

DESIGN AND DEVELOPMENT OF HYBRID COMPOSITE CHASSIS FOR
FORMULA STUDENT RACE CAR

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This report is submitted to the Faculty of Mechanical Engineering
in partial fulfilment of the partial requirement for awarding the
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MAY 2009

“I admit that this report is my own work except
the summary and some statement which is each of them,
I already state the source of it”

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“For my beloved mum, Mrs. Rosita binti Khalib and my caring dad, Mr. Zamri bin
Zainul”

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ABSTRACT

Formula student race car is a developing project to engineering student in purpose to apply their knowledge in race car event. This study is focusing in the development of chassis design which is important part that influences the performance of race car. There is need to study about vehicle dynamics with the aim to develop a great chassis. In this study include the utilization of composite materials that is Glass Fiber Reinforced Polymer (GFRP) which has incredibly properties in exceeding the limit of chassis and provide light-weight component. Analysis is done through determination of force acting on the chassis, thus discover the composite structure needed. Then, a concept design is generated and final selection is drawn using CAD software. Next, fabricating process is conducted after determination of manufacturing process of composite component. Discussions of results determine the need for future study to overcome the weaknesses. Recommendation is suggested for improvements in future study.

ABSTRAK

Kereta lumba formula pelajar adalah projek pembangunan kejuruteraan kepada pelajar kejuruteraan dalam mengaplikasikan kemahiran dan pengetahuan dalam perlumbaan kereta lumba. Kajian ini memberi fokus kepada pembangunan rekabentuk casis yang menjadi salah satu komponen penting yang mempengaruhi prestasi sesebuah kereta lumba. Kajian tentang dinamik kenderaan adalah perlu untuk merekabentuk sebuah casis yang baik. Dalam kajian ini, penggunaan bahan komposit iaitu Polimer Gentian Kaca Diperkuatkan (GFRP) yang mempunyai ciri-ciri yang menakjubkan untuk melangkaui batas prestasi sebuah casis dan menghasilkan komponen yang lebih ringan. Analisa dilakukan melalui pengiraan daya yang bertindak ke atas casis seterusnya lapisan komposit dapat ditentukan. Konsep rekabentuk dihasilkan dan rekabentuk pilihan dilukis menggunakan perisian CAD. Kemudian, proses fabrikasi dilakukan selepas proses pembuatan komponen komposit dipilih. Perbincangan mengenai keputusan yang diperlukan untuk kajian pada masa akan datang untuk menyelesaikan kelemahan yang sedia ada. Cadangan penambahbaikan dicadangkan bagi menambahbaik kajian pada masa akan datang.

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CHAPTER 1

INTRODUCTION

Chassis is widely used in vehicle design to give a support for all components. It has been study heavily to improve the performance of the car and create a suitable one for different type of vehicle. In the race car event, chassis is built to boost it until a limit with the intention of win over challenger. Chassis of a vehicle is usually designed with purpose to hold the load from the components of vehicle and mass from driver and passenger. Chassis need to satisfy a number of requirements whose aims partly conflict because of different operating conditions which are loaded and unloaded weight, acceleration and braking force, level or uneven road and straight running or cornering.

Nowadays, most of the components of vehicle are in the stage of replacing with composite as its materials. This is due to the properties of composite that can be designed freely to hold the load from any direction. Its light-weight property makes it possible to enlarge the performance of the car while maintaining low weight. In the Formula 1 industry already widely used of composite materials and most of the part has been already replace with it. There are various ways to manufacture it such as hand lay-up, resin transfer molding, vacuum assisted resin transfer molding and etc. Each manufacturing process has its own benefit for different condition. Thus, composite material is highly important and it is worthy to study about it.

Formula student race car is a racing car developed by the students particularly from university by following the standard policy set by Society of Automotive Engineering (SAE). It is called Formula SAE which gives opportunities to the students to produce a Formula-style race car and create a starting base about development of racing car. This will give the opportunity to apply the theories from textbook to real work place and also come with clever problem solving of racing car.

Presently, Universiti Teknikal Malaysia Melaka (UTeM) had developed a racing car using a chassis made from the mild steel. However, this race car does not apply to the SAE standard. The chassis system used now is tubular type. Thus, in order to increase its performances and abide to the SAE standard, the new development of chassis is needed. The idea is to optimize the characteristics of chassis and hence, the performance of the racing car by changing its material from mild steel to Glass Fiber Reinforced Polymer (GFRP).



Figure 1 : Composite chassis for Formula 1 race car
(Source: <http://www.one-pablo.com/technique/chassis1.jpg>)

1.1 Objective of study

The purpose of the study is to develop a composite space frame chassis by using Glass Fiber Reinforced Polymer (GFRP) composite for formula student racing car.

1.2 Problem statement

The current racing car use tubular or space frame chassis system built from mild steel with diameter approximately 1 inch. The complexity of design and the arrangement of the components contribute a waste space which not makes the car more compact. By using of mild steel tubes has cause the overweight of the car and makes the car lose the power. Analysis on the chassis has not been done during development which is essential to know the load distribution and the strength of component during worst case scenario. Without any CAD data of design, it is impossible during troubleshooting and optimization process in the future.

Therefore, this study will focus to reduce the problem occurred and make the improvement of design. GFRP composite will be used instead of mild steel to solve the overweight problem. As known that GFRP composite is a light weight material and can be created to have a same strength as mild steel. The analysis for acted load in static and dynamic condition will be determined to protect the driver during the worst case situation. All the data will be documented for further study.

1.3 Scopes of study

The scopes of study are to design a hybrid composite chassis by using computer aided design (CAD) software, to analyze the strength through load calculation and composite calculation and to fabricate by using GFRP composite material.

1.4 Benefit of study

Designing a race car is not a simple matter because it requires deeply knowledge in engineering. A lot of time is needed during analyzing process. Formula student is not complicated and competitive as Formula 1 but it still requires high theoretical and practical skills. Thus, this study will offer an experience on hands-on application, time management and problem solving to the student.

CHAPTER 2

LITERATURE REVIEW

In this chapter, a literature reviews are made to have a better understanding about the project. The purpose of this chapter is to give general information and create an idea about the project. This is the early step to begin he project. It begins with a briefing about formula student racing car. The next section is about introduction to chassis system. In this section is discussing about type of chassis and the important of development of chassis in racing world. Then is about composite material where it focusing about glass fiber reinforced polymer (GFRP). This also consists of fabrication techniques, type of composite and need of composite material. Literature study is done through several sources that are journals, thesis, internet and reference book.

2.1 Formula SAE

Dr. Marshek had conceived a first Formula Student or Formula Society of Automotive Engineers (SAE) and was held in 1979 at University of Houston. It was known as SAE Mini-Indy before. Mini-Indy means the car is small compared to the Formula 1 race car. The first car entered this competition are made out of wood and used five horsepower engine. In this competition, every participants who are engineering students need to design and build a small race car using the same engine power. Thirteen universities were entered in the first series of formula SAE competition but only eleven universities had completed this race.

Formula SAE started to be more systematic and reliable when new proposal has stated a new concept of Mini-Indy on 1980. This is proposed by three students from University of Texas at Austin where a new rules and regulations need to be obeyed. In this proposal stated that all the engine must used four stroke engines with 25.4 intake restriction. In 1985, Dr. Robert Woods from University of Texas with guidance from SAE student activities committee changed the concept of the competition. They wanted students to design and build a race car for limited series production.

Formula SAE has make a lot of changes in term of concept, rules and regulation and also many more. Now, Formula SAE has become more establish and attracts many schools and universities to join this competition.

2.2 Introduction to chassis system

Vehicle chassis is consists of a framework that supports the component of the vehicle that attached with the vehicle suspension. The primary function of chassis is to hold all the part of the vehicle that built on it during static or dynamic condition. For the racing car, it chassis need to have high strength against dynamic load to provide a protection to its cockpit in the same time prevent any injury to driver in the event of collision.

Vehicle chassis has built with different types due to several purposes. Each type of vehicle chassis has its own advantages and disadvantages to achieve its certain requirements and conditions. There are several types of chassis that are tubular, monocoque, ladder and backbone. There are several considerations that must be taken to design a chassis. The chassis should exhibit these characteristics such as offering driver protection in the case of an accident, high rigidity, lightweight, inexpensive, allows easy access to internally mounted components and easy to manufacture.

Load analysis is done to calculate the strength of the chassis due to the load acting. This analysis is performed with analytically and experimentally to get accurate result. The different loading conditions and requirements the vehicle chassis must be discussed focusing on road inputs and load paths within the structure. Different modes of deformation must be understood that are longitudinal torsion, vertical bending and lateral bending.

In the car race, chassis is the most important component that will affect the performance of the vehicle. Car race is all about achieving maximum performance of the vehicle and run it into the limit. Most of the professional racing team spends a lot of money on researching and testing to exceed their current performance. Therefore, vehicle dynamics of the race car are studied heavily in all aspect for each of the components. A race car is a complex system that built from various components and the performance for each part is relied on each other. For example, if a very quality

suspension is installed on a soft flexible chassis, the performance of the suspension system will be wasted by the chassis flexing before the suspension system can work. This is the reason why finding an optimum vehicle configuration is important. Metz (1998) stated that having the correct chassis set up and many component tuning options available, will allow for the system to achieve maximum potential.

In a reality of racing, to optimize a performance of vehicle to its limit for different track condition and event is a difficult and complex task. It can be more complex if a vehicle has more than one driver which each of them has different set up of vehicle. It is unrealistic to produce a perfect optimum but by using modern design methods and some driver compromises, common faults can be overcome and performance satisfaction can be achieved (Metz,1998).

In the chassis design, each racing team need to decide early about the performance of a vehicle when considering cornering and straight line condition. Stobart (2001) stated that the first principal objective for an ideal chassis set up is to have cornering balance which is a neutral steer under lateral load conditions to prevent over steer and under steer during cornering. In order to get a better cornering ability, it is necessary to have high chassis rigidity but an over design of chassis can contribute to overweight which further increase a lateral loading during cornering. A lightweight chassis has a potential to increase a speed but also can cause rolling and deflection of vehicle. This is agreed by Reimpell (2001) who stated that the most common vehicle handling deficiencies are often caused by poor and inadequate chassis designs.

The primary set up for a chassis is to be aware of the center of gravity of the vehicle (Metz, 1998). Center of gravity must be as low as possible to the ground while central along lateral and longitudinal axes. It can affect wheel traction, braking and cornering ability. In the chassis design, the arrangement of each of the components in the vehicle needs to decide so that the optimum center of gravity can be achieved. A racing team usually use ballast for tuning their car. This is due to requirement of the tournament