# CONCEPTUAL DESIGN OF AN AUTOMOTIVE COMPOSITE BRAKE PEDAL

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## Abstract

**Most of the accelerator, brake and clutch pedals of automotive vehicles are metallic but recently some manufacturers have started to replace metallic clutches and accelerator pedals with polymeric-based composite pedals and a few manufacturers have started to offer weight and cost saving pedal brackets using composites. In this research work, possible configurations and geometric profiles of brake pedals have been investigated analytically and computationally. A final design of a composite brake pedal has been made from the properties of available and suitable polymeric-based composite.**

**Keywords: Brake pedal, automotive composites, conceptual design**

## Introduction

A brake pedal in motor vehicles has the task of providing the driver's command through foot leg on master cylinder of the brake system in a vehicle during stopping or reducing speed of a vehicle. At present, brake pedals are largely made from metal (Brunings *et al.*, 1989; Baumann, 1991) but composite clutches and accelerator pedals are already successfully utilized in automotive vehicles. According to General Motors specifications, the maximum load of 2700 N was applied to brake pedal (Hansmann and Bartczak, 1991). It is assumed that this is a possible panic load on a brake pedal (Hansmann and Bartczak, 1991).

Experimental data of strength is very valuable in design. The typical properties of composite are available in manufacturer's literature, handbooks and other sources (Bunsell, 1988; Lee, 1990; Schwartz, 1992; Gibson, 1994; Peters, 1998). A lot of work including design, experiment and consumer's benefit is necessary to introduce brake pedal from metal to polymer composites. Reduced weight, fuel economy, greater design freedom, improved appearance and better corrosion resistance can motivate the manufacturers to introduce composite automotive brake pedals. A good design can be expected from a wide range of design considerations.

## Material

A selection of materials for polymeric-based composite automotive brake pedal depends on a number of factors such as mechanical, physical, and chemical properties together with manufacturing issues. The chosen material must be able to be used in injection molding process where high volume production is possible and unit cost can be reduced. Chosen material must have low specific weight to strength ratio compared with metallic materials so that the concern of reducing weight of automotive vehicle can be fulfilled.

A Suitable selection of material involves thousands of data analysis out of several

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thousand types of polymeric-based composites. Short glass fibre reinforced material is chosen as a suitable material which can be used in manufacturing brake pedals.

There are polyamide (nylon) with short glass fibers in varying percentages. The long glass fibers are not suitable because of fiber intermeshes and their corners may be overlapped. Thus, from consideration of material strength and stiffness (Bunsell, 1988; Lee, 1990; Schwartz, 1992; Gibson, 1994; Peters, 1998), the short glass fiber is the lightest among the materials, which has the lowest density. Moreover nylon with short glass fiber has other advantages for automotive brake pedals. For example, it has modulus of elasticity in tension and high failure stress. Nylon with short glass fiber has high impact strength, which is an important factor of brake pedal design. When elongation and other properties have been taken into consideration, nylon with short glass fibre is chosen for the material of the brake pedal.

## Conceptual Design of Brake Pedal Lever Profile

The conceptual design of the polymeric-based composite brake pedal is a primary stage to generate the solution. Various alternative designs have been considered. The conceptual design of the polymeric-based composite brake pedal concentrates on beam for the design of the brake pedal lever. There are five concepts of beam. The concepts of the beam generated are shown in Figure 1.

## Finite Element Analysis To Aid Concept Evaluation of Brake Pedal Profile

The concept evaluation begins with the calculation of each concept regarding the weight of the beam and displacement in bending and tensile load. The calculation was performed using the conventional formulae and the finite element analysis. Unigraphics Scenario software package was employed. Figure 2 shows the finite element analysis of brake pedal lever with 'I' profile. The results of finite element analysis for different concepts are compared with one another. These are carried out to select the most suitable and economical design to reach.

The data required for brake pedal design were collected from General Motors (Table 1). The brake pedal has to withstand 2,700 N maximum static load. This load has caused the displacement of 10 mm when 220 N is applied as traverse load.

The computational results of FEA and the conventional calculation are shown in Table 2 and they are considered for concept evaluation. Concept 1 of Table 3 is chosen as reference for high stiffness in torsion. The relative weight, maximum deflection, maximum stress to Concept 1 are taken as reference parameters and the corresponding values for other concepts are calculated in comparison to concept 1 as shown in Table 3.

A matrix evaluation in Table 4 is performed to select the best concept among Concept 2, Concept 3, Concept 4 and Concept 5 based on the results in Table 3. The matrix evaluation is an

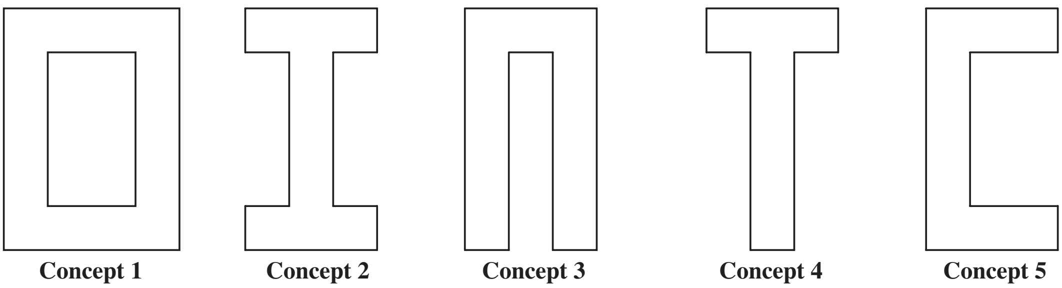


**Figure 1. Profiles of beam of brake pedal**

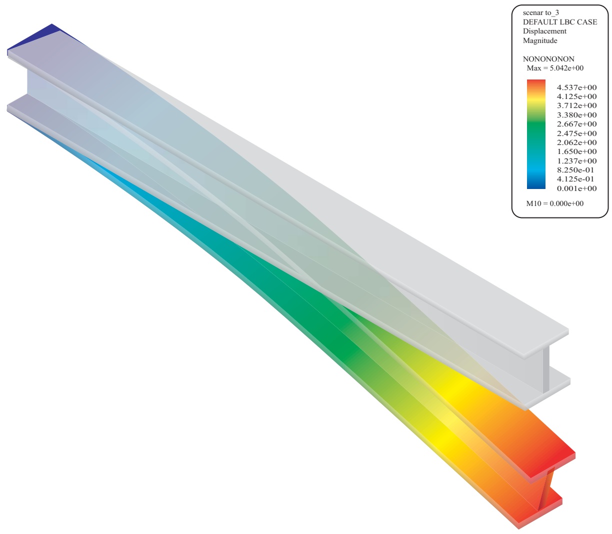


**Figure 2. Finite element analysis of brake pedal profile**

**Table 1. Brake pedal loads and deflection in a car (Hansmann and Bartczak, 1991)**

| Requirement | | Brake |
|---|---|---|
| Static load (maximum) | | 2,700 N |
| Deflection at | | |
| transverse load | 220 N | 10 mm |
| normal force | 1,100 N | 10 mm |
| normal force | 2,700 N | 15 mm |

**Table 2. Comparison of calculated results with computational results for different concepts with 220 N traverse load**

| Concept | Volume $(cm)^3$ | Mass (g) | Maximum deflection (mm) | | Maximum stress ($N/mm^2$) | |
|---|---|---|---|---|---|---|
| | | | Calculated | Computed by FEA | Calculated | Computed by FEA |
| Concept 1 | 159.6 | 252.17 | 4.422 | 4.499 | 18.952 | 17.56 |
| Concept 2 | 121.8 | 192.44 | 4.872 | 5.042 | 20.878 | 19.54 |
| Concept 3 | 128.8 | 203.5 | 6.379 | 7.10 | 33.135 | 32.81 |
| Concept 4 | 85.4 | 134.93 | 12.349 | 11.1 | 72.915 | 61.19 |
| Concept 5 | 121.8 | 192.44 | 4.872 | 11.64 | 20.878 | 30.45 |

**Table 3. Relative weight, maximum deflection and maximum stress compared to concept 1**

| Concept | Weight ratio | Maximum deflection ratio | Maximum stress ratio |
|---|---|---|---|
| Concept 1 | 1 | 1 | 1 |
| Concept 2 | 0.76 | 1.21 | 1.113 |
| Concept 3 | 0.81 | 1.578 | 1.868 |
| Concept 4 | 0.54 | 2.467 | 3.485 |
| Concept 5 | 0.76 | 2.587 | 1.734 |

**Table 4. Matrix evaluation of the beam used to select the best concept**

| No. | Criteria | Weight factor | Rating | | | | Weight factor x Rating | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | C2 | C3 | C4 | C5 | C2 | C3 | C4 | C5 |
| 1 | Weight | 3 | 2 | 1 | 5 | 2 | 6 | 3 | 15 | 6 |
| 2 | Maximum deflection | 5 | 5 | 4 | 3 | 2 | 25 | 20 | 15 | 10 |
| 3 | Maximum stress | 4 | 5 | 3 | 2 | 4 | 20 | 12 | 8 | 16 |
| | | | | | | | 51 | 35 | 38 | 32 |

established method to select the best design concept as reported by Wright (1998), Cross (1994) and Pugh (1991). The weight factor is calculated for each criterion based on scale 1 to 5. The scale of weight factor represents the importance of criteria for each concept. Then the criteria weight factor value is multiplied by rating value to give a score. In this way Concept 2 gives the highest score, i.e. 51. Therefore Concept 2 is chosen as the best brake pedal profile design. According to Cross (1994) rating and weighting factor can be quantified by listing the criteria in a rank order of importance. One way of doing this is by relative weightings. For instance, the most important criterion is given the value 5, and the others then given values relative to this. Another way is converting the statements of criteria into parameters that can be measured, or at least estimated with some confidence. Thus, for instance, a criterion for a machine to have 'high reliability' might be converted into a performance parameter of 'breakdowns per 10,000 h running time' which might be either measured from available data or estimated from previous experience with that type of machine (Cross, 1994).

## Results and Discussion

From FEA and computational results the following are observed:

- The I-beam is found more suitable for composite brake pedal lever profile.
- The sharp edges should be eliminated to reduce possibility of injuries of users and to facilitate the material flow inside the mould.
- The weight of polymeric-based composite brake pedals came to 0.19 kg but a typical metallic brake pedal is 0.72 kg. Thus, the weight reduction that can be achieved using polymeric-based composite is 73%.
- Finite Element Analysis (FEA) is carried out using Unigraphics Scenario with a traverse load of 220 N. The maximum brake pedal load that can be applied is 920 N with stress of 180 N/mm$^2$ on polyamide with glass fiber reinforcement.

## Conclusions

- The advantages like low weight, high strength and freedom to design in complex shape can encourage manufacturers to carry out an investigation on utilizing polymeric-based composite brake pedals in automobiles.
- Polyamide with short glass fiber can be chosen as most suitable materials to use in polymeric-based composite brake pedals.
- The weight of reduction of 73% can be possible by proper design of polymeric-based composite brake pedals.

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