DESIGN AND MANUFACTURING OF FORMULA VARSITY RACE CAR PEDAL SYSTEM

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Abstract—**This paper presents the design and manufacturing of a new pedal system for UTeM Formula Varsity race car. The new pedal was designed according to the rules and regulations for the Formula Varsity 2012. Through finite element analysis, the pedal design was found to be safe for operation. The prototype of the pedals was fabricated using 6061-T6 aluminum alloy material. The new end product was found to be 0.245 kg or 40% lighter than the previous design. The new pedal is expected able to perform successfully as per design requirement in the new 2012 UTeM**

Keywords- **Pedal system, design, Formula Varsity race car.**

I. INTRODUCTION

UTeM Formula Varsity is a racing competition where engineering students from various Malaysian higher learning institutions participated in the challenge to design, fabricate and race a working prototype of an open wheel, four-wheel formula style race car in real track condition. The event was organized by Faculty of Mechanical Engineering, Universiti Teknikal Malaysia Melaka (UTeM) and in the 2010 event, saw the participation of over 20 cars from 16 institutions all over Malaysia including 2 teams from Universiti Teknikal Malaysia Melaka [1]. Based on knowledge and experienced gathered in the race event, a new team was created to produce a similar race car as the preparation for the upcoming 2012 event. Among the initiatives made is to design the new UTeM pedal box which are aims to be lightweight components and able to maintain the structural strength needed for safety during its operation. This paper describes the development process of the new UTeM race car pedal box as well as the analysis done to determine the structural properties of the structure during its operation.

II. LITERATURE REVIEW

In general, pedal system for a car consists of several major parts which are the brake pedal, clutch pedal, accelerator pedal, cylinder pump, and linkages. Current pedal system design operates either using a hydraulic clutch or a cable clutch mechanism [2].The pedals act as to control the amount of braking required on each axle to achieve the desired balance in braking as well as the amount of throttle opening at the vehicle engine carburetors or at the throttle body to increase or decrease vehicle acceleration [3]. The pedal components on conventional vehicles are normally operated by foot or both feet of the driver, therefore it is crucial that the pedal system is designed with careful consideration on its structural integrity with respect to the amount of force applied by the foot the components, especially during panic braking [4].

III. RESEARCH METHODOLOGY

The overall project consists of several stages which is pedal system design, material selection for the pedal components, structural analysis on the pedal components, component fabrication and final assembly on the real race car. The performance of the new pedal system design is measured in term of its weight compared to the previous pedal system design as well as its actual capability to operate after been assembled onto the actual race car. Product design specifications for the new pedal system was established and use in the design selection stage. Fig. 1 below shows the overall project flow chart carried out in this research.

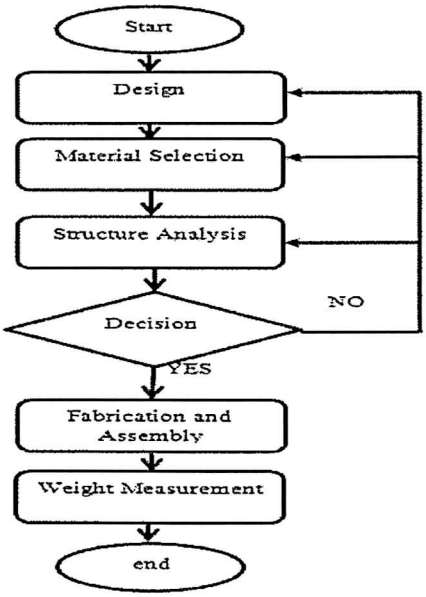
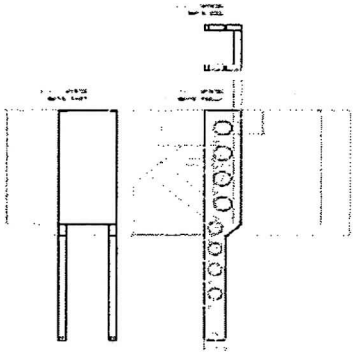


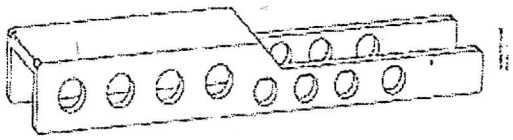
Figure 1. Overall project flow chart

IV. PEDAL DESIGN CONCEPT

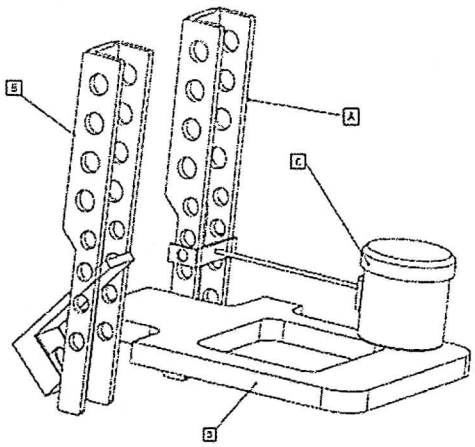
The pedal system design concept has been developed based on the specification that has been outlined in the UTeM Formula Varsity car regulation. A design criterion is required to clarify the physical and operational characteristics of the pedal system design concept. The pedal design should be ergonomic, safe to use, using lightweight material, easy for installation, can be made using appropriate fabrication process and low cost. The pedal system design however, is focused on the accelerator and brake components only, where the clutch component is neglected. Based on the design criterion, the team has produced three design concept of the new pedal system design. Upon the selection for the best concept, the team has decided to use Pahl & Beitz method to evaluate and select the alternative concept [5]. The full view of the finalized design concept is shown in the Fig. 2 below.



(a) Top and side view



(b) Isometric view



(c) Assembly view

Figure 2. Final pedals system design (a) top and side view, (b) isometric view, (c) assembly view

V. MATERIAL SELECTION

Since no limitation from the technical specification of using material for the pedal, the characteristics of lightweight and strength are the prime concerned [1]. In this project, two materials have been selected which were 6061 – T6 aluminium alloy and AISI 1010 low carbon steel. It compromise with the low density, high strength and cost effective material. The evaluation of the materials properties were done by using the CES EduPack software [6]. This software showed the mechanical properties of aluminium alloy were better than the low carbon steel based on yield strength, density and Young's modulus. Table 1 shows the comparison of material properties between aluminium alloy and low carbon steel.

Table 1. Comparison between 6061-T6 aluminium alloy and AISI 1010 low carbon steel material properties

Material Properties	Aluminium Alloy 6061-T6	Low Carbon Steel AISI 1010
Density (kg.m^{-3})	2.5-2.9 x10^{3}	7.8-7.9 x10^{3}
Yield strength (MPa)	30 - 500	250 – 395
Young's modulus (GPa)	73 - 89	200 – 215
Tensile strength (MPa)	58 - 550	345 – 580
Fatigue strength at 10^{7} cycles	21.6 - 157	203 - 293

VI. STRUCTURE ANALYSIS

The designed pedals were analyzed to determine the structural ability. Every race car must be able to complete 1.6 km race track for the total of 30 laps without failure, thus the pedal box integrity to adhere the forces is very critical. It is not subjected failed the race only, but most important is the safety of the driver. By using CATIA V5, the Finite Elements Analysis (FEA) was performed. Completing the Generate Structural Analysis module, the appropriate pressure loadings were applied to the model.

Based on the structural analysis results, it was found that the maximum stress showed at the bottom of the pedal lever. In all analysis, it has been considered-under the 'worst case' scenario. The load apply to the brake pedal structure must be maximum and the material that will be apply is the lowest strength among the selected material [7]. For the FEA brake pedal test, the applied load was 2000 N, which is the actual applied load from the human maximum force. The materials selected were low carbon steel AISI 1010 and aluminium Alloy. For the accelerator pedal, the load that was applied is 370 N [8].This structures for both pedals were analyzed using tetra polygon mesh. Fig. 3 shows the stress distribution result on the pedal by using CATIA V5 software.

Figure 3. Stress distribution on the pedal by using CATIA V5

Based on the structural analysis results, aluminium alloy 6061-T6 was selected. Therefore the material has been selected in this project due to higher structural strength compared to AISI 1010 low carbon steel. Table 2 shows the comparison of structural performance between the two types of material after performing the finite element analysis.

Table 2. Brake pedal and accelerator pedal structural performances comparison between aluminium alloy and low carbon steel material

	Brake Pedal		Accelerator pedal	
Material used	Al 6061-T6	AISI 1010	Al 6061-T6	AISI 1010
Load applied	2000 N		370 N	
Maximum stress on pedal ($N.m^{-2}$)	1.51×10^8	4.32×10^8	2.2×10^7	7.99×10^7
Yield strength (MPa)	500	395	500	395
Design factor of safety	3.31	0.91	22.72	4.94
Conclusion	Best	Poor	Best	Poor

VII. PEDAL MANUFACTURING AND ASSEMBLY

Both the new accelator and brake pedals as well as the pedal base component are fabricated in house at the Faculty of Mechanical Engineering, UTeM laboratory from aluminium alloy stock material using conventional milling machine and a HAAS 3-axis CNC Machine as shown in Fig. 4. Then, the fabricated components are assembled together with the master cylinder pump to make up the pedal system assembly using mechanical bolts and nuts as shown in Fig. 5. Finally, the pedal system assembly is fitted to its desired location at the race car chassis as shown in Fig. 6. Hydraulic and cable linkages were also installed to the pedal system to connect the brake and accelerator pedals to the engine carburetor and the race car disc brakes. Final test on the new pedal assembly was conducted and it was found that it is able to operate smoothly and fit the given space inside the chassis successfully without any disruption to the functionality of the existing suspension system of the car.

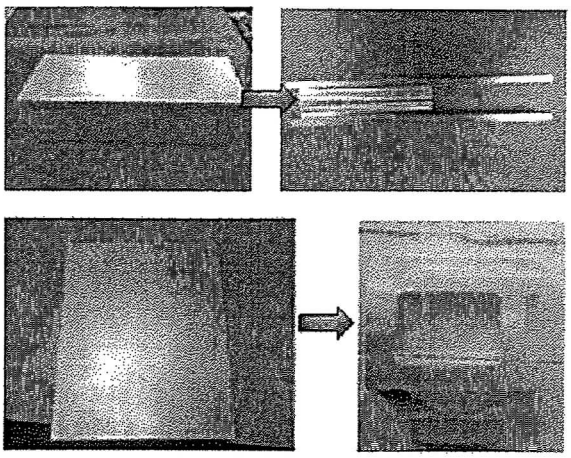


Figure 4. Manufacturing of pedal and pedal base from metal stock to finish product

Figure 5. New pedal components after assembly

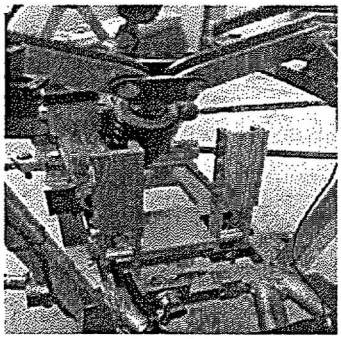
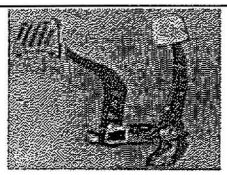
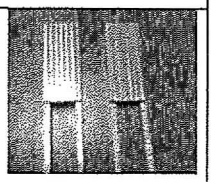


Figure 6. Fitting process of new pedal assembly to the UTeM Formula Varsity race car

VIII. RESULTS AND DISCUSSION

The propose design of automotive pedal is used for Formula Varsity 2012. This propose design is compared the previous design that used in Formula Varsity 2010 as shown in Table 3 below.

Table 3. Weight comparisons between the new and previous pedal design

Pedal Component	Component Weight	
	New Design	Previous Design
		
Accelerator	0.360 kg	0.191 kg
Brake	0.240 kg	0.164 kg
Total weight	**0.600 kg**	**0.355 kg**

In this comparison, the weight of the previous accelerator pedal is approximate to 0.360 kg and the new design is only 0.191 kg. The difference is around 46.9%. Then, the weight of pedal for previous design is equally to 0.240 kg and the propose design is 0.164 kg. The difference percentage is around 31.67%. For a total difference for both designs is 40.83%. According to this result, the total of weight on automotive pedal is decreased up to 40%. In racing matter, it will influence the total performance of racing car, independently when the race is on the road. Besides, the performance of pedal is same as for the previous one. It is also easier to maintain and can move easily because the weight is reduced.

Last but not least, the propose design is implemented the distance pedal ratio between pedal lever and fulcrum, and from the open literature, if the propose design follow this root, it is more accurate and the legs of the racing car driver is in comfort zone position during driving a car [9]. The position of the new pedal design with respect to the vehicle chassis built using a manikin as the simulated driver on board is shown in Fig. 7 below.

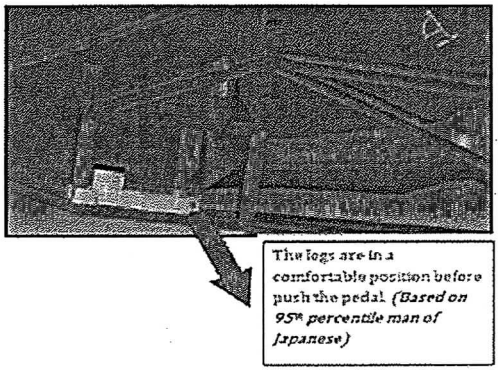


Figure 7. Position of the new pedal design inside the vehicle chassis

IX. CONCLUSIONS

In conclusion, a new pedal system design for UTeM Formula Varsity race car was developed in this project. The new pedal was designed according to the rules and regulations for the Formula Varsity 2012. Through finite element analysis, the pedal design was found to be safe for operation. The prototype of the pedals was fabricated using 6061-T6 aluminum alloy material. The end product was found to be very lightweight where the new pedal weight achieved was 0.245 kg or 40% lighter than the previous design. Thus, it is expected that the new pedal is able to perform successfully as per design requirement in the new 2012 UTeM Formula Varsity race car.

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