conceptual design.

INTRODUCTION

Engineering design is a total activity, with activities such as market development, product design specifications (PDS), conceptual design, detailed design, manufacture and sales (Dieter, 2000). In carrying out these activities, other sub-activities such as material selection and cost estimation are important to consider. In the initial stage of design, designer needs to carry out market survey, competitors' analysis, gathering information from as many sources as possible and as in the very beginning less emphasis is placed on 'hard' engineering skill but the emphasis is on 'soft' engineering skill.

Once the information is gathered, an engineer can safely perform his engineering task commencing from the development of very dynamic technical document called PDS and finally up to sale and disposal. Therefore the use of established total design model such as the one developed by Pugh (1991) is very essential. In this paper a case of development of composite bumper fascia is presented by adopting the total design approach mentioned earlier.

The car bumper is designed to prevent or reduce physical damage to the front and rear ends of an automobile at low speed collisions. Automobile bumpers are not typically designed to be structural components that would significantly contribute to vehicle crashworthiness or occupant protection during front or rear collisions. It is not a safety feature intended to prevent or mitigate injury severity to occupants in the passenger cars. Polymeric-based composite is normally used as components in automobile because of the benefits of lightweight and comparable strength and stiffness to that of steel (Owen *et al.* 2000). Bumper system consists of three parts namely bumper beam, energy absorber and fascia (bumper cover). Fascia is an aesthetic cover, which is usually a flexible, non-structural component.

Various studies have been carried out in the past on the development of composite bumper system. Parks *et al.* (1995) developed a prototype of a structural reinforced injection moulding bumper beam capable of withstanding 5 miles per hour pendulum and barrier impact requirements without an additional energy absorber. In another development, Cheon *et al.* (1995) came up with a composite bumper beam that has two pads at the ends of the bumper. The two pads were designed to hit the front two tyres of the car when the bumper brackets collapsed during collision. The composite bumper beam was made of glass fibre epoxy composite materials. The reduction of 30% weight was achieved compared to steel bumper. The aim of weight reduction is to minimise fuel consumption.

The study by Berg (1995) used reaction injection moulding polyurethane as the material for automotive bumper fascia. The fascia possesses good painted appearance, durability and performance. Grasso *et al.* (1998) applied thermoelastic technique on a lorry bumper of sheet moulding compound (SMC) material under static loads. Meaningful results were achieved and compared with other measurement techniques such as X-ray image and deformation analysis.

A complete review of automotive composite bumper system was carried out by Sapuan *et al.* (2002). The information of bumper design and manufacture, bumper materials, and other important aspects of bumper system was critically studied.

Despite some work on composite bumper, there is very limited information on development of bumper fascia that follows Pugh's total design approach which considers issues like PDS and conceptual design of composite bumper. Therefore, a study of total design of composite bumper fascia is presented in this paper. The total design of the front-end bumper fascia for Proton Iswara 1.3 Aeroback is chosen as a case study. It is shown in Figure 1.

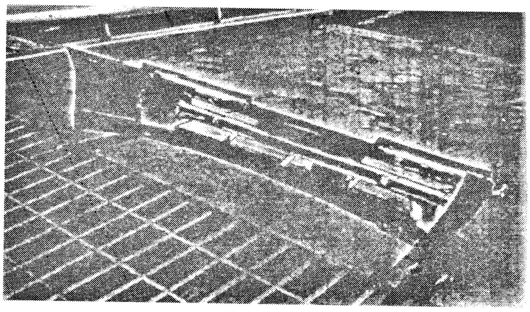

Figure 1. *Existing front-end bumper fascia*

TOTAL DESIGN PROCESS

In total design, the main activities that are normally involved include market investigation, PDS development, concept design and detail design. Figure 2 shows the relationship between various steps and tools adopted in this study. After carrying out comprehensive market investigation, a document called PDS is developed. Various concepts are then put forward using various methods. The characteristics of bumper fascia is determined using morphological chart method. The decision on the outer shape of fascia is made based on five conceptual design methods namely Why? why? why?, analogy, mind mapping, brainstorming and random input. Then four concepts were put forward for final evaluation. The concepts were evaluated using weighted objective method and finally, detail design is carried out and the main tools in detail design are expert system and solid modelling system.

Market Investigation

Market investigation was the first activity to be done. The study of the existing component to be improved was initially carried out. This involves dismantling of the existing bumper system and studying detail layout, arrangement and design of the fascia. Collection of extensive literature was performed from various existing resources as well as the concerned technologists.

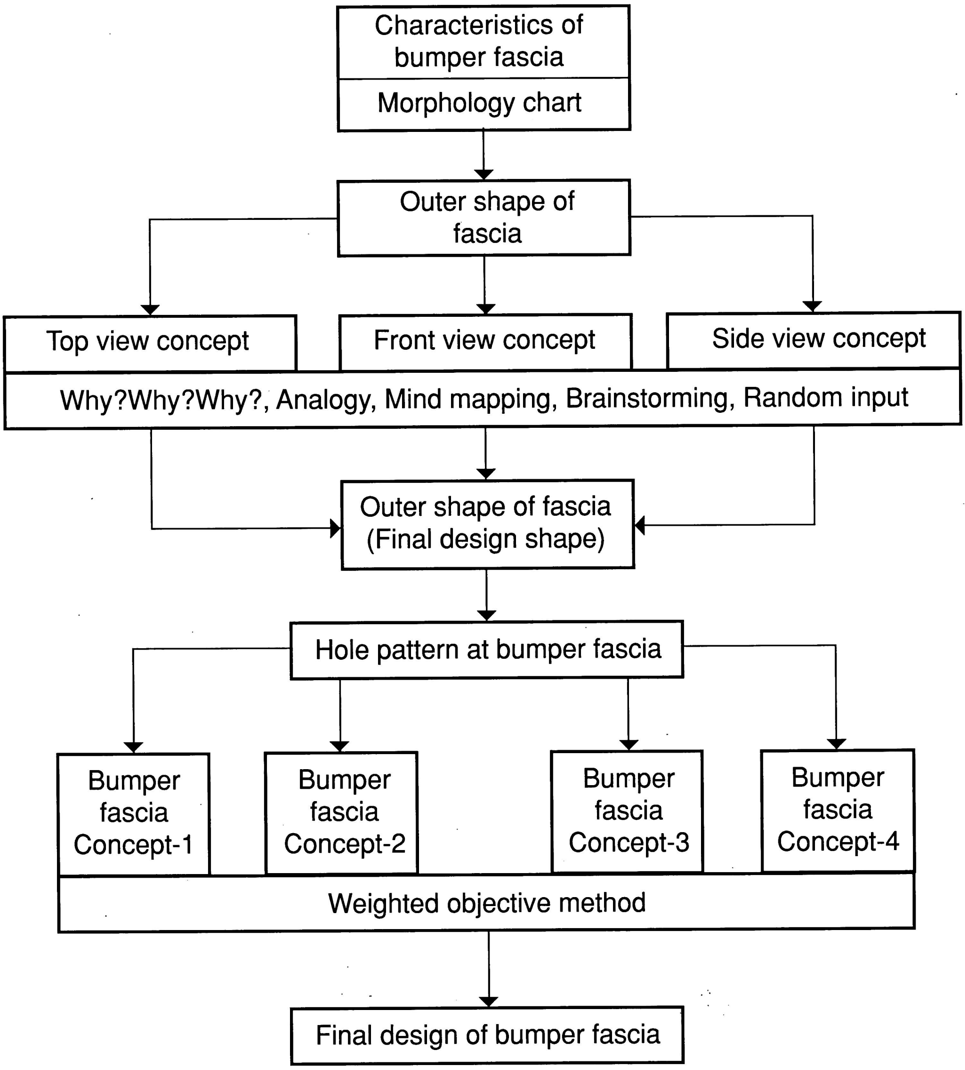

Figure 2. *The architecture of the research on polymeric composite bumper fascia*

Product Design Specifications (PDS)

The next activity was the development of a control document called PDS. It was prepared based on the various attributes proposed by Pugh (1991), who suggested about 32 attributes such as performance and cost that must be considered as the main listings in PDS. However, in this study only pertinent attributes were taken into consideration and details can be found in Suddin (2004).

Conceptual Design

The conceptual design stage was the third step in 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 is the most scope for striking improvements. It is the phase where engineering science, practical knowledge, production methods, and commercial aspects need to be brought, and where the most important decisions are taken.

Final Concepts

After much free hand sketching using the combination of brainstorming, four new ideas were generated, modified, and then plotted with the aid of a computer-aided drafting. Four concepts were put forward for further evaluation. Table 1 shows the characteristics of concept design of bumper fascia.

Concepts Evaluation

The evaluation for bumper fascia conceptual design 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 are summed up to get the total values of each concept. The concept with highest values is selected.

Table 1. Characteristics of concept design of bumper fascia

Characteristics	Concept-1	Concept-2	Concept-3	Concept-4
1. Means connection to bracket	bolts and nuts	bolts and nuts	bolts and nuts	bolts and nuts
2. Number of pieces	one	one	one	one
3. Attachment to absorber	adhesive	adhesive	adhesive	adhesive
4. Plate number placement	upper and centre portion of fascia	upper and centre portion of fascia	upper and centre portion of fascia	upper and centre portion of fascia
5. Weight	32.43N	31.98N	30.98N	31.23N
6. 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

DETAIL DESIGN

The final process in this study is the detail design of the product. In this study, the bumper fascia is made of conventional polyurethane +8% PRIMGLOS/4% K46 glass sphere material. In this design the fascia consists of a lot of curvatures and it is one piece of moulded part. To reduce the bumper fascia weight, the lower portion of bumper fascia material was removed. This design is to allow enough air to enter the engine compartment for the cooling purpose. To strengthen the bumper fascia the energy absorber (foam) that was made of polyurethane was attached on the backside of fascia. The rib was designed to support the portion of bumper that has been removed. The rib has 3 mm thickness, 40 mm width and it follows the shape of the removal portion on fascia.

The final design of bumper fascia shows the dimension of the rib designed according to the size of available bumper fascia of Proton Iswara in the market.

The bumper fascia has "C" profile, where the aerodynamic design of fascia is to reduce air resistance when the car is moving. In this design, the thickness of fascia was fixed at 3 mm. This thickness was decided based on the ideal thickness of fascia of most passenger cars. The bumper fascia was designed with smooth outer surface and was mounted to the bumper bracket through bolts and nuts. In order to ensure the fascia can be easily assembled and disassembled, the number of bolts required to attach the fascia to the car was reduced to two pieces and the design of mounting bracket was also improved. The comparison of features in existing and proposed design is shown in Table 2.

Table 2. Characteristics of proposed design and existing design of bumper fascia

Proposed design	Existing design
1. Smooth outer surface	Outer surface has a lot of grooves and ridges
2. Thickness of fascia distributed evenly in whole surface	Thickness of fascia not evenly distributed in whole surface
3. Made of Conventional Polyurethane +8% RRIMGLOS/4%K46 Glass Sphere	Made of polypropylene
4. Stylist and good apperance	Looks ugly
5. Used 4 bolts and nuts as means of fascia connection to bracket	Used 4 bolts and nuts as means of fascia connection to bracket
6. Low material realisation	High material realisation
7. Overall dimension : 1460mm - length 380mm - heigth 600mm - width	Overall dimension : 1460mm - length 380mm - heigth 600mm - width

Solid Modelling Design For Bumper Fascia

The final product was drawn in 3-D solid modelling system called Pro/Engineer developed by the Parametric Technology Inc. (PTC). Pro/Engineer is a parametric, feature-based modelling system for design through documentation of the mechanical parts and assemblies. It permits users to write equations to set up a chain of 'constraints'. Figure 3 shows the final designs of 3-D solid model of composite bumper fascia. Figures 4-6 show detail drawings of composite fascia in different views.

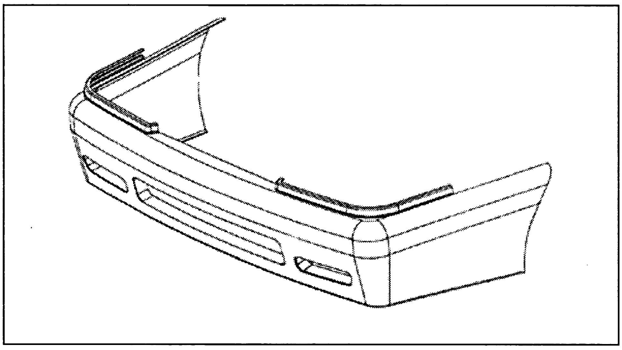

Figure 3. *The final design of 3-D solid model of composite bumper fascia*

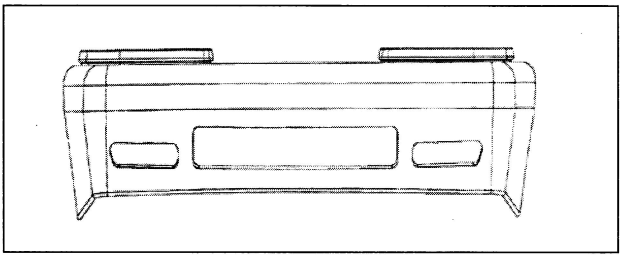

Figure 4. *Front view of 3-D solid model of composite bumper fascia*

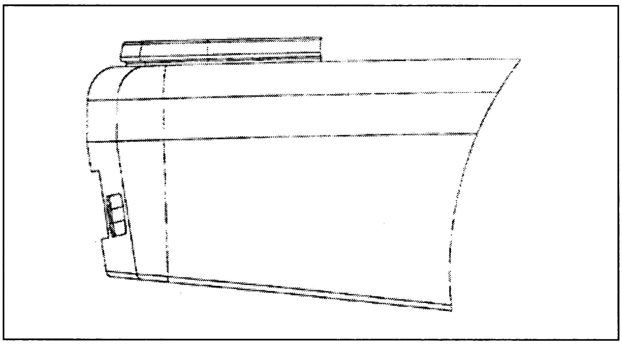

Figure 5. *Side view of 3-D solid model of composite bumper fascia*

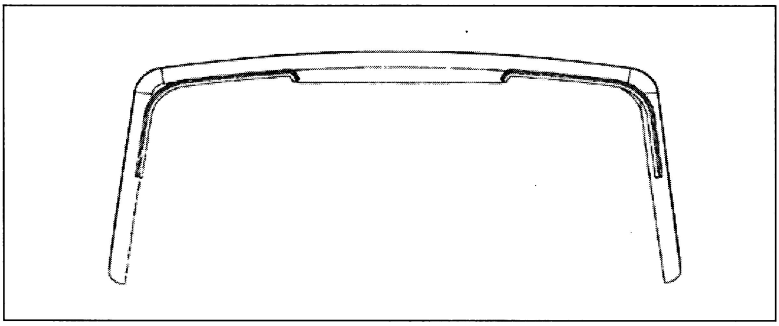

Figure 6. *Top view of 3-D solid model of composite bumper fascia*

Material selection

Material selection is a very important activity in composite design (Crane and Charles, 1997). In this section, a prototype knowledge-based system (KBS) of material selection of polymeric-based composite for bumper system is briefly presented. The KBS comprises two main tools namely frame and rule-based systems to arrive at the goal of selecting the most suitable for automotive components, namely automotive bumper system. The system goes through the materials being proposed in the frame-based system against some constraints. If any one of this constraint is violated, the system gives a message of the unsuitability of that particular material for a specified component.

The rule-based system is the major important tool in the materials selection procedure. For bumper, several rules are created. These are chained by using forward chaining technique. The constraint or limiting values are selected from the product design specifications. A chaining occurs when a conclusion of one rule matches the condition of another rule. This is particularly useful when different types of information, like those mentioned earlier, have to be evaluated. The selection of a material for the automotive bumper is carried out using the following rules :

If
(material density of this material is less than constraint material density) *and*
(tensile strength of this material is higher than constraint tensile strength) *and*
(yield strength of this material is higher than constraint yield strength) *and*
(Young's modulus of this material is higher than constraint Young's modulus) *and*
(corrosion resistance of this material is high) *and*
(the wear resistance of this material is high)
Then
(this material is a candidate for bumper) *and*
Display rank list

The slot and slot value editor in KBS for material selection for bumper is shown in Figure 7. Any material that satisfies all the requirements above can be considered as materials for the component.

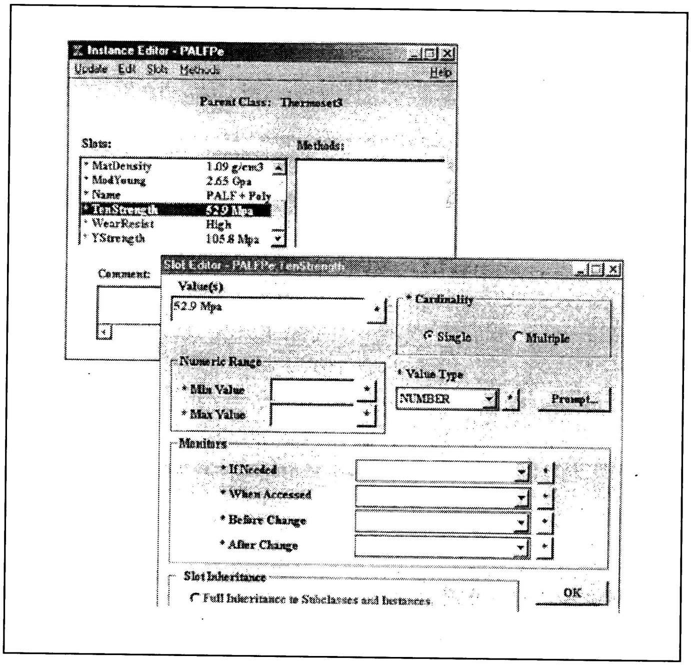

***Figure 7.** Slot and slot value editor window*

CONCLUSION

In this paper, a polymeric-based composite bumper fascia is designed based on total design model. The following conclusions can be drawn from this study :

The use of various design methods has enabled designer to make various improvements on the existing design.

Knowledge-based system can be employed as the material selection tool in designing automotive components.

Concept generation and evaluation should be performed thoroughly before detail design could be carried out on the products.

ACKNOWLEDGEMENT

The authors are indebted to the patience and perseverance of Mrs Nadiah Zainal Abidin and Ms Qurratu Aini. This paper forms part of the study of the principal author during his sabbatical leave in Universiti Malaya in 2002 and the work of the second author during his MS studies at Universiti Putra Malaysia in 2004.

REFERENCES

Berg, J.W. (1995). Lightweight reaction injection moulded polyurethane for automotive fascia, *SAE Paper 950552.*

Cheon, S.S., Choi, J.H. and Lee D.G. (1995). Development of the composite bumper beam for passenger car, *Composite Structures*, **32**: pp. 191-499.

Crane, F.A.A. and Charles, J.A. (1987). *Selection and use of engineering materials*, Butterworths, London.

Dieter, G.E. (2000). *Engineering design*, Third Edition, McGraw Hill, Boston.

Grasso, G., Rossa, G.L., Oliveri, S.M. and Risitano, A. (1998). Thermoelastic analysis of mechanical elements in composite materials. *Key Engineering Materials*, **144**: pp 155-162.

Owen, M.J., Middleton, V. and Jones, I.A. (2000). *Integrated design and manufacture using fibre-reinforced polymeric composites*, CRC Press, Boca Raton.

Parks, K.L., Kelman, J., Muller, H. and Chiba, T. (1995). Advancements in low cost bumper systems, *SAE Paper 950547.*

Pugh, S. (1991). Total Design, *Integrated methods for successful product engineering*, Addison Wesley Publishing Company, Wokingham.

Sapuan, S.M., M.N. Suddin and M.A. Maleque (2002). A critical review of polymeric based composite automotive bumper system, *Polymer and Polymer Composites*, **8(8)**: pp. 1-10.

Suddin, M.N. (2004). *Design of a polymeric-based composite automotive bumper fascia*, MS Thesis, Universiti Putra Malaysia.