APPROVAL

"I hereby verify that I have read this report and I find it sufficient in term of quality and scope to be awarded with the Bachelor Degree in Mechanical Engineering (Automotive)"

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Date : 25 NOV 2008

DESIGN AND DEVELOPMENT CHASSIS FOR THE FIRE FIGHTING VEHICLE

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This thesis report submitted to Faculty of Mechanical Engineering in partial fulfill
Of the requirement of the award of Bachelor's Degree of Mechanical Engineering
(Automotive)

Faculty of Mechanical Engineering
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

October 2008

DEDICATION

For beloved parents

Mr. Nazray b. Ishak and Rosnah bt. Ngah

and

lecturers and staff of Faculty Mechanical Engineering

all student Bachelor Degree of Mechanical Engineering (Automotive)

ACKNOWLEDGEMENT

Alhamdulillah...Thanks to Allah The Almighty because finally I have complete Projek Sarjana Muda to fulfill the requirement of Mechanical Engineering Faculty for graduation. Firstly, I would like to express my thanks to my dedicated advisor, Mr Mohd Zakaria Mohammad Nasir, for his commitment, guidance and credibility in the preparation stage of this report. His cooperation and advice help me to prepare a well-prepared report at last.

Secondly, I would like to thanks to all the Automotive Lab technician, especially Mr Syakir for his full co-operative during my session in Automotive Lab. Finally , I would like to express my gratefulness to my parent and especially to all my friend for their support and contributes the idea in accomplished this report from the beginning to the end of the process. Wassalam.

ABSTRACT

This project will study briefly to improve a new invention of remotes fire fighting vehicle which done by local company Sinar Laser & Robotic System Evertrade Sdn. Bhd. However, this project just covers the chassis component which will be improved due to weight, material and chassis structure design. There are several approach have been made to minimized the weight included the study of design and material used in chassis manufacturing with chassis torsion stiffness aspect will one of the criteria required. Finite element approach is used in the study by using FEA software which Msc. Nastran Patran software will be performed from CATIA chassis modeling to seek the stress concentration on the chassis structure for static load condition. This project also investigates how to reduce failure phenomenon on chassis structure and the Safety Factor (SF) as a benchmark for a better improvement to the chassis structure overall. With all this research, the new improvement chassis produced with all aspect has been count suitable to fire fighting operation and environment.

ABSTRAK

Projek ini akan melakukan kajian secara terperinci terhadap rekaan terbaru daripada sebuah syarikat tempatan iaitu Sinar Laser & Robotic System Evertrade Sdn. Bhd. Walaubagaimanapun projek ini hanya akan merangkumi kajian terhadap komponen casis di mana penambahbakan akan dilakukan dari segi berat, bahan yang digunakan dan juga rekaan struktur casis. Terdapat beberapa pendekatan yang telah digunakan untuk meminimumkan berat termasuk kajian terhadap rekaan dan bahan yang digunakan untuk penghasilan casis dengan aspek daya tahan kilasan menjadi salah satu criteria yang perlu. Pendekatan elemen unsure terhingga digunakan di dalam kajian ini menggunakan program analisis elemen terhingga (FEA) iaitu program Msc Nastran Patran akan dijalankan daripada model casis daripada program CATIA untuk melihat tumpuan tekanan pada struktur casis dalam keadaan bebanan statik. Projek ini juga akan menyiasat kaedah yang sesuai untuk mengurangkan fenomena kegagalan terhadap struktur casis dan Faktor Keselamatan (SF) sebagai pananda aras untuk menghasilkan penambaikan yang lebih baik terhadap struktur casis secara kesuluruhannya. Dengan segala kajian ini, casis yang lebih baik akan dihasilkan dengan segala aspek diambil kira bersesuaian dengan keadaan semasa operasi memadam kebakaran.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Fire Fighting stands to techniques and equipment used to extinguish fires and limit the damage caused by them. Fire fighting consists of removing one or more of the three elements essential to combustion-fuel, heat, and oxygen-or of interrupting the combustion chain reaction. This day, fire fighting techniques and equipment has goes parallel with the technologies with the invention of fire fighting machine such as fire engines vehicles and fire fighting apparatus to help fire fighter to cut off the fire from propagates to a serious conditions. These are the common equipment that we can see this day used by fire fighter in their job frequently.

With the technology today, a new invention has been done to help the fire fighter do their job more efficiently and in better safety condition. The machine what we call a "robots" can replace human to accomplished the task given to do the fire fighting job with a guarantee safety aspect without concern about human life.

Sinar Laser & Robotic System Evertrade Sdn. Bhd are among the company to do the effort in inventing a Fire Fighting Vehicles and this vehicle are operates by remote to control the vehicle in doing the task. This fire fighting vehicles are equip with two tanks fire extinguisher and hose role pipes and move using chain tyres. The first prototype of the vehicles has been produced by this company and as usual there will be a weakness in term of design and operating systems.

Due to this, I have been assign to make an improvement on chassis for this fire fighting vehicle project. Chassis play the main role for vehicles to assured the good performance and operating of the vehicle. A good chassis can perform without any failures at any environment conditions and can stand the load given. This report will discuss briefly about frame analysis and selection started from literature review, theory, the method used till the improvement to the frame.

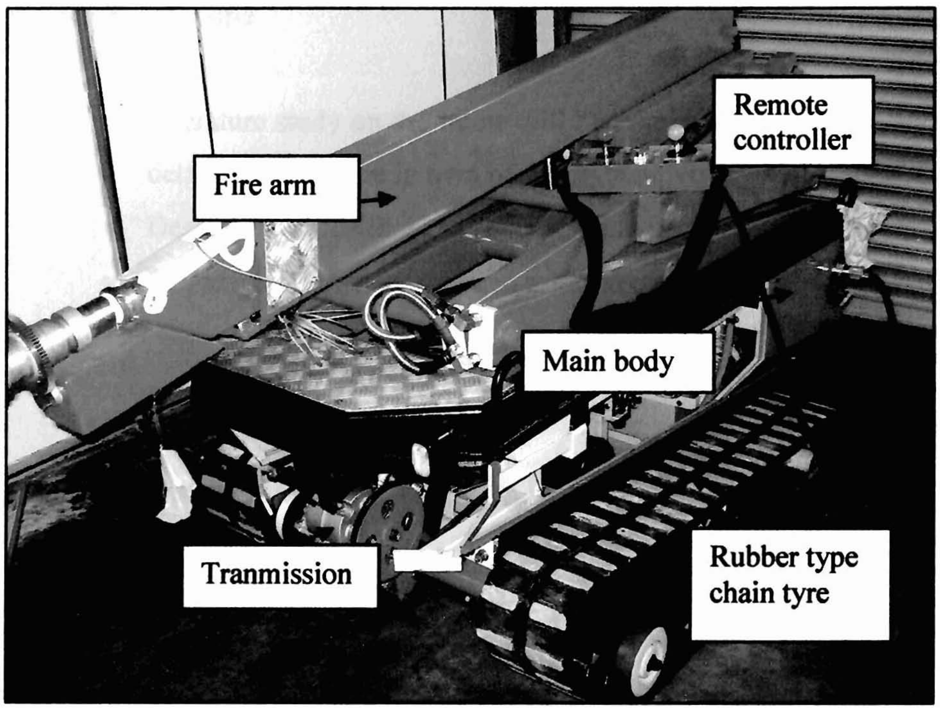

Figure 1.1: Project Fire Fighting Vehicle

1.2 Objective

The main aim of the project is to design and analysis frame structure for fire fighting vehicle.

1.3 Research scope

- Literature study on the frame will be discussed briefly to analyze the details due to frame in term of fire fighting vehicles
- Design and modelling in CATIA/ Solidworks.
- Perform an analytical study on critical components.

1.4 Problem statement

Since the failures are believed due to fatigue behaviours, an approach of fatigue failure is used. This criterion can determine the performance of the component at certain cyclic loading. The analytical or mathematical approach is used to obtain the fatigue failure and fracture mechanics criteria.

The calculated data is then entered in the computer for finite element analysis. Msc Nastran analysis is used to obtain the distribution of stress on frame design in a static load condition. Msc Nastan Patran analysis is used because it is supported with 3D part with an unlimited element and the illustration of stress distribution more clearly and stress at certain nodes can be obtained.

Before the part of failure frame design are analyses, several basic understanding in terms of methods of fabrication, materials used and design gained as the reference in performing the analysis of failure frame.

1.4 Outline of the Thesis

The thesis subdivided into three main chapters. Chapter 1 is only covers a brief on fire fighting vehicles and highlight on frame design and problem statement. Since the main item is frame, chapter 2 covers the history, types of chassis, theory of failure and the material used for frame design of fire fighting vehicles. Chapter 3 covers the methodology used in emphasizes the failure of frame and Finite Element Analysis (FEA) theory and methods. Chapter 4 consist the result of analysis and the discussion of chassis frame. Finally, Chapter 5 is the summary of the thesis where the modification and the improvement details were made.

CHAPTER 2

LITERATURE REVIEW

2.1 Fire Fighting History

The history of portable fire fighting apparatus is an interesting panorama of mechanical progress. It has been a long step mechanically, as well as in terms of years, from the earthen buckets to the modern pumping engine. Ancient efforts at fire extinction were confined to the use of earthen, metal or leather buckets for carrying water and throwing it on the fire. The first mechanical device for fire extinction was a syringe. In England in the sixteenth century it was known as a "hand squirt." These "squirts" were of very limited effectiveness for their capacity was only about two to four quarts of water, and usually three men were required to operate them -- two to hold the cylinder and one to work the plunger. Other people were of course needed to carry the water.

Sometime about the middle of the sixteenth century a "fire engine" was built, consisting of a giant syringe having a capacity of perhaps a barrel of water, mounted on a two-wheeled carriage. The plunger, or piston, was controlled by turning a crank attached to a threaded plunger-rod. Water was poured from buckets into the syringe through a funnel near its mouth.

Then came the "pump engine" - a plunger pump set in a large tub of water.

Two men operated the pump handle and another directed the jet of water. In order to transport this "engine" it was mounted on a sled and dragged by ropes to the fire.

This machine was more effective than the "hand squirts" because of its greater capacity, but its effectiveness was impaired because of the interrupted action of the jet. Water was projected in spurts, ceasing with the completion of the piston stoke. As a consequence, considerable water was wasted in falling between the engine and the fire. That disadvantage was greatly overcome later by connecting two such pumps to one discharge pipe, and operating the pumps alternately. But even this machine had its limitation, and much reliance was still placed on buckets and "hand squirts.In the course of time there was developed the "man-power" pumping engine with the rocking handle operated by two or more men, and mounted on a four-wheeled carriage drawn by men. This type of engine, which was improved upon from time to time, was used a great many years. A few pieces of this type are still in existence.

The next mechanical device of importance for use in fire extinction was the steam pumping engine, drawn by horses. Its advent marked considerable progress in fire fighting equipment and though the first of such engines was crude, yet the idea was developed to a point where the "steamer" possessed a high degree of efficiency. For years it served very capably in fire extinction.

The idea of using the gasoline engine to both transport fire apparatus and to furnish power for the pump was approached from two directions; one, from the use of the gasoline engine as a transporting power only and the other from its being used only to drive the pump. About 1908 a pumping engine consisting of a piston pump driven by a four-cylinder gasoline engine was built. This was mounted on a vehicle drawn by horses. This "pioneer" apparatus proved the practicability of using the gasoline engine for furnishing power for a fire department pump.

To adapt the gasoline engine to performing the double duty of transporting the apparatus and of driving the pump was soon accomplished. From that time, eventual motorization of fire departments was a certainty. It was then a matter of improving upon the principle whose inherent practicability had been demonstrated. Efforts at increasing the efficiency of the early motorized pumping engines included a study of the various types of pumps in order to ascertain which one of the three types could best be adapted to use with the gasoline engine. The three types were: the piston pump, the rotary gear pump, and the centrifugal pump.

2.2 Chassis & Frame

Vehicle chassis is the most important thing in construct a vehicle, without chassis a vehicle cannot be produce. The chassis is the framework of any type of vehicle. The suspension, steering and drive train components are mounted to the chassis. The chassis should have the ability to support the suspension components, besides that it should be strong and rigid platform.

Normally people will confuse between the chassis and frame. Chassis is a based or main structure of vehicle and frame is the sub-structure from the chassis. Vehicle chassis designs include frame, unit body, and space frame construction. A full-frame vehicle is often stronger and quieter, and also permits the towing of heavier loads. Units-body and space frame construction is often lighter than more fuel efficient.

Different basic chassis designs each have their own strengths and weaknesses. Every chassis is a compromise between weight, component size, complexity, vehicle intent, and ultimate cost. And even within a basic design method, strength and stiffness can vary significantly, depending on the details. There is no such thing as the ultimate method of construction for every vehicle, because each vehicle presents a different set of problems. For this case (fire fighting vehicle), a few aspect will be consider to structure the chassis because there are big different between car and this fire fighting vehicle in their chassis design. Any good chassis must have :

- Be structurally sound in every way over the expected life of the vehicle and beyond. This means nothing will ever break under normal conditions.
- Maintain the suspension mounting locations so that handling is safe and consistent under high cornering and bump loads.
- Support the body panels and other passenger components so that everything feels solid and has a long, reliable life.
- Protect the occupants/equipment from external intrusion.

2.3 The Important of Frame

Frame normally is the rectangular, usually steel frame, supported on springs and attached to the axles, that holds the body and motor of an automotive vehicle. The frame is important to hold the structure of vehicle from any force. Normally, the frame design for vehicle depends of their uses. For fire fighting vehicles, their frame size is not too big and lighter than passenger car or any other vehicles. It's because the fire fighting vehicle not carry too much load and it operation require work in narrow condition in case of real situation. In safety issue, the requirement of frame is to protect the equipment and operating kit system of the vehicle itself.

In the real world, few chassis designs will not meet the criteria of structural sound. Major structural failures, even in kit cars are rare. Most kit designers, even if they're not engineers, will overbuild naturally. The penalties for being wrong here are too great. The trouble is, some think that having a "strong" (no structural failures) chassis is enough. Structural stiffness is the main criteria of chassis component. It defines how a vehicle handles, body integrity, and the overall feel of the vehicle. Chassis stiffness is what separates a great vehicle to moving from what is merely. Some think an aluminum chassis is the path to the lightest design, but this is not necessarily true. Aluminum is more flexible than steel. In fact, the ratio of stiffness to weight is almost identical to steel, so an aluminum chassis must weigh the same as a steel one to achieve the same stiffness. Aluminum has an advantage only where there may be very thin sections where buckling is possible but that's not generally the case with tubing only very thin sheet. For this project, we will only discuss on ladder frame and space frame due to suitable purpose of operation- fire fighting vehicle.

2.3.1 Types of Frame

Usually frame construction consists of the shape steel beam welded and fastened together. The welded must be strong to ensure that the frame is in the good condition to use and suitable to the vehicle. For common vehicle such as SUV, the frame must be stronger than coupe or sedan vehicle, it because SUV' loads is more heavy than coupe or sedan vehicle. Most trucks and larger rear-wheel-drive cars use the full frame. There are many terms used to label or describes the frame of a vehicle such as ladder frame, perimeter frame, and sub-type frame.

2.3.1.1 Ladder Frame

This is the earliest kind of chassis. From the earliest cars until the early 60s, nearly all cars in the world used it as standard. Even in today, most huge vehicles still utilize it. Its construction, indicated by its name, looks like a ladder - two longitudinal rails interconnected by several lateral and cross braces. The longitude members are the main stress member. They deal with the load and also the longitudinal forces caused by acceleration and braking. The lateral and cross members provide resistance to lateral forces and further increase torsional rigidity. Most pickup trucks are constructed with a ladder-type frame it is strong and suitable with truck and rear-wheel-drive. This type of ladder is a common name for a type of perimeter frame where the transverse (lateral) connecting members are straight across. When viewed with the body removed, the frame resembles a ladder.

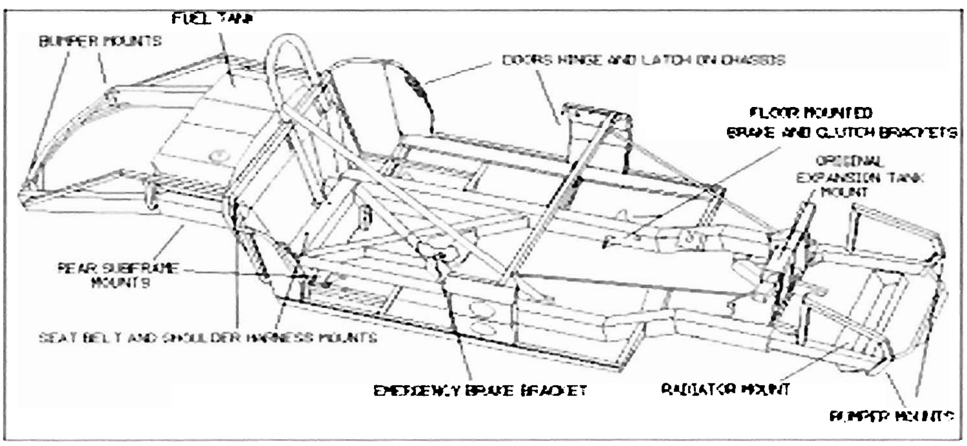

Figure 2.1 : Example of ladder chassis

2.3.1.2 Tubular Space Frame

As ladder chassis is not strong enough, motor racing engineers developed a 3 dimensional design - Tubular space frame. Tubular space frame chassis employs dozens of circular-section tubes (some may use square-section tubes for easier connection to the body panels, though circular section provides the maximum strength), position in different directions to provide mechanical strength against forces from anywhere. These tubes are welded together and form a very complex structure, as you can see in the pictures below.

For higher strength required by high performance sports cars, tubular space frame chassis usually incorporate a strong structure under both doors (see the picture of Lamborghini Countach), hence result in unusually high door sill and difficult access to the cabin.

In the early 50s, Mercedes-Benz created a racing car 300SLR using tubular space frame. This also brought the world the first tubular space frame road car, 300SL Gullwing. Since the sill dramatically reduced the accessibility of carbin, Mercedes had to extend the doors to the roof so that created the "Gullwings". Since the mid 60s, many high-end sports cars also adopted tubular space frame to enhance the rigidity / weight ratio. However, many of them actually used space frames for the front and rear structure and made the cabin out of monocoque to cut cost.

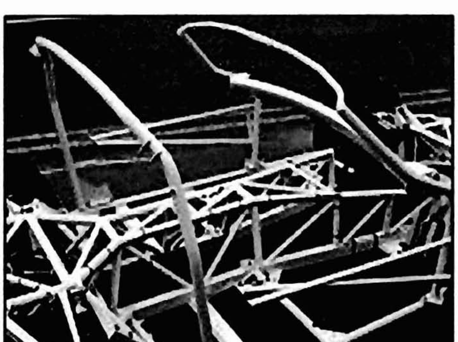

Figure 2.2 : TVR Tuscan

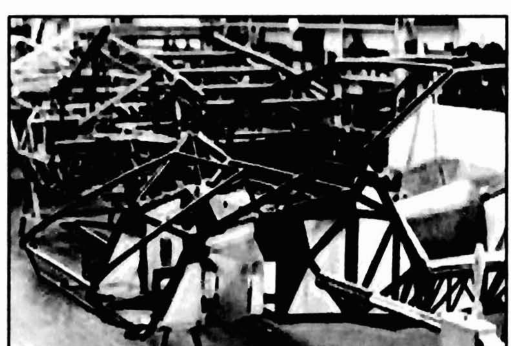

Figure 2.3: Lamborghini Countach

2.3.1.3 General Results for Space Frames and Ladder Frames

The basic way of assessing a chassis design is to establish its torsional stiffness. A high stiffness usually indicates a good chassis design. The advantage of a properly designed space frame is probably about five percent or less, in weight and stiffness for the complete car, over an equally well designed simple X braced ladder frame. A more complex space frame with fully triangulated front and rear suspension regions, engine bay and sill structures will give a bigger advantage but will be harder and more expensive to make. This difference is important for race cars especially when the skills to produce a good design are available. However for most road cars and some race cars a ladder frame would be perfectly adequate. If a space frame chassis does not have enough bracing in the correct places in the form of diagonals or welded in panels then the stiffness advantage is reduced. This is why many space frame chassis are not as good as ladder frame chassis of the same weight.

Space frames have an additional advantage in both weight and complexity where the chassis panelling forms a significant portion of the bodywork as on many Seven type cars. This maximises the advantages of a space frame by removing the need for the extra weight and complication of additional bodywork and the extra structures needed to support it.

The most common mistakes for space frames are absence of sufficient triangulation or panelling around the front suspension region and the engine bay. Poor triangulation or panelling of the rear suspension region and engine bay is common on mid engined cars. Poor triangulation or panelling of the transmission tunnel is common on front engined cars.

Ladder frames have advantages that are often overlooked. Access to mechanical parts is often better and engine intake and exhaust systems are less likely to be restricted by the need to route them around chassis tubes. The number of tubes required is less than for a space frame and welding is easier due to the thicker steel usually used for ladder frames. Additional structures are often required with ladder frames to support bodywork but these can often be designed to brace the basic chassis structure.

For a panel to be structural it should be a welded in steel panel. Panels should be stitch welded or, preferably, continuous welded by stitching twice, the second