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CONCURRENT DECISIONS USING ANALYTICAL HIERARCHY PROCESS AT THE CONCEPTUAL DESIGN STAGE

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ABSTRACT: Considering the appropriate decision on design concept and material during early stage of development process is a crucial decision. Inappropriate decisions always lead to huge cost involvement and ultimately drive towards premature component or product failure. This paper presents the use of concurrent engineering principles and analytical hierarchy process (AHP) to assist designers in making the right decisions during the development process of products. The development of automotive bumper beam was chosen as a case study to illustrate the use of concurrent engineering principles and AHP in making the right decision during early stage of development process. The paper reveals that glass fibre epoxy (25.8%), and design concept 6 (23.8%) (22.8%) are the best decisions during development of automotive bumper beam at the conceptual design stage.

KEYWORDS: Concurrent engineering; Analytical hierarchy process; Automotive bumper beam.

1.0 INTRODUCTION

Considering early decision making in the development of products is very important. Inappropriate decision on design and material during product development can be disastrous from both performance and economic perspectives. The level of success of product design achieved depends significantly on the right decisions on the design concept and material during early stage of development process. Conceptual design is an early stage of the product development process which

involves the generation of solution concepts in order to satisfy the functional or design requirements of a design problem (Chakrabarti and Bligh, 1994). Conceptual design is the preliminary stage of design process in which both well-defined problem specifications and high level design solutions are developed (Lin *et.al.*, 2004). Therefore, it is more important compare to the other design stages in product development process. Implementation of concurrent engineering principles (CE) by considering early decision making design problems at the early design stage is essential in developing a new product. Considering concurrently decisions on design and material have been addressed in the literature. However, there are few researchers that clearly addressed the concurrently decisions on material and design. For instance, Edwards and Deng (2007) suggested a multiple-mapping strategy and an inter-level behavioural modeling strategy. Lu and Deng (2004) proposed a system modeling methodology to support the integration between materials design (including materials selection) and engineering systems design at the early design stage. Ljungberg and Edwards (2003) developed an integration system called integrated product materials selection (IPMS) model, which has highlighted the importance of integrated design of product and materials selection, and market-oriented design.

In this paper, the concurrent decision task for both materials selection and design concept selection is proposed during concept selection at the conceptual design stage. Analytical hierarchy process (AHP) through utilizing Expert Choice software is addressed in this paper to show the importance of addressing concurrent engineering tools in product development process. The use of AHP in the context of concurrent engineering environment is less explored in the literature. So far, there is no paper discussed the use of analytical hierarchy process in determining concurrently decisions. Even though the great deal of using analytical hierarchy process in determining right decisions but it is no studied has been focused on deciding the right concurrently decisions for the automotive components. Thus, this paper presents the approach to determine the right decisions on design concept and material for the automotive component using analytical hierarchy process during concept selection at the conceptual design stage.

2.0 SELECTION PROCESS DURING CONCEPT SELECTION AT THE CONCEPTUAL DESIGN STAGE

Figure 1 shows the step to consider and determine the best design concepts and materials concurrently during concept selection process

at the conceptual design stage. It provides a systematic approach for designers to determine the most optimum decision during concept selection at the conceptual design stage. AHP was used to determine the most appropriate decisions. In general, AHP technique is composed of three main steps namely decomposition of the hierarchy structure, comparative judgements and synthesis of priorities (Saaty, 1980). These steps can be elaborated by structuring them in a more encompassing nine steps process (Hambali *et.al.*, 2009). To illustrate the selection process, 8 design concepts (DC) (Figure 2) and 6 different types of composite materials (Table 1) of automotive bumper beam were considered.

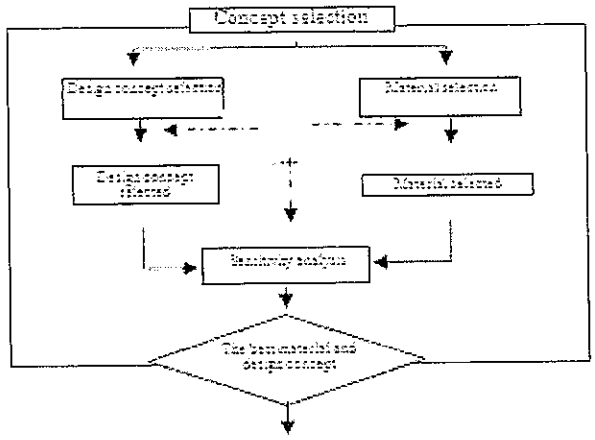

Figure 1. Selection process during concept selection.

Table 1: Materials used in automotive bumper beam design.

No	Materials
1	Glass-fibre epoxy (M-1)
2	Carbon-fibre epoxy (M-2)
3	Carbon fibre reinforced polypropylene (10%) (M-3)
4	Glass fiber reinforced polypropylene (40%) (M-4)
5	Glass fibre-reinforced Polyester (30%) (M-5)
6	Glass fibre vinylester SMC (60%) (M-6)

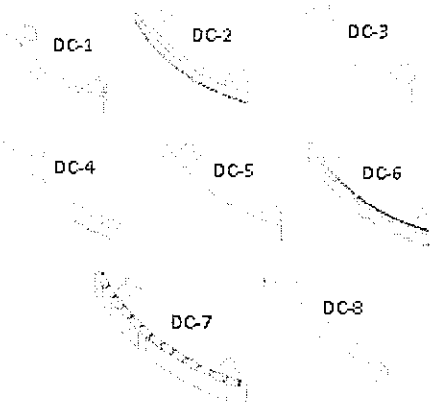

Figure 2. Various design concepts of automotive bumper beam.

3.0 DETERMINATION OF RIGHT DECISIONS

Various selection factors that influence the selection process were considered as illustrated in Figure 3. AHP steps are performed through utilizing Expert Choice software. The software developed by Forman *et.al.* (2000), is a multi-attribute decision support software tool based on the AHP methodology, and it is easy to use and understand, as well as providing visual representations of overall ranking on a computer screen. Generally, implementing AHP is based on experience and knowledge of the experts or users to determine the factors affecting the decision process (Ho, 2008). Pairwise comparisons are fundamental to the AHP methodology (Forman and Selly, 2001). Designers have to perform the judgement of pairwise comparison by using pairwise numerical comparisons. All the judgements for the design concept selection and materials selection are acceptable due to consistency ratio (CR) for each pairwise comparison is less than 0.1. AHP reveals that the design concept 6 (DC-6) with a weight of 0.191 (19.1%) as a first choice as shown in Figure 4, and the glass fibre epoxy (M-1) is the most appropriate composite material with a weight of 0.257 (25.7%) as depicted in Figure 5.

4.0 VERIFICATION OF THE DECISIONS THROUGH SENSITIVITY ANALYSIS

The purpose of performing the sensitivity analysis is to verify the results of the decision and to study the effect of the different factors on deciding the best decision option. The final selection of the design concept is highly dependent on the priority vectors attached to the main

criteria. The minor changes in the priority vectors might contribute to the major changes in the final ranking (Chang *et.al.*, 2007). Table 2 and Table 3 depict the various sensitivity analysis scenarios that have been conducted. The results showed that glass fibre epoxy and design concept 6 (DC-6) are the most appropriate decisions after performing various scenarios of the sensitivity analysis.

Table 2: The results obtained after simulating four scenarios of sensitivity analysis.

Criteria	EA		PR	
Rank	Reduced (20%)	Increased (20%)	Reduced (20%)	Increased (20%)
1	M-1	M-1	M-1	M-1
2	M-6	M-2	M-2	M-6
3	M-2	M-4	M-6	M-4
4	M-4	M-6	M-4	M-3
5	M-5	M-3	M-3	M-5
6	M-3	M-5	M-5	M-2

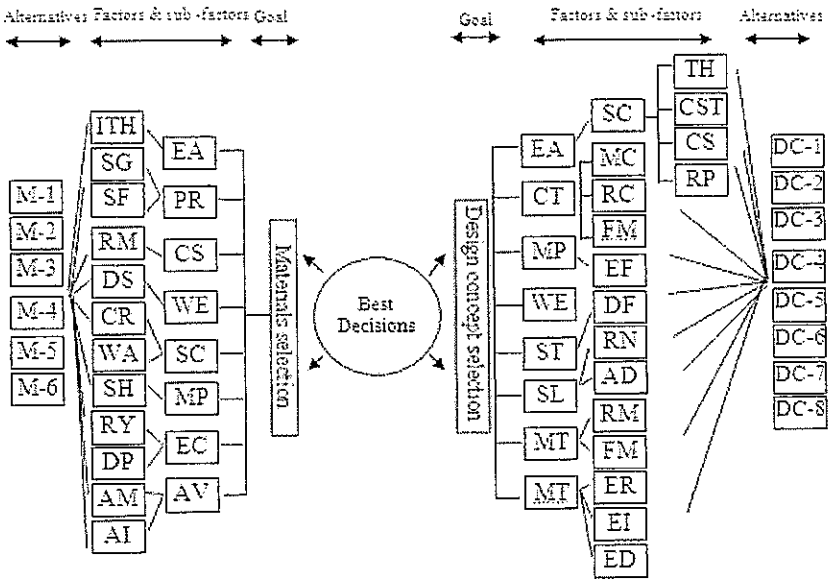

Figure 3. Hierarchy structure of AHP model.

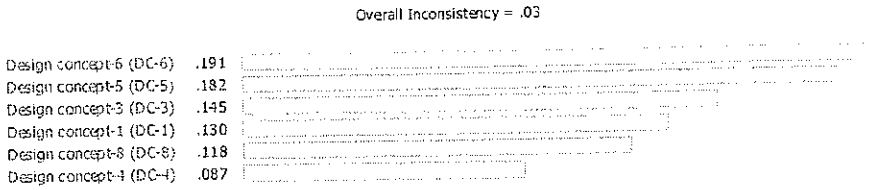

Figure 4. Result of selection of design concepts.

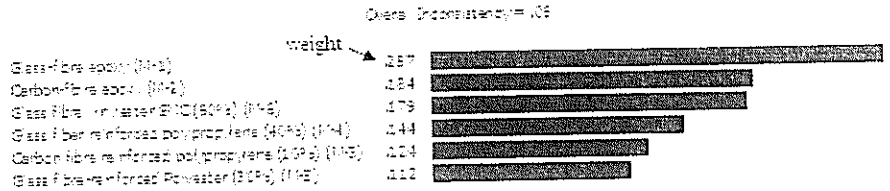

Figure 5. Result of selection of materials.

Table 3: The results obtained after simulating two scenarios of sensitivity analysis.

Main criteria	Energy absorption (EA) Decreased (15%)	Strength Increased (15%)
Rank		
1	DC-6	DC-6
2	DC-5	DC-5
3	DC-3	DC-3
4	DC-1	DC-1
5	DC-8	DC-8
6	DC-4	DC-4
7	DC-7	DC-7
8	DC-2	DC-2

5.0 CONCLUSIONS

Determine the right selection of design concepts and material during concept selection at the conceptual design stage is very important. The use of analytical hierarchy process (AHP) through utilizing Expert Choice software for solving design concept and materials selection at early stage of product development process was explored in this research. Various scenarios of sensitivity analysis scenarios were conducted to verify the final decisions. The AHP and sensitivity analysis reveals that the glass fibre epoxy ((25.7%) and concept-6 (19.1%) are the most appropriate decision for the material and design concept respectively.

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