Structural Design and Styling of Composite External Body for Hybrid Electric Vehicle

by

Haszamail Ridzeli Bin Ridzwan

Dissertation submitted in partial fulfillment of
the requirements for the
Bachelor of Engineering (Hons)
(Mechanical Engineering)

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Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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Approved by

____
(Dr. Abdul Rashid Bin Abdul Aziz)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
May 2004

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

HASZAMAIL RIDZELI BIN RIDZWAN

ABSTRACT

Basically the objectives of this project is to design and construct an aerodynamic hybrid electric vehicle and also minimizing the overall vehicle weight and body part by using other alternatives sources instead of steel.

The reason of concentrating on aerodynamic is due to the Coefficient Drag (C_D) that exerts on the vehicle body and hence by reducing the force will increase the car performance. Moreover the conventional car body is not practical to be used for hybrid vehicle thus lightweight material has to be replaced in order to maintain and increase the performance while reducing the fuel consumption.

The study involves on the existing car as the point of references by upgrading or changing the body part, which is not applicable for hybrid car. In fact feasibility study has to be done to understand the concept. The process flows is start from the design, testing and until the construction of the real car as the practical solution. The testing that may involve in this project will be the tuft testing and wind tunnel testing. Both testing are necessary to be done as it will determined the aerodynamic and wind flow that occur upon the surfaces.

ACKNOWLEDGEMENTS

Life has been great to me while doing my final year project as there are many people that stood beside me in making this project such a great and ambitious one it could be. Although it seems tough to finish and reach the point set at the initial stage but yet this project still can be accomplish within the allocated time frame. Alhamdulillah as what that has been expected is done and yet there are many things that should be considered undone has been done.

So first I want to say thanks to my family for their supportive roles in providing moral support through out the one year session and gladly it keeps me motivated. To my parent who always on my side no matter what and keep believing in me that I can do well in my project which I think I already did and I'm glad to achieve that.

Then to my respective supervisor, Dr. Abd. Rashid who always being such an understandable lecturer which always provide knowledge and helps in completing the project. His ambitious expectation gave a motivation to achieve a better design and results. Besides knowledge, nothing more than can be compared to his experience which he shares in encouraging me to become a good engineer in the future. Thank you.

Not forgetting thank you to Mr Saifuddin who's acted as the co supervisor that is willing to teach informally and guide trough the long term session. There are lots of knowledge that has been shared with and considered valuable for a future experience.

Finally, thanks again to all LG staff for all the help and knowledge and making this project such a great one and involve in this team project had gave an experience and better opportunities for me to be involve in real engineering world. Lastly not forgetting to all my friends for all the help especially my team member for the cooperation gave in ensuring the completion of the project.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

This project is on **"Structural Design and Styling of Composite External Body for Hybrid Electric Vehicle"** series hybrid electric vehicle (HEVs) that was proposed by Dr. Rashid and currently undergoing few stages before the completion session, which is on May 2004. Basically Hybrid electric vehicles (HEVs) combine the internal combustion engine of a conventional vehicle with the battery and electric motor of an electric vehicle, resulting in twice the fuel economy of conventional vehicles.

This combination offers the extended range and rapid refueling that consumers expect from a conventional vehicle, with a significant portion of the energy and environmental benefits of an electric vehicle. The practical benefits of HEVs include improved fuel economy and lower emissions compared to conventional vehicles. The inherent flexibility of HEVs will allow them to be used in a wide range of applications, from personal transportation to commercial hauling.

The main target of involving in this project is to come out with a design that has the certain requirement set in the initial stage of the project, which is an aerodynamic interchangeable body and new architectural invention. The shape of a moving vehicle causes the airflow to create force acting on the surfaces of the vehicle that is known as a drag force. Therefore, by having a streamlining body will reduce the effect of this forces acting on the surface such as the frontal area and increase of its speed performance.

1.2 PROBLEM STATEMENT

1.2.1 Problem Identification

The typical problem of a conventional car is usually due to the Drag Coefficient (C_D) that is normally from 0.3 to 0.5 that is considered high enough to cause extra fuel to powered the speed and affecting the car performance. Thus a car with a Drag Coefficient (C_D) ranging 0.1 to 0.3 has the ability to fit the requirement of being an aerodynamic. Technically by reducing the drag coefficient impose onto the surfaces of the car less power will be needed to overcome the drag force acting on its body. Thus, the car will have higher energy efficiency with low fuel consumption.

Apart from focusing on the aerodynamic, the selection material of the car's body also has to be consider too as a smooth surface and light material will help to reduce the drag coefficient and maintain the car performance such as using carbon fiber or fiberglass instead of steel which is totally have the different in weight. Thus by having lightweight material will reduced the overall vehicle weight.

Another problem is due to the energy losses. Typical internal combustion engine vehicles convert fuel energy to shaft work, which is used to overcome the tractive energy needed to drive forward. The same energy is used to operate a vehicle's accessories. A vehicle with only an internal combustion engine uses only about 16% of its energy to accelerate the vehicle. The rest becomes waste heat (from the thermodynamic cycle of the engine), is used to overcome frictional losses (such as aerodynamic drag or rolling resistance), or powers auxiliary equipment.

An HEV uses regenerative braking, composite body metals, and special aerodynamic body shapes to minimize energy losses, making as much energy available as possible to propel the vehicle.

1.2.2 Significant of the Project

This project is focusing on the designing of the structural body of the hybrid electric vehicle. The main purpose is to construct the body of the outer frame of the car by using the composite material. Thus in order to transform the idea into a one solid model, a 3D design process has to be undergone first and currently this project is still under this stage.

The reason of designing 3D model is to project the body into a software simulation which is the Star CD that will simulate the body flow of the required model by having a simulated wind tunnel trough the body. Thus it will shows that either the design body created has the characteristic of a streamlining design that will simply allow simulated air flow passes over the surfaces.

With the simulated wind tunnel testing done by the Star CD, supposedly a real practices has to be done in order to see and justify on the real situation. It is required to run a testing under a real condition which is under the wind tunnel that can really simulated the air flow that will passes over the body and thus proved that which part of body that will generated either lamina or turbulent flow.

By having this process, it is expected to come out with a real scale design body that fit the requirement and characteristic of the 3D design that has undergone all the simulation and considered approval for a real construction process.

1.3 OBJECTIVE AND SCOPE OF STUDY

1.3.1 Objectives

The main objective of this project is to design and build the hybrid electric vehicle with an aerodynamic shape. The first propriety takes place is the Drag Coefficient that is the ranging should be in between 0.1 to 0.3 as to increase the car performance while minimizing the fuel consumption.
Another objective is to have a less body part in order to minimize the overall car weight and to achieve this; a lightweight material has to be put under consideration, which is carbon fiber of fiberglass. But still it is required to maintain the practical automobile geometry.

Meanwhile, the project scopes are:

a. **Undertake literature into basics of designing a 3d model.**
b. **Understand the used of a part design and surface design.**
c. **Created a 3D design that possesses the fine streamlining body.**
d. **Test 3D model under the Star CD simulation.**
e. **Construct a small scale design body of the car.**
f. **Test the body under a tuft testing.**
g. **Test the body under a wind tunnel testing.**

1.3.2 Scope of study

The scope of this project is to do a research based on the existing car as a reference and try to come out with an idea as a solution prior to the body of the car such as the windshield or the trunk. There might be a study on the aerodynamic of the part. Apart from that research are more on the literature review on the required references book or on the website. Done with the research, a design has to be produced as a solution based on the findings throughout the required time frame allocated. Development work on the

Second last stage will be the turf testing which is one of the testing that can be run in order to see and test yet confirm either that the design body produces an aerodynamic body or not. It can be monitor upon the threads that are glued over the top surfaces of the body. The wind flow acted upon the surfaces will created either a turbulent or lamina flow and can be seen clearly.

Last stage will be the testing done under the small scale wind tunnel in order to monitor the flow of an air that passes over the surfaces. This testing is considered important as it will really simulate the air flow generated from the smoke generator and thus can proved the aerodynamic body of the model hence firm up with the result obtain through the turf testing.

CHAPTER 2

LITERATURE REVIEW AND THEORY

Hybrid power systems were conceived as a way to compensate for the shortfall in battery technology. Because batteries could supply only enough energy for short trips, an onboard generator, powered by an internal combustion engine, could be installed and used for longer trips. In the old days, we thought that by biasing the system toward battery-electric power and operating on wall-plug electricity as much as possible, efficiency and emissions would then be about as optimal as we could hope for until better batteries came along. The natural conclusion of this concept was that, with better batteries, we probably would not need hybrids at all. But after 20 years of study, it seems that hybrids are taking center stage and electric vehicles are only being used in niche market applications where fewer miles are traveled.

More efficient cars can make a big difference to society in terms of environmental benefits, and the serious deterioration of urban air has motivated regulators to require cleaner cars. Use of production HEVs will reduce smog-forming pollutants over the current national average. Hybrids will never be true zero-emission vehicles, however, because of their internal combustion engine. But the first hybrids on the market will cut emissions of global-warming pollutants by a third to a half, and later models may cut emissions by even more.

Thus the properties of the material used to construct the body has to be take under consideration while ensuring several testing that has to be done in a way of producing a high performance vehicle.

2.1 LITERATURE REVIEW

2.1.1 Composite Material

A composite material is a combination of two materials, with its own distinctive properties. Its strength or other desirable quality is better or very different from either of its components working alone. The principal attraction of composite material is that they are lighter, stiffer and stronger than most other structural materials. They were developed to meet the severe demands of supersonic flight and other application.

The idea of load bearing component or structure is made of a material that is light in weight, strong in tension and not easily corroded. It must expand very little with changes in temperature, with a high resistance to abrasion and a high softening or melting point. Materials with this property are ceramics such as glass, boron carbide, alumina, silicon carbide as well as carbon. They also have high softening or melting point and low coefficients of expansion.

Composite normally combine the potential, reinforcing strength and stiffness of glass or ceramics with the ductility of metals or polymers. The reinforcement is commonly divided into small particles or longer fibers, so that any cracks present cannot find a continuous path through the composite material. The properties of the matrix are therefore of equal and vital importance.

Firstly it must not allow fiber damage by rubbing and scratching. Secondly it must act as a medium to transmit the external forces as stresses on to the fibers. Thus there needs to be some adhesion between the matrix and the fibers usually assisted by the use of chemical coupling agents. Thirdly the matrix must deflect and control the cracks in the overall composite material.

The matrix properties of polymers such as epoxy and polyester resins and more recently thermoplastics such as nylons and those of ductile metal such as copper, aluminum and fracture the broken pieces can still carry loads and so remain useful which has 2 benefits. The benefits are:

a) Reinforced thermoplastic can be processed using conventional techniques.
b) The strongest materials can only be obtained as short single crystal filaments known as whiskers form materials such as alumina and silicon nitride.

The largest tonnage composites at present are glass fiber reinforced polyester resin materials, GRP due to the relatively low cost of these raw materials. Glass can be easily be drawn to give high strength filaments although they need a protective coating within the coupling agent system to prevent surface cracking. Unsaturated polyester resin can be cured at low temperatures and pressures. The combinations of fiber and resin can give limitless shapes, the larget6s of which are naval minesweeper hulls so that vehicle body parts present no problems of scale. Still glass fiber composite do have limitations. Whilst glass fibers are strong they are not stiff and the polyester resin degrades above 200 degree Celsius. Thus for high modulus components, carbon and boron/tungsten fibers are used with newer polymers such as epoxy resins and polyamides. These composite materials have high strength and stiffness to weight ratios, compared with steel.

2.1.2 Importance of Light weighting

Reducing mass is the highest leverage means of reducing peak power available to vehicle designers. During steady state driving which is most of the time vehicles required only a small fraction of their maximum power output to sustain their speed. Peak power is needed during hard acceleration and in other high load driving conditions. The power required to achieve a given level of acceleration is determined to the first order by the vehicle's rate of change of kinetic energy:

$$P_{acc} = m/2\,[(v^2_1 - v^2_0)/t]$$

Where m= mass of the vehicle and its occupant, v_1 is the final velocity, v_0 is the starting velocity, and t is the time elapsed to reach the final velocity. It is clear from this equation

Plasticity is the ability of a material to be changed permanently in shape by external forces or blows without cracking or breaking. Some materials are more plastic when heated. Two subsidiary terms are:

a) Malleability
b) Ductility

Malleability refers to the extent to which a material can undergo permanent deformation in all directions under compression by pressing or rolling without rupture or cracking as in forging or sheet manufacture. Malleability increases with temperature.
Ductility on the other hand is the ability to undergo cold plastic deformation in bending, torsion or tension. It contrasts to malleability it decreases with temperatures.

Hardness is a complex property. It is the ability of a material to resist both abrasive wear and indention. It is important quality in bearing materials as well as for drills and other machine tools. Toughness is a term usually used to denote the ability of a material to withstand sudden shocks or blows without fracture. In contrast to toughness is the property of brittleness which is a tendency to show a little or no strain or plastic deformation before fracture.

Dimensional stability is the resistance to changes in size and shape. Plastics at room temperature and metals at high temperature also gradually deform with time and may eventually fail, when subjected to a steady or constant force for long periods. This gradual deformation at constant load is known as creep. Creep resistant material must therefore be used when high loads are applied for long times at high temperatures. Fatigue failure is caused by repeated or reversed stress cycles in any of the above stressing modes usually at stress levels which would not have caused failure under static conditions. Fatigue failure may be accelerated by corrosion, higher temperatures and poor surface finish.

2.2 THEORY

2.2.1 Tuft Testing

Basically tuft testing is the process whereby the body of the desired model is attached to the numbers of threads and it is glued all over the top body. The main purpose of having these threads is to monitor the effect of wind flow that acted upon the surfaces. And by that the type of wind flow can be determined which is:

a) Turbulent flow
b) Lamina flow

Turbulent flow will indicate that there are high speed flow of wind occur at certain point of the body while lamina flow is referring to the low speed flow that happen to be at the body surfaces.

Figure 2.1: Prepare Model for a Tuft Testing

Based on the picture it shows how does threads are glued over the body. The line of the threads has to be constant in a way that easier to monitor the effect when acting with the wind flow. Thus the shape of the body can be determined either it is aerodynamic or not. Tuft testing will help to visualize more on the effect of the wind flow.

The diagram below shows how does tuft testing result can be obtained when testing has been done. The arrows symbolize the wind flow represented by the threads and there are normally two colors used to represent this flow which is red and blue. The red color shows the turbulent effect while the blue color indicates that the body has a streamlining body because laminar flow occurs at that point. At certain point different flow is needed as to ensure the speed of a car performance.

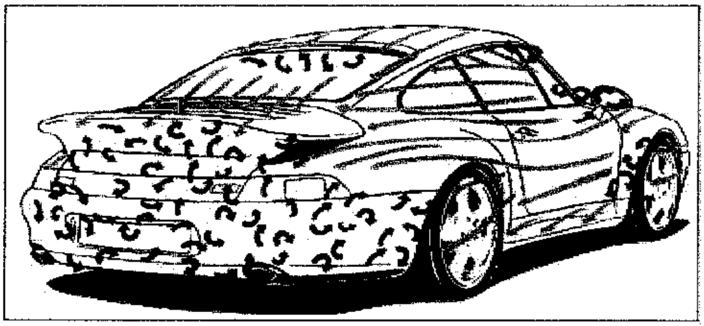


Figure 2.2: Effect of the Tuft Testing

2.2.2 Wind Tunnel Testing

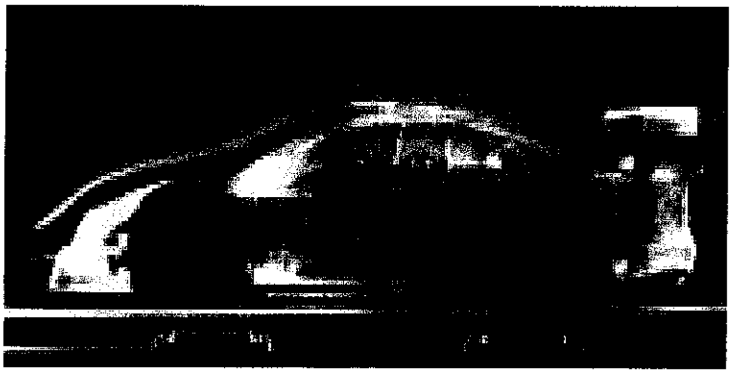


Figure 2.3: Effect of Wind Tunnel Testing

Wind tunnel testing is recommended when the model or the real car has to be checked concerning the aerodynamic purpose. The wind tunnel has its own equipment to generate the simulation of a real wind flow that it will release a smoke that will be acted as the real main source which is the wind and then the fan will derive the smoke to flow over the surface of the model. It results for an optimized simulation of a real environment when the car being release on the road. From here it will give more visualization on the effect of the wind flow that is referring to the turbulent or laminar flow.

Properly conducted wind tunnel tests provide a tailored assessment of wind effects by accurately modeling both the prototype and its immediate surroundings to produce realistic simulation of the local wind conditions. In some situation this is the only way that a model can have an assured design and environmental performance and that economy of design may be realized.

CHAPTER 3

METHODOLOGY

In order to proceed with the project, a clear and concise methodology is important to ensure that the flow of the project would be smooth and organized. There are few steps taken to ensure that the design and testing done will be handled successfully for the time period being. Below is the flow chart of the project report methodology.

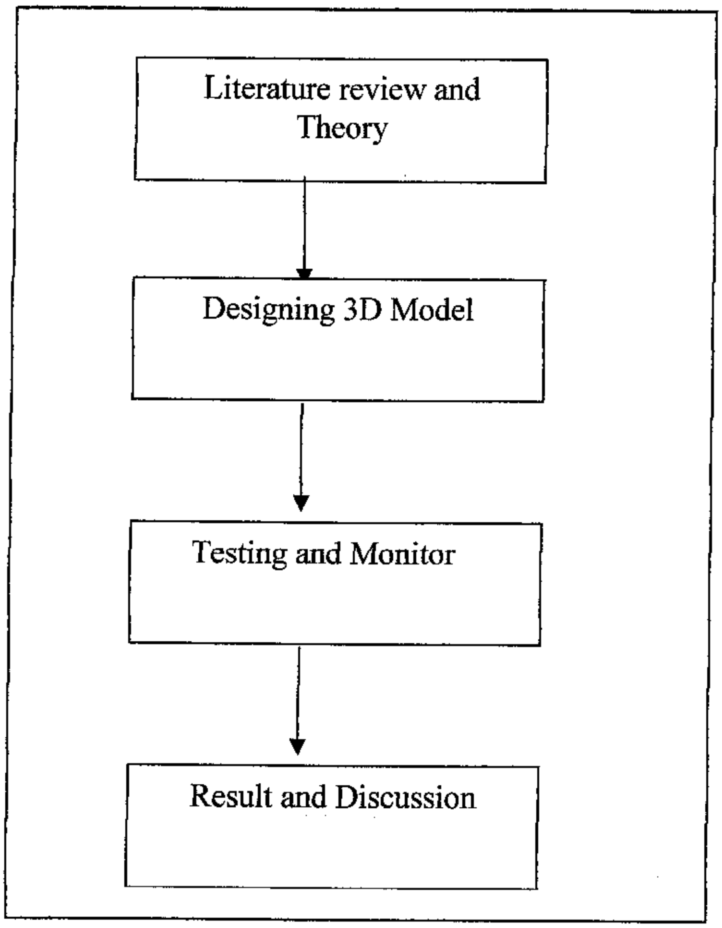


Figure 3.1: Flowchart of project methodology

For a more thorough detail of the project methodology see diagram on the next page.

In order to understand the project, literature review is important in undermining the objectives of the project. This is because, from literature review, the whole concept of the project will be explained and thoroughly understood. Hence, from the reference guide such as books, journals and websites; lots of information can be gathered.

For this project, the most important things is to design the 3D model and also the small scale model of the car as it will be the main source of the project. These two models are needed to run under the simulation and also the required testing as to monitor the results of an aerodynamic body.

Apart from that, the focusing on the literature review are also on the CATIA surface design technique which can create more fine surfaces compare to the part design that somehow can lead to an error when it comes to a complicated shape of the body. Thus it is really required to get used with the technique as it will provide better alternatives when dealing with a body that has complicated geometry surfaces.

Finally, through the testing done, the results of the project can be seen clearly and easier to come out with a firm prove that the design either possess an aerodynamic body or not. And with that a comparison can be made between two designs which is the body that has a rough surfaces and a body with a fine surfaces. Different body will produces a different results of testing and it will helps to generate a justification perspective which model will produce a turbulent or lamina at certain part of the body.

3.1 PROJECT FLOW CHART

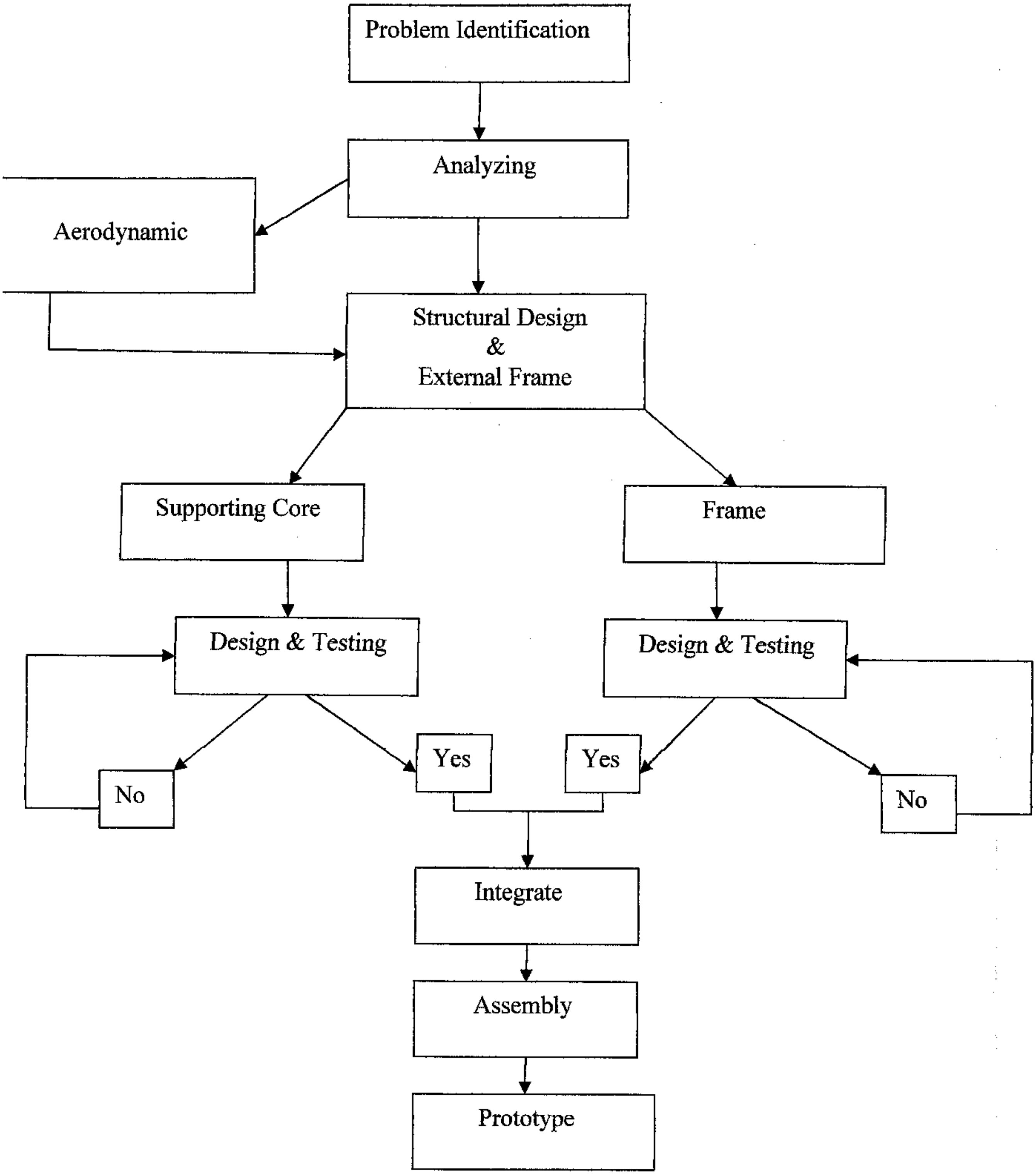


Figure 3.2: Project Flow Chart

The flow chart shows the procedure that will be taken throughout the entire project and apart from the gant chart done in the first place is also considered as the guideline and what step should be taken after that. The flow chart is more emphasizing on the structural and external frame, as other team will do the aerodynamic part. But in the end the both design will be assembled together in order to produce the prototype.

3.2 MODELLING PARAMETERS

Basically in order to come out with a 3D model, certain requirement are needed which is the basic dimension of the car itself. For this model, the reference car is Proton Wira and the basic dimension is as follows:

Wheel base	= 2500 mm
Overall height	= 1385mm
Ground clearance	= 150mm

For other constraint, it is based on the discussion among the team to come out with a solid model which is still under the discussion session.

Instead on Proton Wira model another model was choose as the point of reference which is the Cadillac model. So basically, some other parameters also taken to see whether the model constraint can be satisfied. For the model the ratios taken was 1:10 from the original size of Cadillac and thus the parameters are:

Wheel base	= 250mm
Overall height	= 138.5mm
Ground clearance	= 10mm
Width	= 87.5mm (half plane)

There is some of the alteration done in ensuring that the model fit the agreed parameter which is the sporty car.

3.2.1 Views from different angle

The 3D model was done by using CATIA software and requires two techniques to construct the model in order of having fine surfaces.

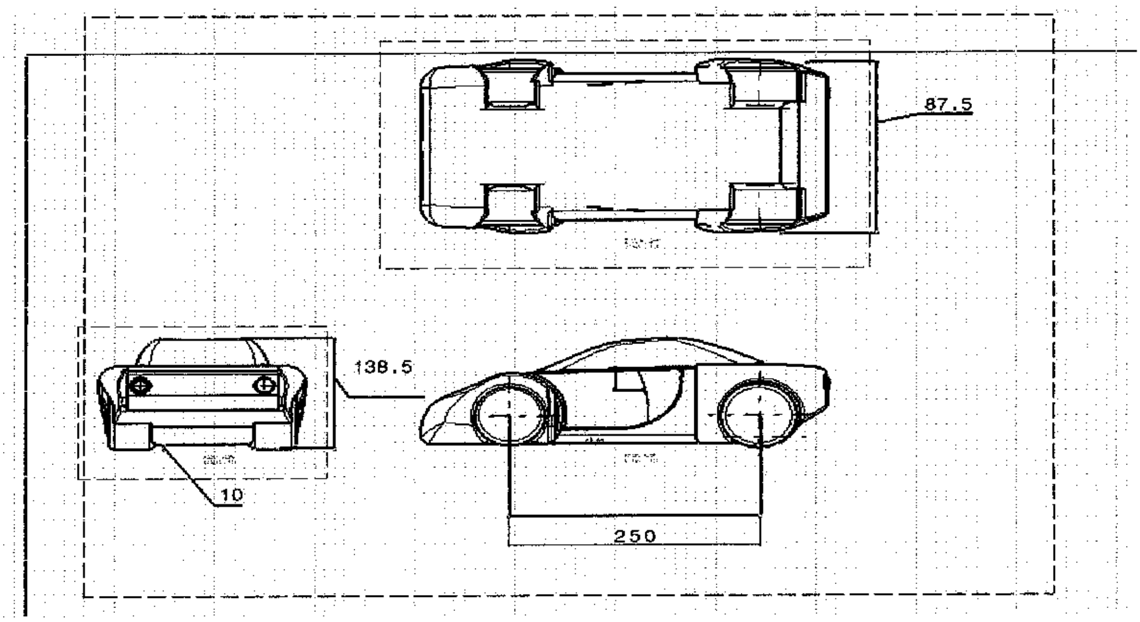


Figure 3.3: Model Scale Parameters (Previous Version)

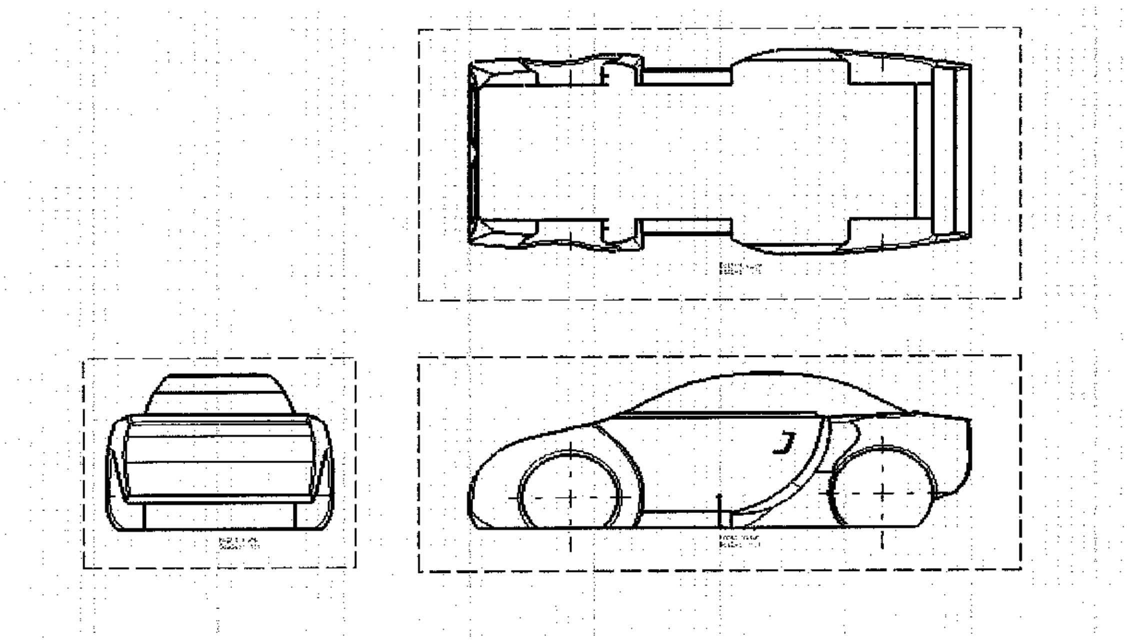


Figure 3.4: Model Scale Parameters (Update Version)

3.2.2 CATIA Part Design Interface (3D Model)

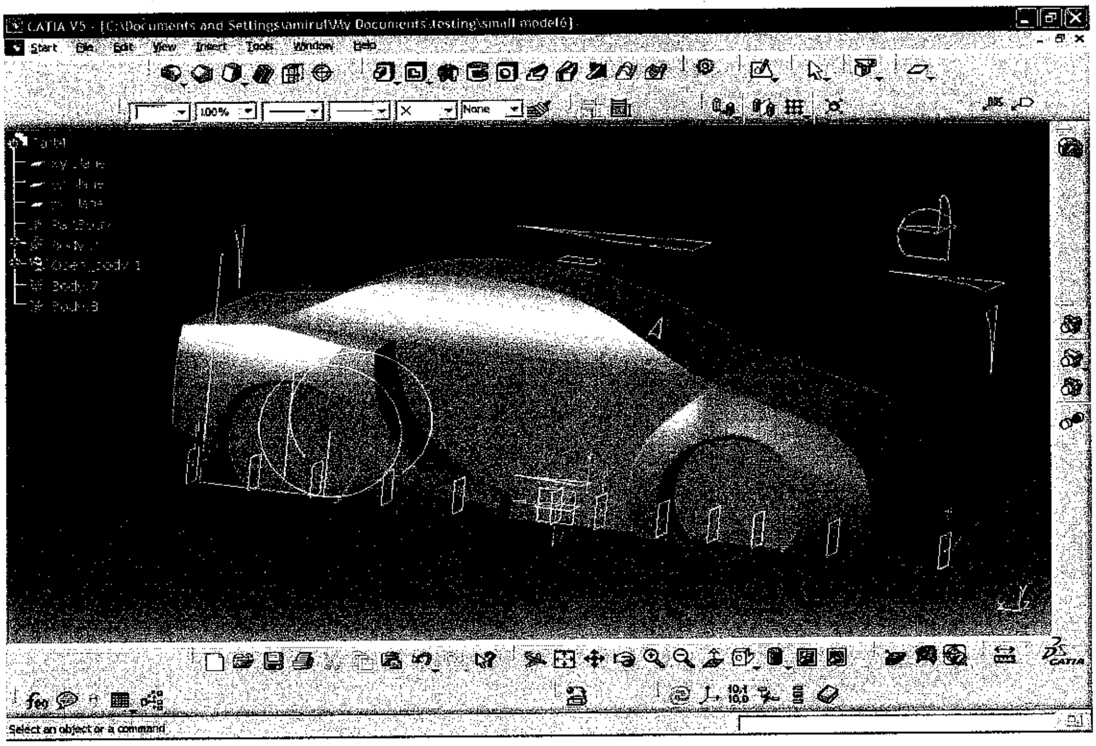


Figure 3.5: CATIA Interface

3.3 PROCEDURE OF CONSTRUCTING 3D MODEL

Based on the drawing below it shows the method of getting the model into the desired shape. Basically there are 5 major steps taken in order to come out with the design model neglecting the small parameters taken.

The procedures are:

a) Sketch in 2D drawing
b) Removed and adding profile
c) Loafing features
d) Creating tyre profile
e) Adding tyre
f) Adding rear light
g) Creating a fine smooth model and extra features
h) Creating mirror image
i) 3D Wire Frame

1) Sketch on 2D drawing

The desired shape was drawn in the 2D mode using CATIA and during the sketching part, the outline parameters should be considered. Then the profile was extrude to become the 3D shape.

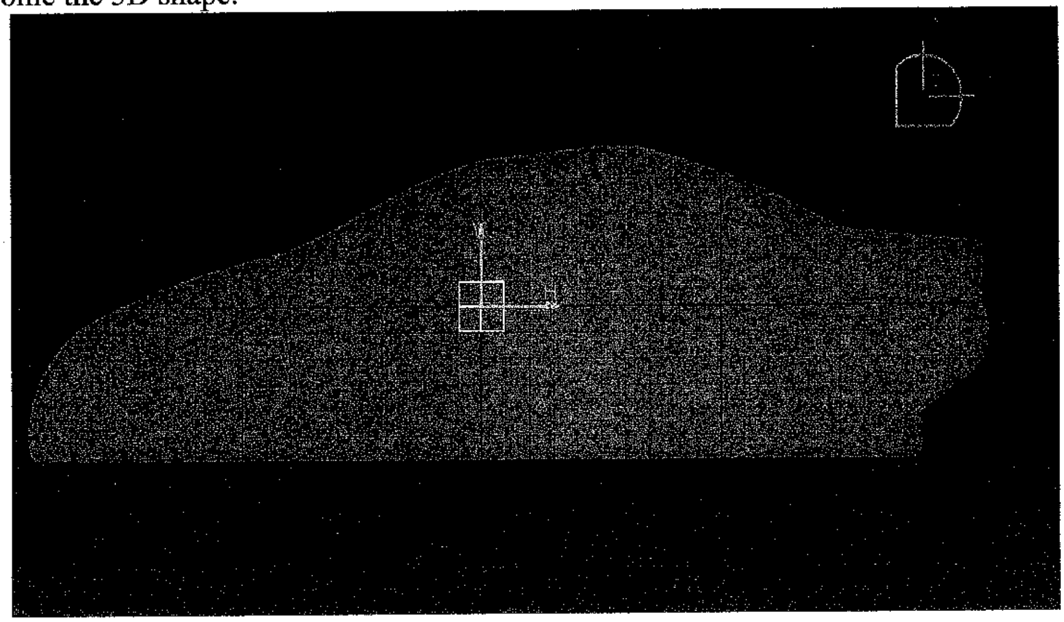


Figure 3.6: Model 2D Drawing

2) Removed and adding profile.

At this part, the model was ready to be turned into the desired shape. The features need was the pad features, pockets features and removed features. The upper part was done by using removed features.

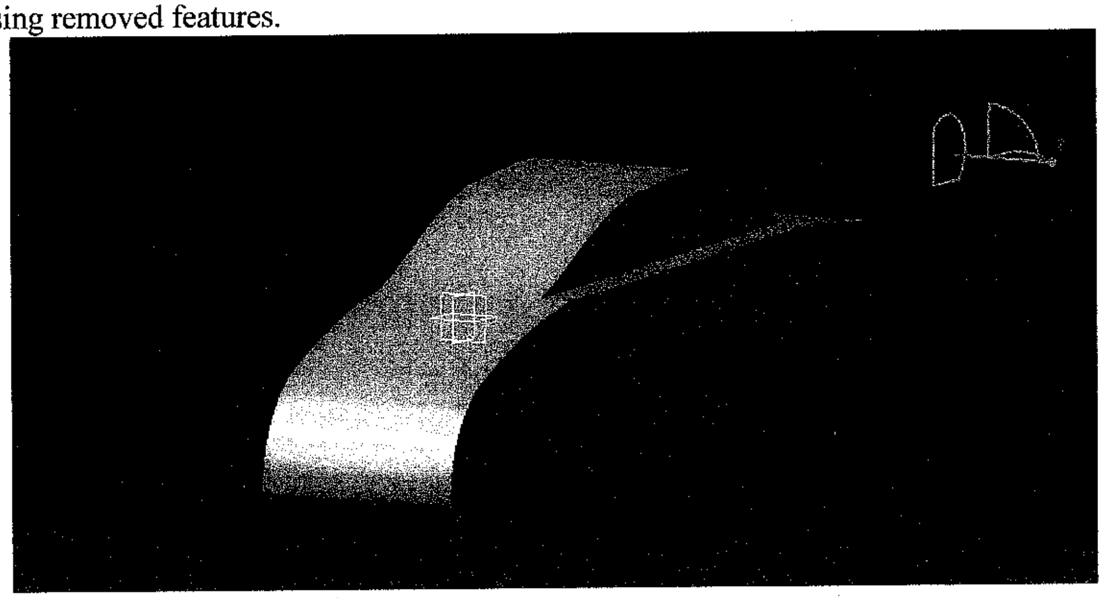


Figure 3.7: Adding Profile onto the Surface

3) Loafing features

By using the loafing features, the rear and front profile can be created and by additional trimming and filleting the desired model can be obtained as below. But before constructing loaf several panes were required as a basis of the generated solid.

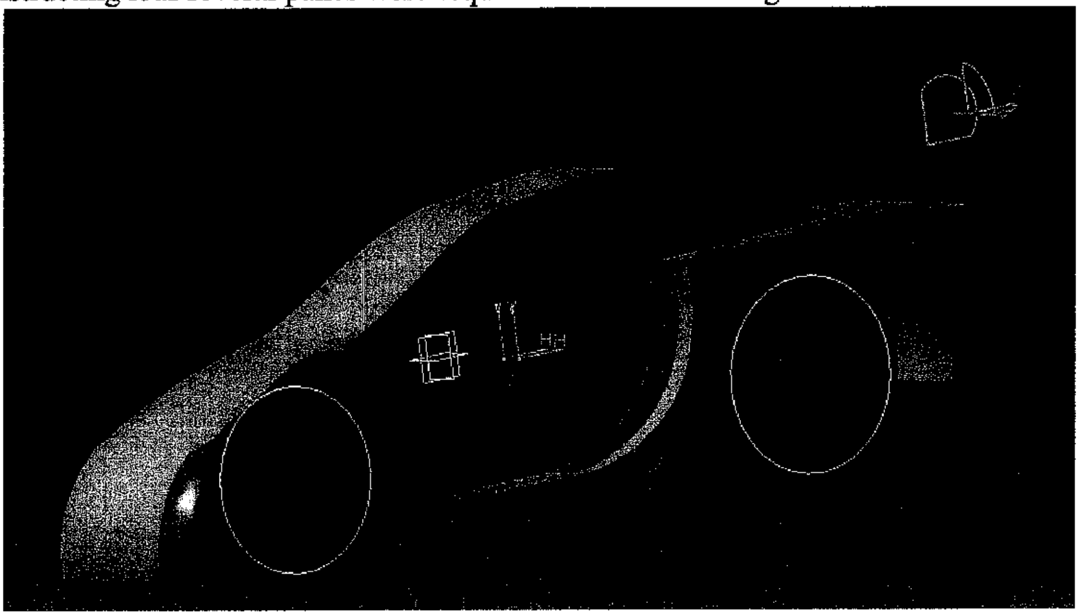


Figure 3.8: Loafing Features

4) Creating tyre profile

Tyre profile was created on the generated loafing solid whereby a required dimension was needed to construct this feature. By having the profile easily it can be generated using the pocket features.

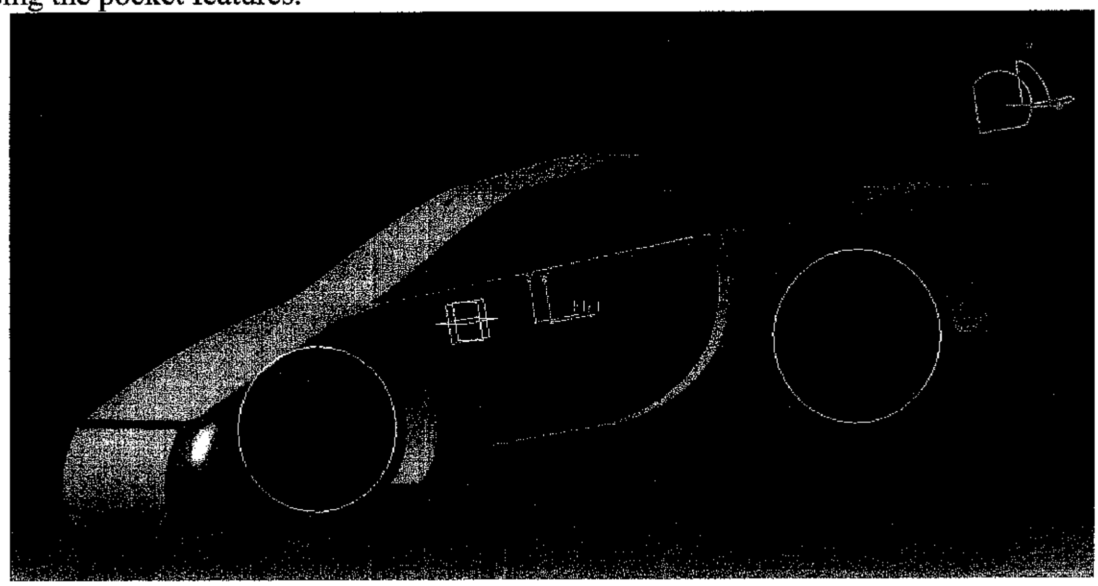


Figure 3.9: Creating Tyre Profile

5) Adding tyre

Based on the drawing done previously, 3D tyre can be generated using the pad profile and fillet features was required to create a round up image of the solid.

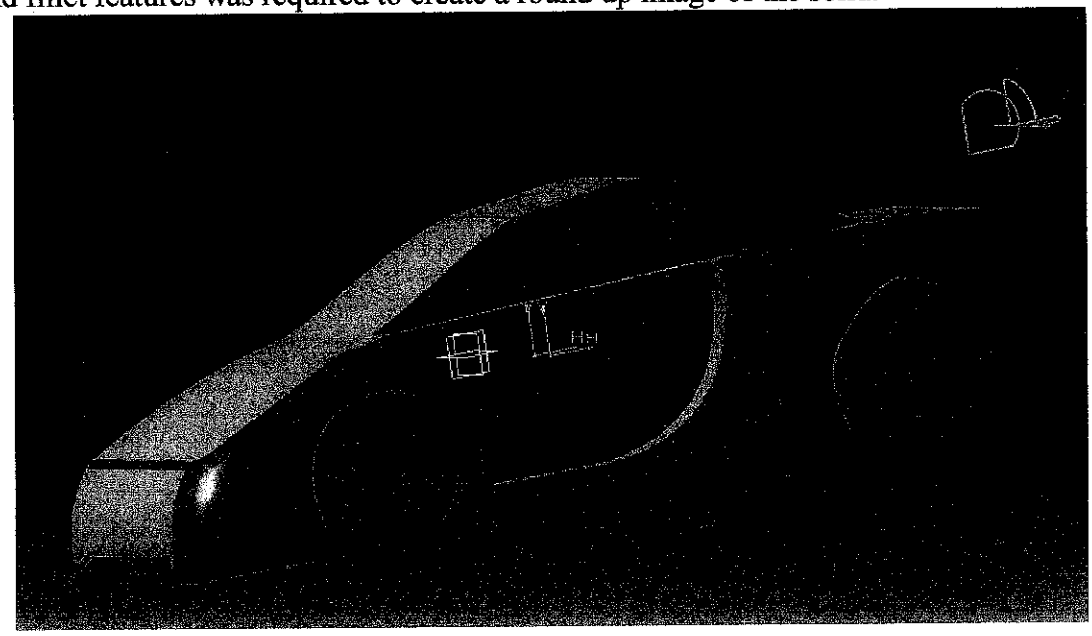


Figure 3.10: Adding Tyre to the Model

6) Creating a rear light

This process needs a pick point features whereby at this plane there are no flat surfaces thus this features were required as a basis for the 3D axis. By having this featured generated pad and pockets can be made.

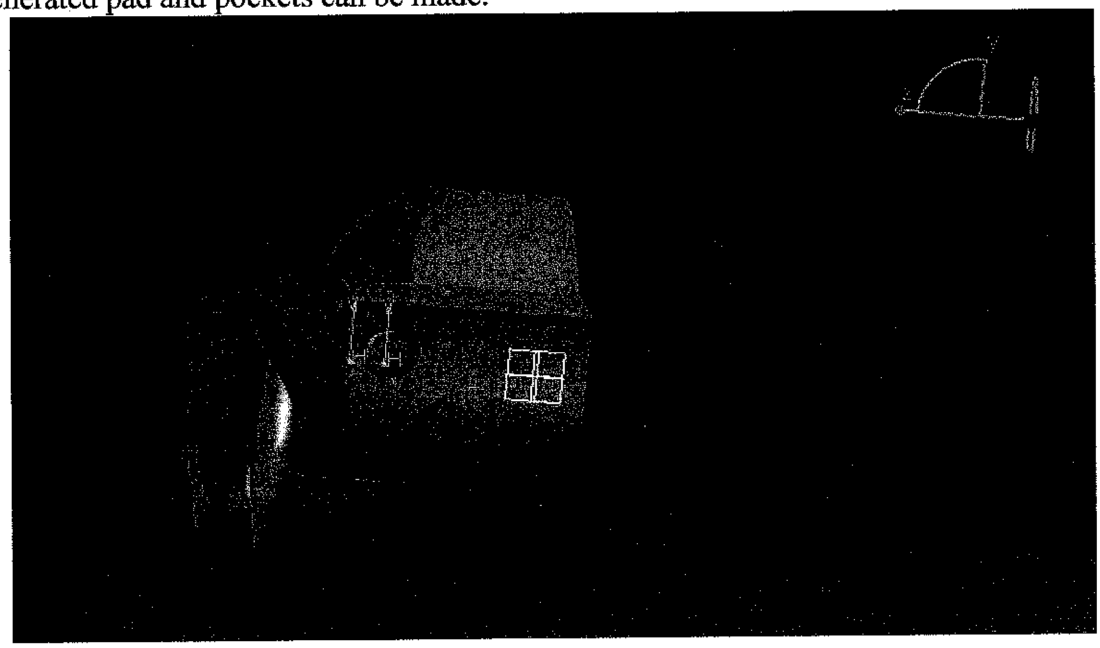


Figure 3.11: Creating Rear Light s

7) Creating a fine smooth model and extra features.

And after done with that, fillet and chamfer features were used in making the shape becoming smooth without having any of curvy edge at the body. This step consider as the finishing of the part.

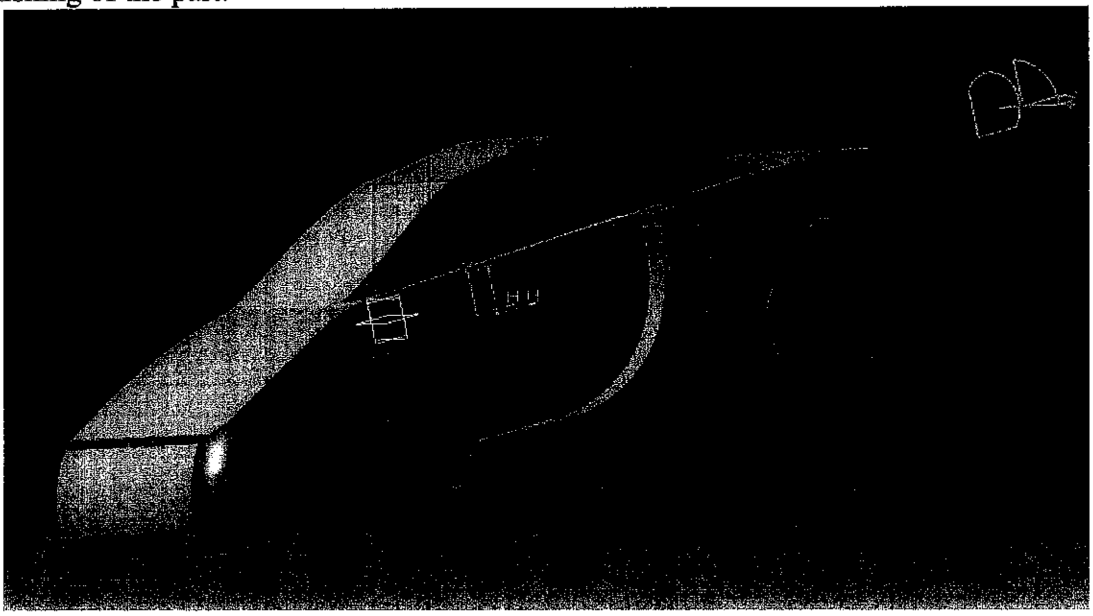


Figure 3.12: Creating a Smooth Features

8) Creating a mirror image.

By using the mirror features, the one side model was mirrored to the other side at the symmetrical line which is at the centre of the model.

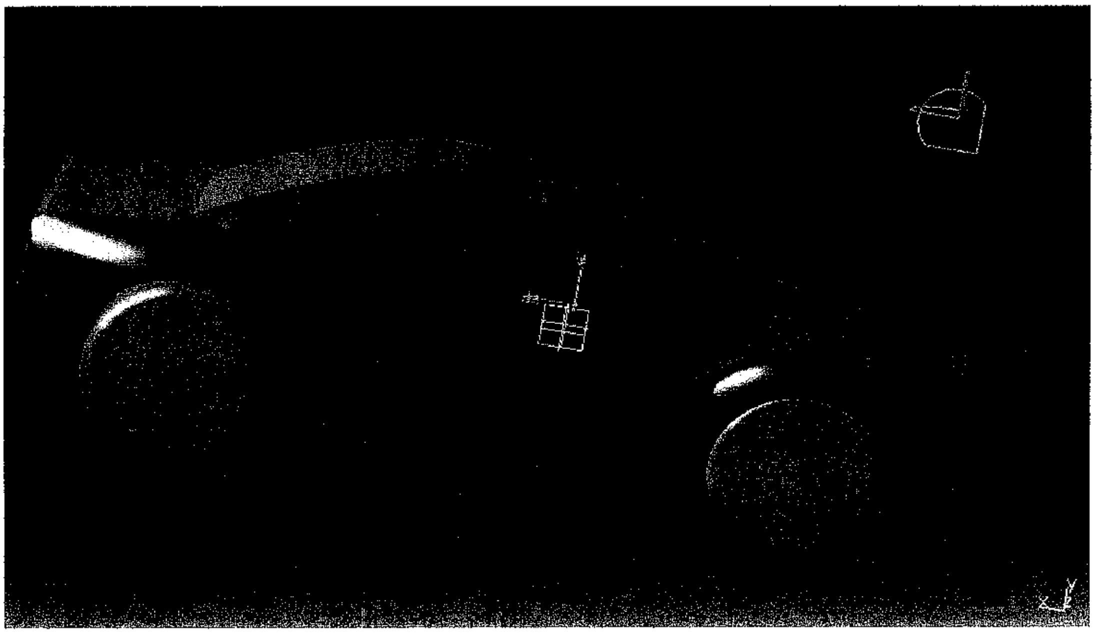


Figure 3.13: Mirror the Half 3D Image

3.3.1 Updated Design Model

Previously the model produce was still under construction and had lots of errors when undergoing the simulation done by the Star CD and by that improvement had been made at the body design of the vehicle as to ensure less error and possess streamlining surfaces that will fit the requirement set at the initial stage. Thus a new design has been made that has more streamlining body and also possesses an aerodynamic shape.

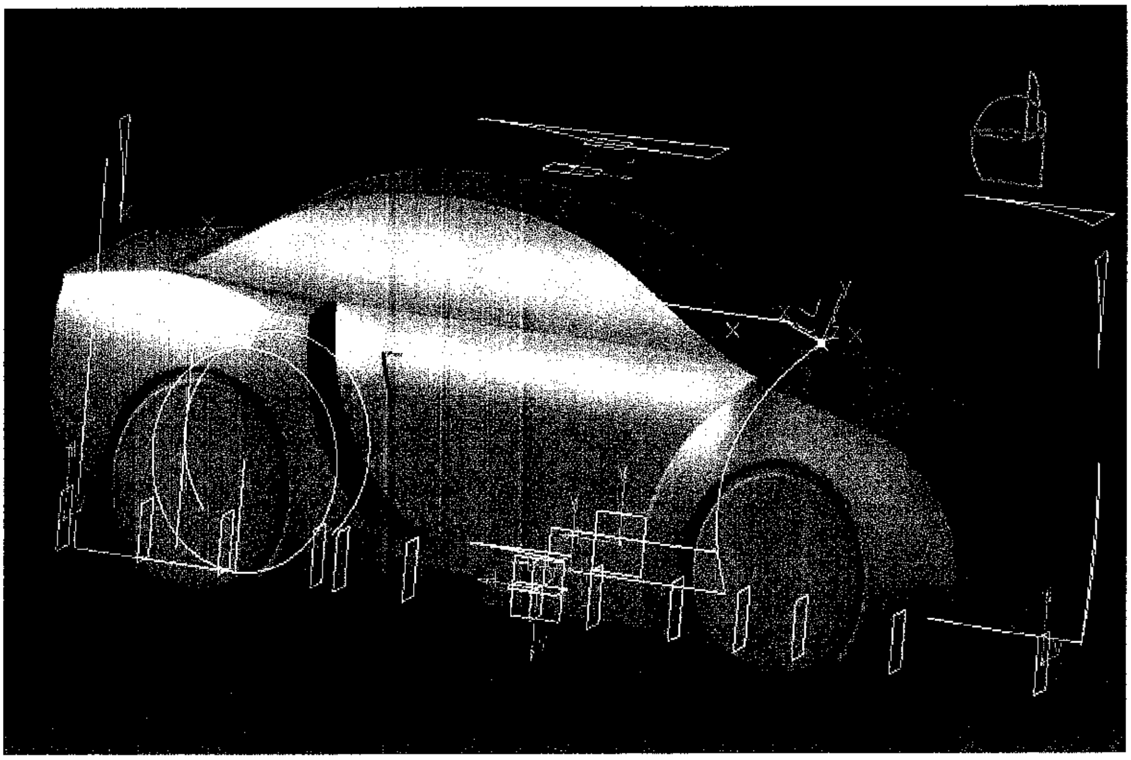


Figure 3.14: Updated Design Model

Based on the design it definitely shows an improvement in terms of body styling that has a better aerodynamic requirement compare to the previous 3D model. Reshaping process does involve all over the body surfaces which is it has to start back from the 2D drawing and after extrusion process than the body can be remodify starts from the trunk, fender, side and also rear body of the car. More body connection is needed for the loafing process to overlap onto the surfaces in a way to get the fine body surfaces.

3.3.2 3D Wire frame

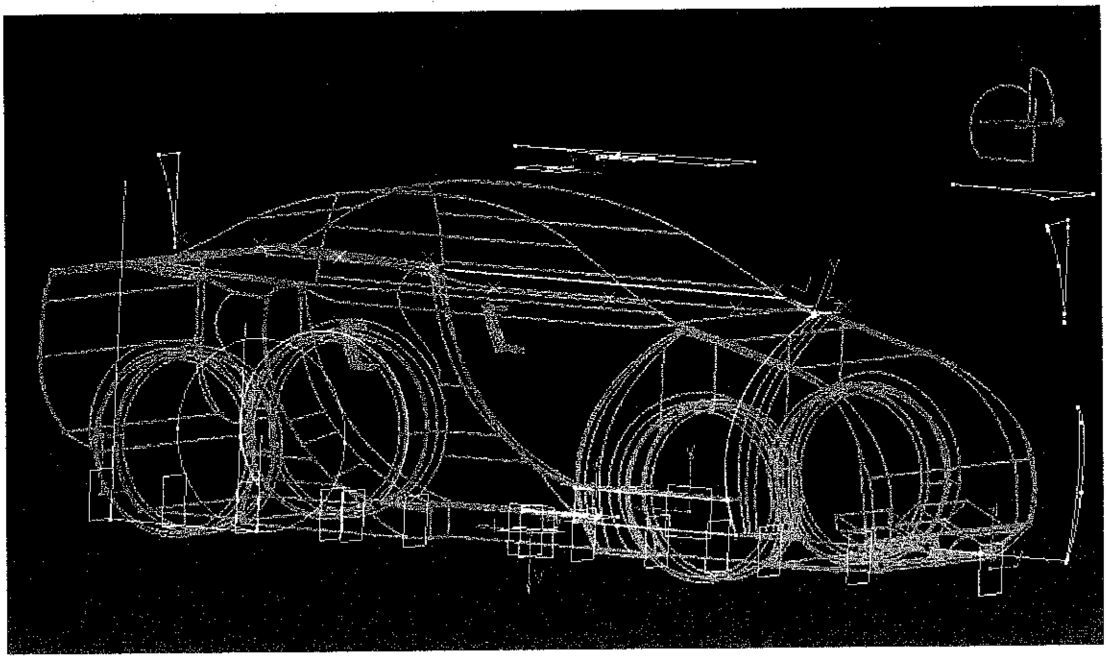


Figure 3.15: Wire frame

3.4 DIMENSION

3.4.1 Small Scale (Ratio based on 1:10)

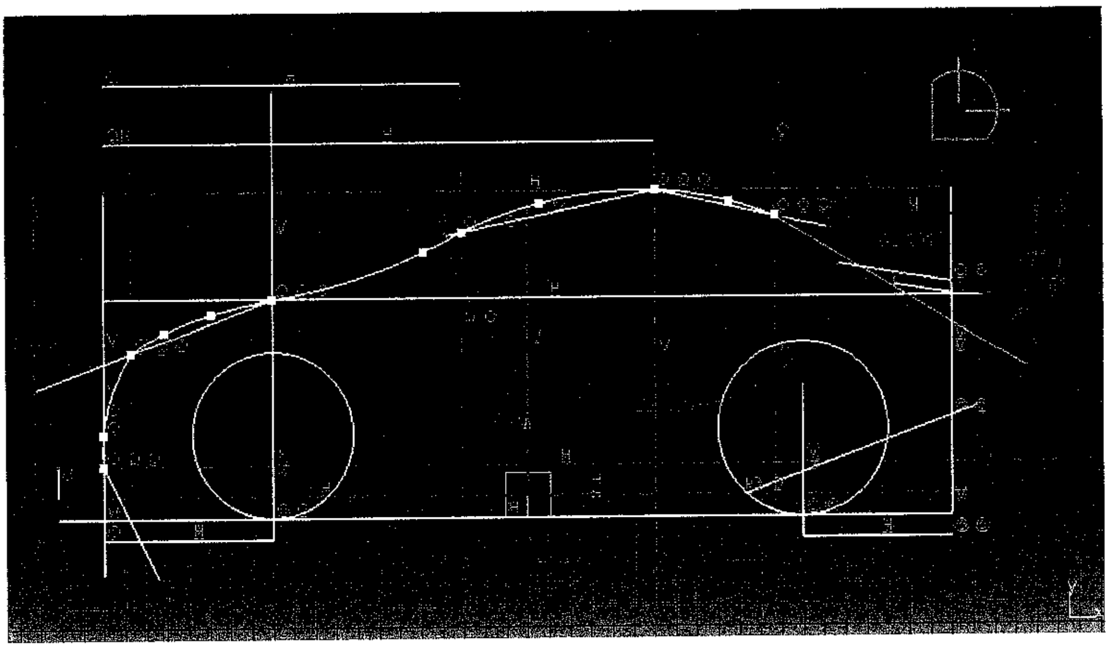


Figure 3.16: Dimension of Small Scale

3.4.2 Real Scale

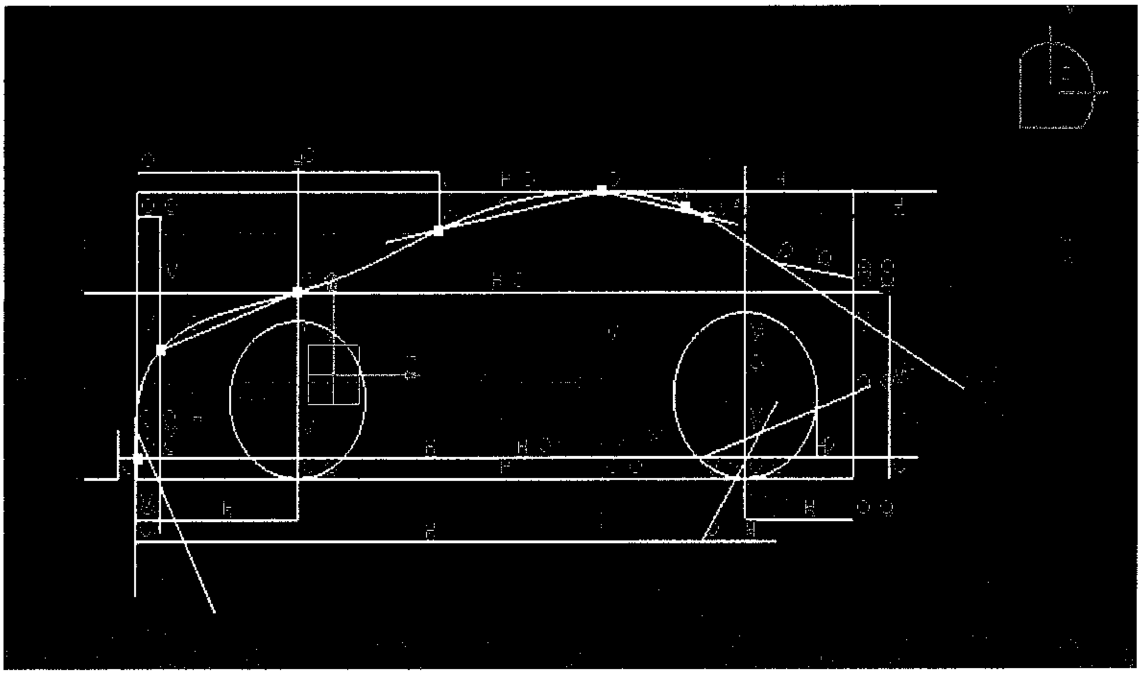


Figure 3.17: Dimension of Real Scale

3.4.3 Views from Different Angle

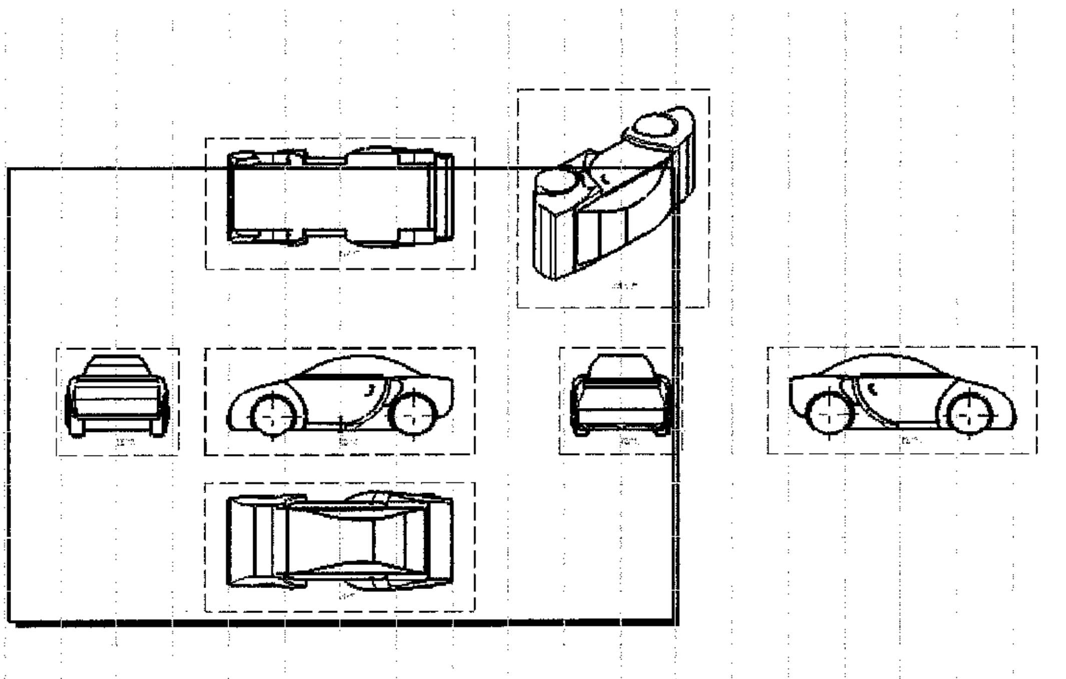


Figure 3.18: Views form Different angle

3.5 MODEL IMPROVEMENT

3.5.1 First 3D Model

Currently this was the first 3D model created and basically it doesn't fit the requirement of an aerodynamic shape as some of the part does not have a fine surface that lead to sharp edges. Further more the complicated edges presence might caused an error when being simulated by using Star CD.

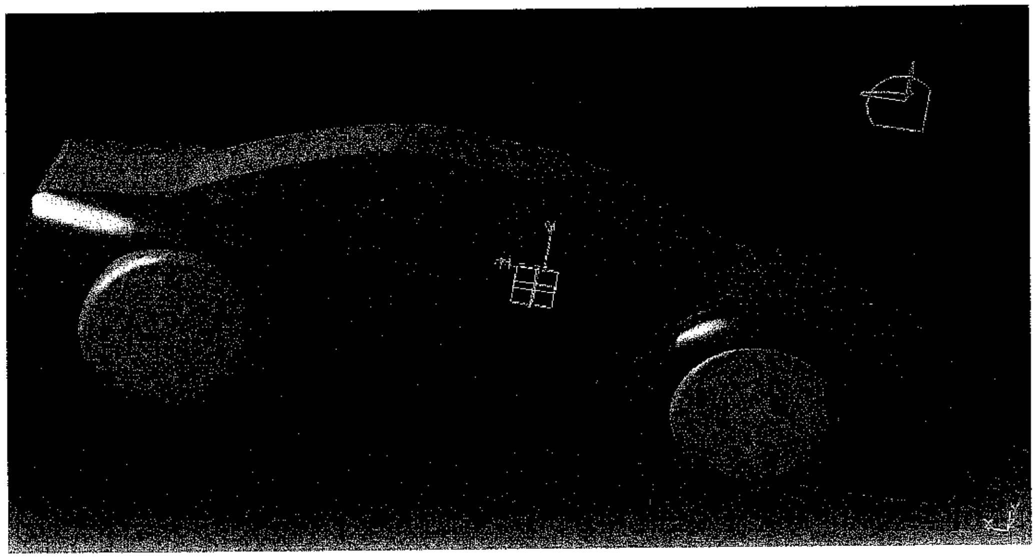


Figure 3.19: First 3D Model

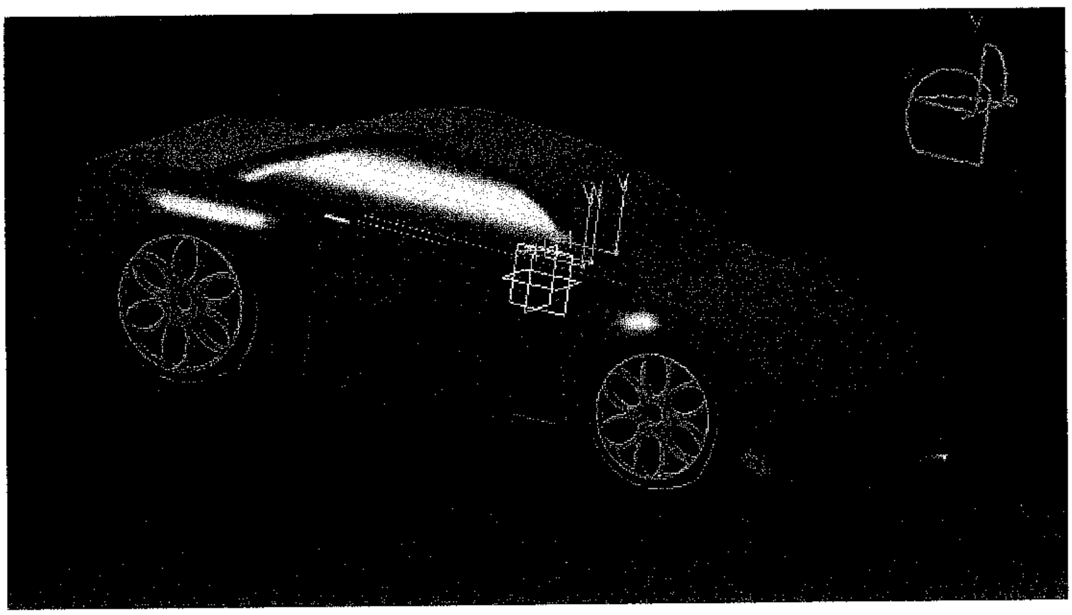


Figure 3.20: First 3D Model with Tyres

3.5.2 Improvised 3D Model

Reshaping has been done in order to get the body to its certain point of aerodynamic.

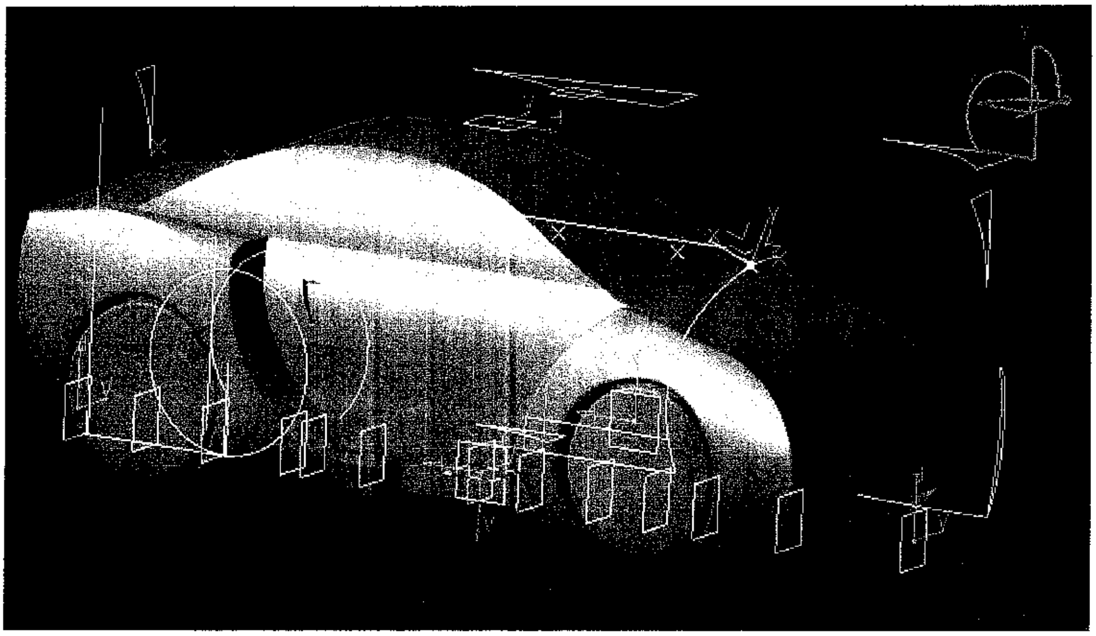


Figure 3.21: Improvised 3D Model

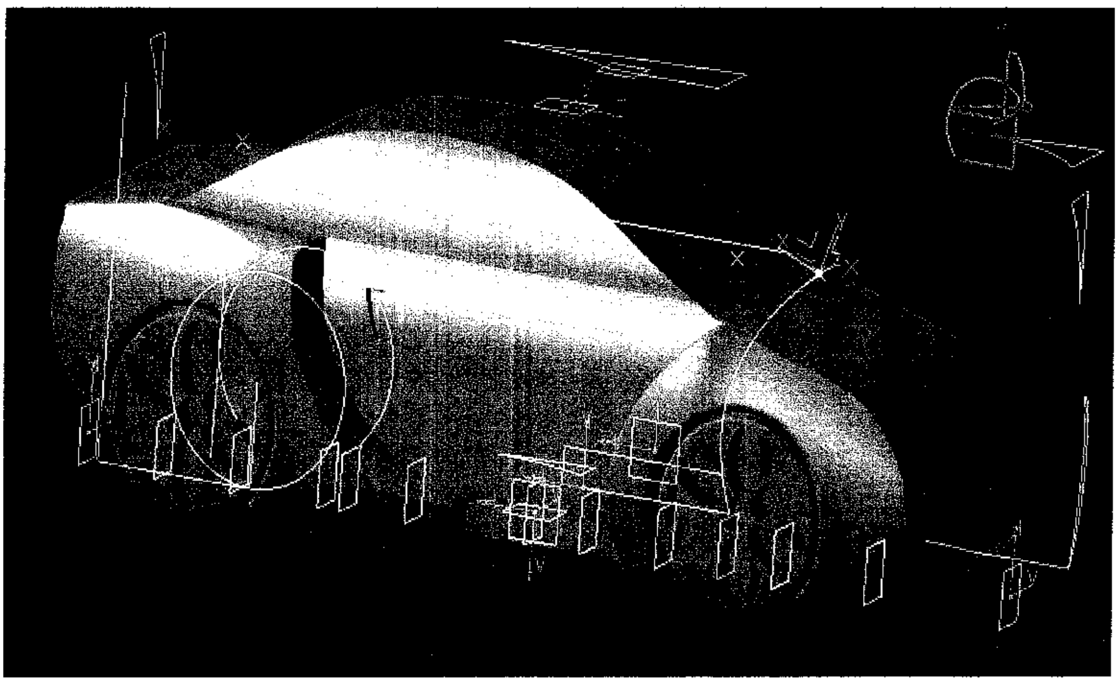


Figure 3.22: Improvised 3D Model with Tyres

3.6 MODEL CONSTRUCTION PROCESS

1) Main source of creating the model is the vase sponge as it is easy to be shaped based on the specific requirement of the model. The sponge are arrange in rectangular shape as it will fit all the length, width and height of the model that will be constructed later.

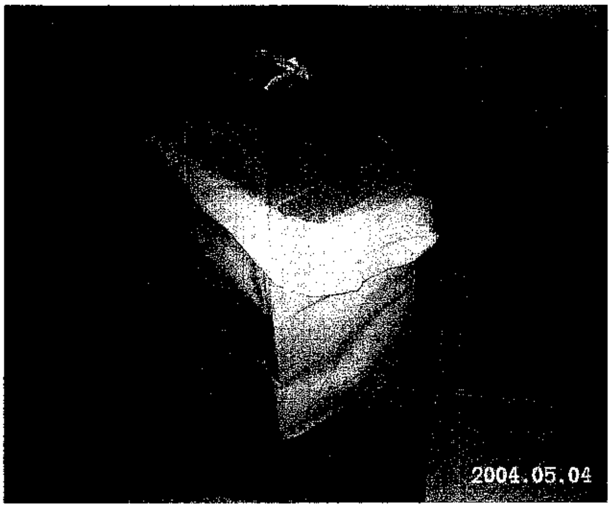


Figure 3.23: A stack of Vase Styrofoam

2) Then when all of them are glued together and then the shaping process takes place. To cut it into the desired shape, cutter has to be used and the cutting process just takes for a while as it is just considered as a basis for a real shaping process.

Figure 3.24: Cutting Process

3) The next process is to refine the body surfaces of the model by using a sand paper to scrub and polish the body of until the desired shape can be seen and with that a slowly polish has to be done in order to avoid damages upon the surfaces. Several sand papers were used such as the coarse are used to reshape the body while the for a smooth surfaces a fine sand paper was used to get the specific shape.

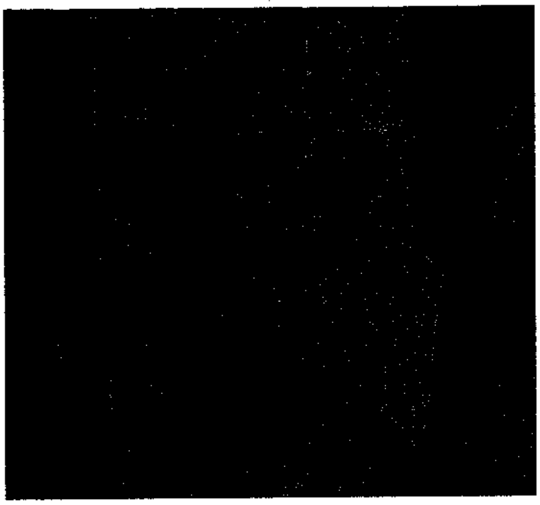


Figure 3.25: Sand paper Polishing Process

4) Next stage would be the covering process. This process is necessary because the Styrofoam itself cannot sustain an environment effect as it will produce debris all over and yet it cannot sustain the aerosol spray that acted upon the surfaces. And thus with that a cover up layer is needed acting as the protective layer also for a finishing layer. The layer used was plaster of Paris. The time taken for the plaster to hardened is just for a few minutes.

Figure 3.26: Plastering Process

5) After the plaster is totally become hard and dry then a polishing process will take place. To start the process a coarse sand paper were used to smooth the surfaces. During the process it is considered as the bottleneck part because if the polishing processes are not smooth to a certain requirement than during the spray process flaw upon the surfaces might occur and disrupt the process. Thus is important to ensure really fine surfaces can be obtained.

Figure 3.27: Polishing Process (Second Stage)

6) For a smooth surfaces another sand paper has to be used which is the fine one as to ensure that the body of the model will possesses a streamlining shape without a curvy shape that will caused a turbulent effect during the tuft testing session.

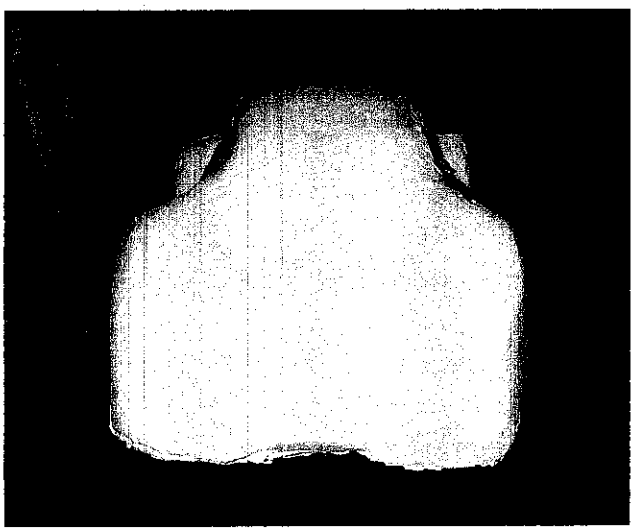


Figure 3.28: Polishing Process (Third Stage)

7) The bottom of the model was not been plastered as this part will be cut later on to placed a cube wood inside the model to ensure that the body will not move and can sustain the wind flow effect when undergone the tuft and wind tunnel testing. A wood with a 3/4 of the length and width of the model was used and the depth of placing it is almost half from the model height.

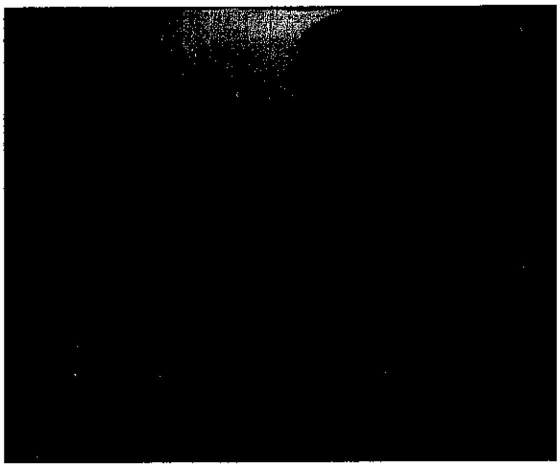


Figure 3.29: Model Bottom Part

8) After the plastering process, next one is to ensure that the model is covered by the second layer which is the painted layer. Aerosol spray was used to cover the surfaces and black color was choose as to ease the monitoring process during the tuft testing and wind tunnel testing. Dark color will highlight more on the wind flow or the movement of the thread upon the surfaces. The spray process takes only a few minutes to cover all over the body.

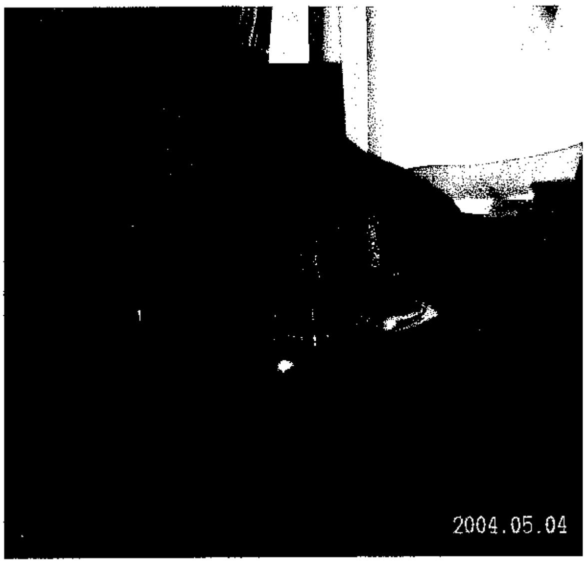


Figure 3.30: Spraying Process

9) After the spraying process, model need to be put under a windy condition or in a way to ensure that the spray will dry and ready to be simulated. The time taken for the drying process depends on where the model was located. And if it is really dry than the model will undergo another process. This model projected the updated version of the model with a slightly different from the previous model with a more streamlining body.

Figure 3.31: Drying Process

10) As mentioned earlier two models have been constructed as it's projected the different model design during the 3D model session. This model is referring to the previous version before improvement has been made onto the design. The different are more into the size of the model and also certain shapes that are curvy

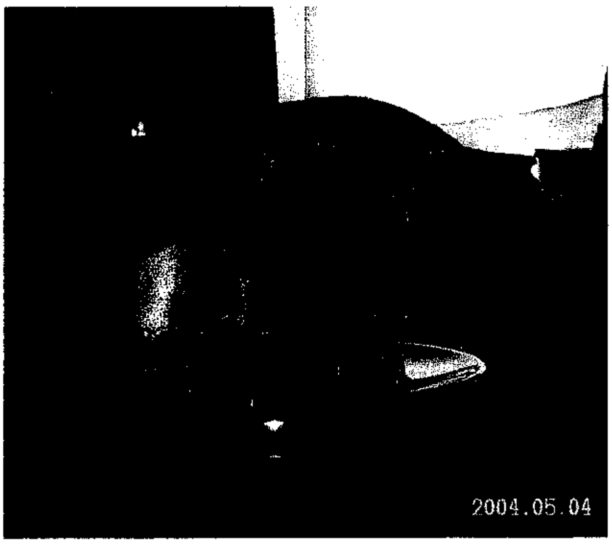


Figure 3.32: Previous Design Model

11) Last step was to place the wooden cube into the model from the bottom part. The purpose of having this wood is to make sure that the body will not move during the testing process that might affect the results. But the main reason of putting this wood is to act as a base during the wind tunnel testing process. The wood will be mounted as to attach the model to the ground layer of the wind tunnel. It will hold the body through out the session.

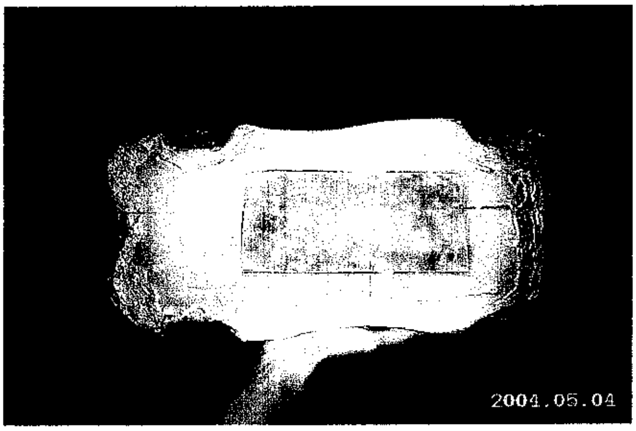


Figure 3.33: Wooden Block

3.7 PREPARATION MODEL FOR TUFT TESTING

1) As for tuft testing, several equipments were needed to create this tuft condition. The equipments used were glue, scissors and thread. Meanwhile fro the model itself it is important to ensure that the body does not glue with any other things that may distract the testing afterwards.

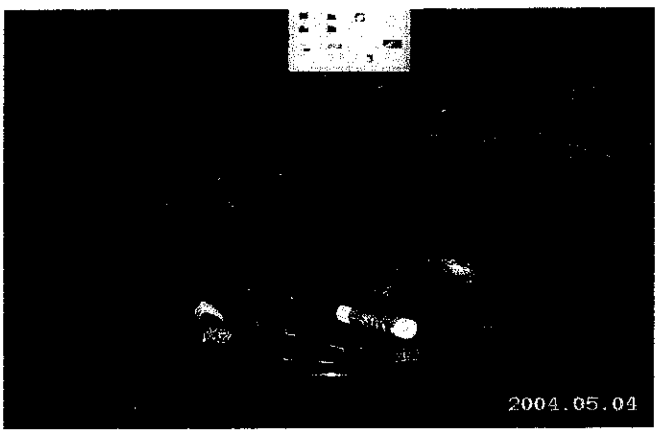


Figure 3.34: Equipment Used for Preparing Tuft Testing

2) Next step was to glue the thread onto the top surfaces of the model. The threads were placed side by side in a way there were 4 threads in one row and 7 threads in a one column. The reason of putting it over the top of the body is to monitor the effect of the body because during the testing the thread will be blown by the wind thus the effect can be seen clearly.

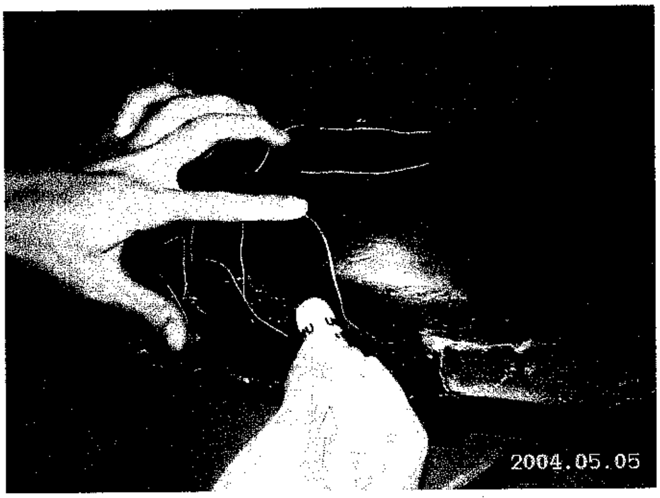


Figure 3.35: Gluing Process

3) This image was taken for the body of a 3D design model with the updated version. Threads were placed until at the rear part of the body.

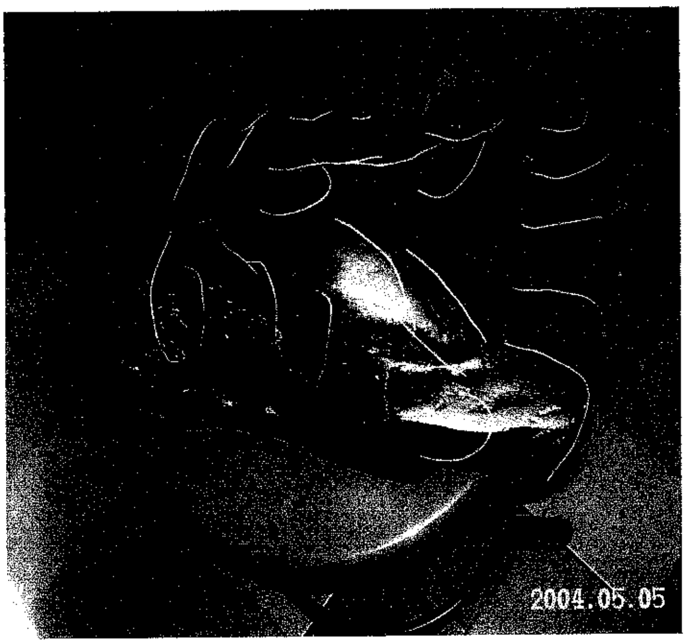


Figure 3.36: Threads Finishing Process

4) This image was taken for the model of a previous design.

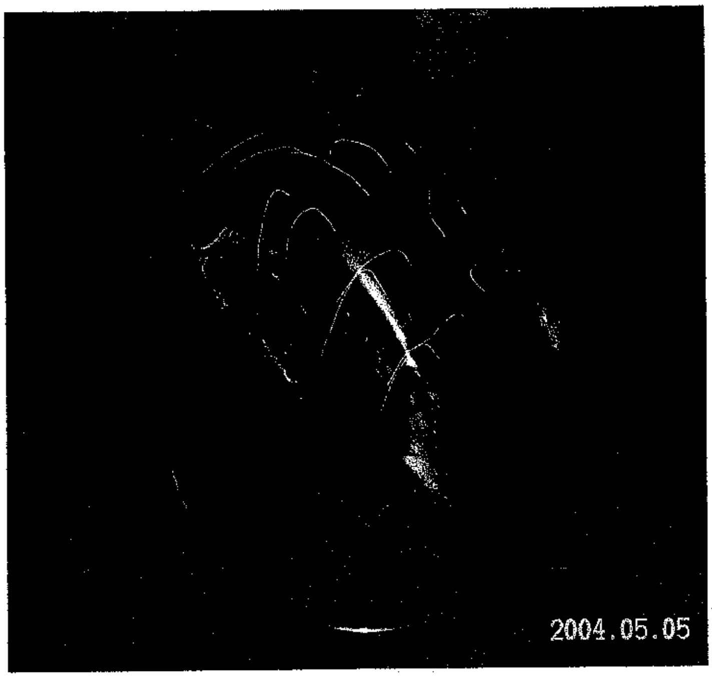


Figure 3.37: Previous Design Threads Location

5) In order to ensure that the threads are all stick to the body a tape was used just to make sure that during the testing the threads will not be blown away by the wind generated from the industrial fan.

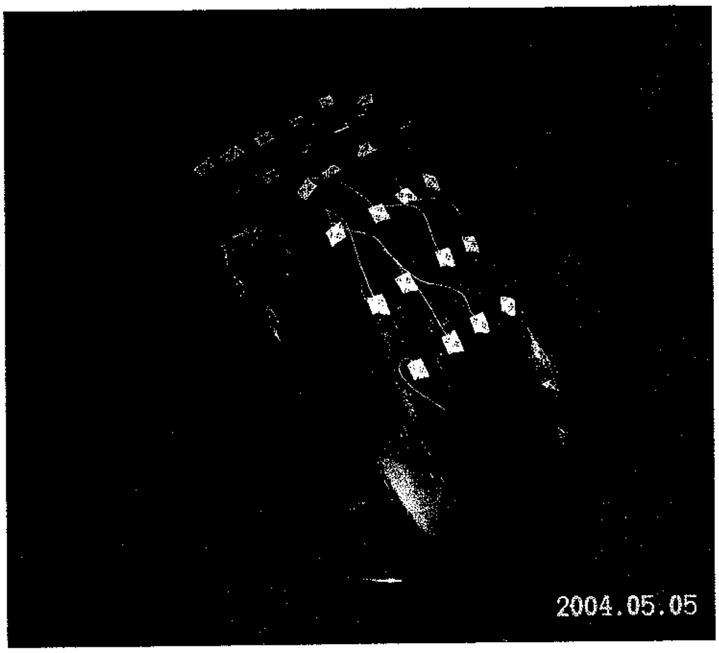


Figure 3.38: Another alternative of Sticking Threads on the Model

CHAPTER 4

RESULT AND DISCUSSION

4.1 MATERIAL SELECTION

4.1.1Polymer Composites

These materials have the advantage over steels of being lightweight and have been under investigation for vehicles since the 1930s. The 1970s saw the development of new reinforcement and matrix materials together with the evolution of new and innovative manufacturing methods.

Body parts using fiber reinforced polymers are used by most vehicle manufacturers for doors, tail gates, rear spoilers and roofs. Dough molding compounds, DMC and pre-formed sheet molding compounds, SMC can be fabricated using low cost tooling to make low volume parts economically. Composites body parts are not without criticism. Safety and crashworthiness remain under investigation as is the recycling situation with thermosetting resins.

4.1.2 Fiber Reinforced Composites

The most important heterogeneous composites are the fiber reinforced composites. They involve the usual problems associated with fiber reinforced materials. A condition for high strength stiff fibers is that they consist of a tightly packed continuous network of strong bonds. Because of the desire for low density, the elements that are most suitable are those of the first two rows of the periodic table, e.g. Boron, Carbon and others.

The stiffness, strength and thermal expansion of the plastics differ from those of the reinforcing material by about a factor of 20 to 30. The values for strain at failure are approximately the same for all three materials. At the same elongation, composites absorb stresses in proportion to their elastic modulus. Therefore a nearly ideal pairing results if the ratio of the tensile strength and the moduli of elasticity are near unity.

4.2 MODEL JUSTIFICATION

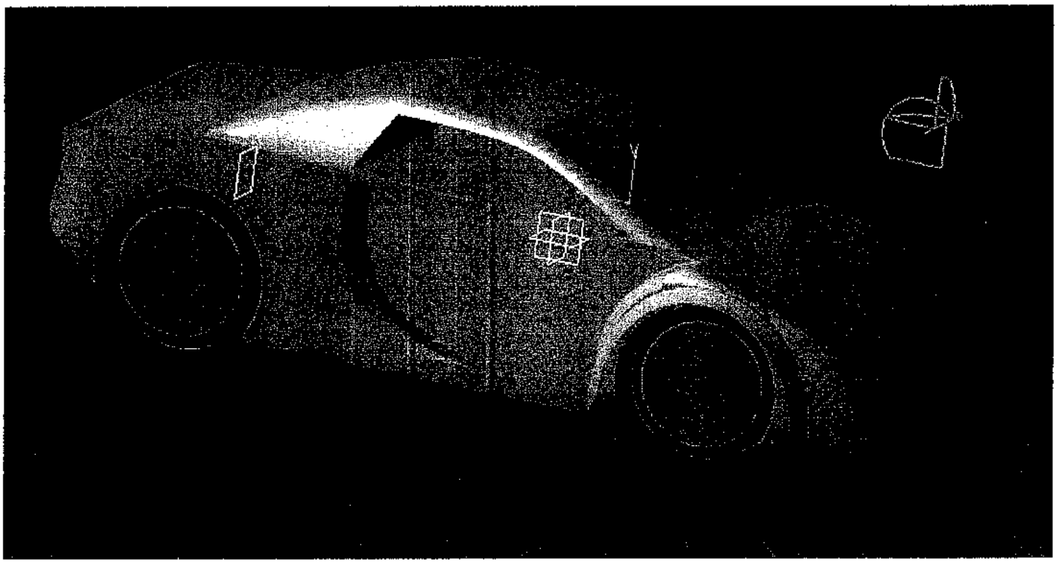


Figure 4.1: 3D Model with A Streamlining Shape

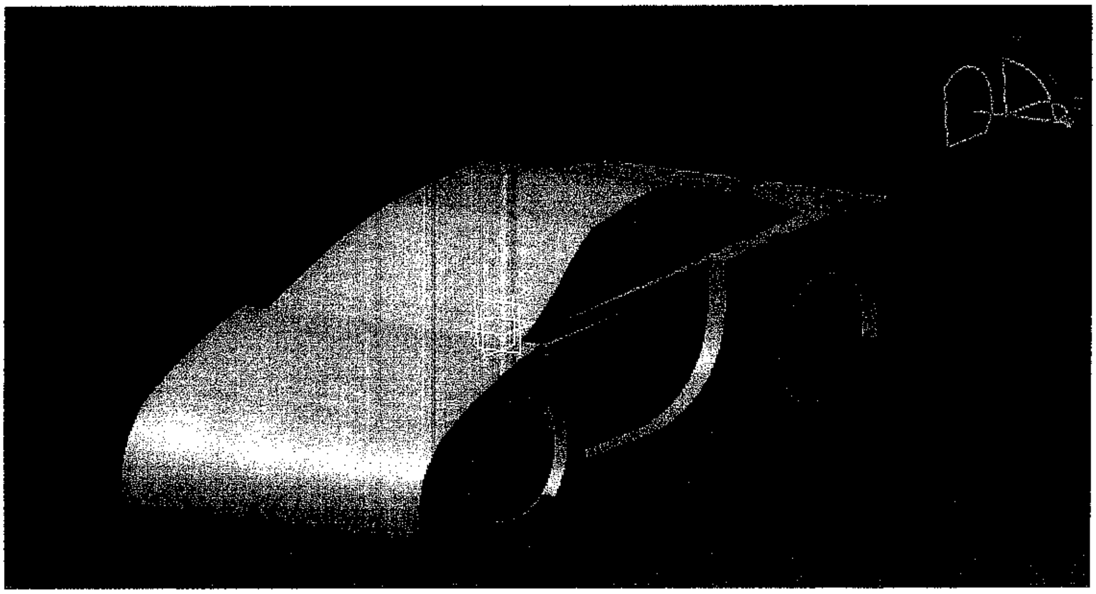


Figure 4.2: 3D Model With A Curvy Shape

Based on the two models drawn, it shows a different perspective of the car body design which is on figure 4, the model is more aerodynamic while on figure 5 it is in flat shape.

The sharp edges will affect the aerodynamic of the body thus causing to increase the drag coefficient and eventually decrease the car performance.
While on the other hand, figure 4 shows a model with a streamlining body which means that it is aerodynamic as the fillet at every corner and edges of the body will allow the air to flow smoothly upon the body.

Form another view a smooth body will look even more stylish compare to the curvy and sharp edges. So basically based on this comparison, it does show the advantages of having a streamlining body and thus, the model should be in these features.

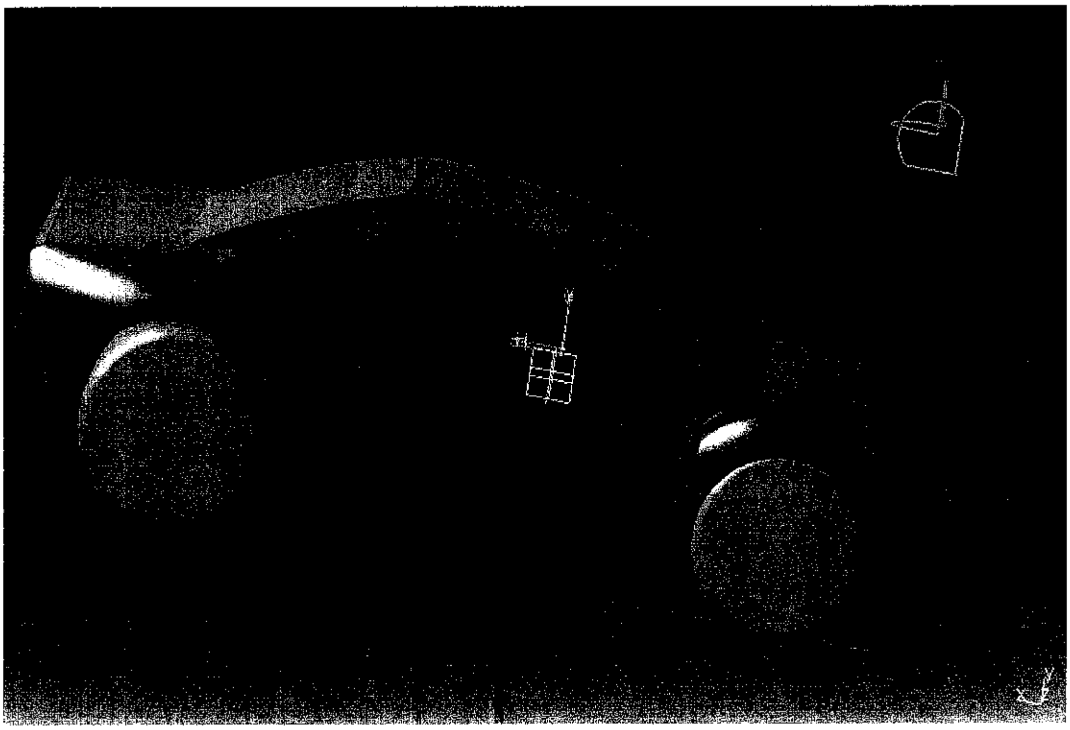


Figure 4.3: 3D Model with Upgrading Features

Due to the comparison features, an upgrading 3D model has taken place as the solution of the previous model. The modification basically concentrated on the fining the body surfaces by having a smooth curve or edges. In order to ensure that the body has the desired shape, certain CATIA features have to be used such as loaf and fillet. This combination will create a more outstanding result in 3D modeling. Loafing was needed in order to create the streamlining body that has a certain shape and angle. And that is why when it comes to the car features such as at the fender and rear side, to create this part loafing can generate this kind of solid shape. To generate the loafing solid, it is required to have a certain several plane which acted as the basis of the shape. By having this plane then the profile can be drawn based on the desired shape.

Loafing is a combination of more than one plane to generate the shape, thus base on the previous profile, the shape can be obtained. Fillet was used as features to have more smooth surfaces at the sharp edges. At the front and side of the car, located an air intake as an alternative to cool the equipment such as linear piston engine and the rows of batteries at the bottom part. By having these shapes it is near to the desired shape based on the drawing sketches previously.

4.3 BODY MODIFICATION

4.3.1 Updated 3D Model

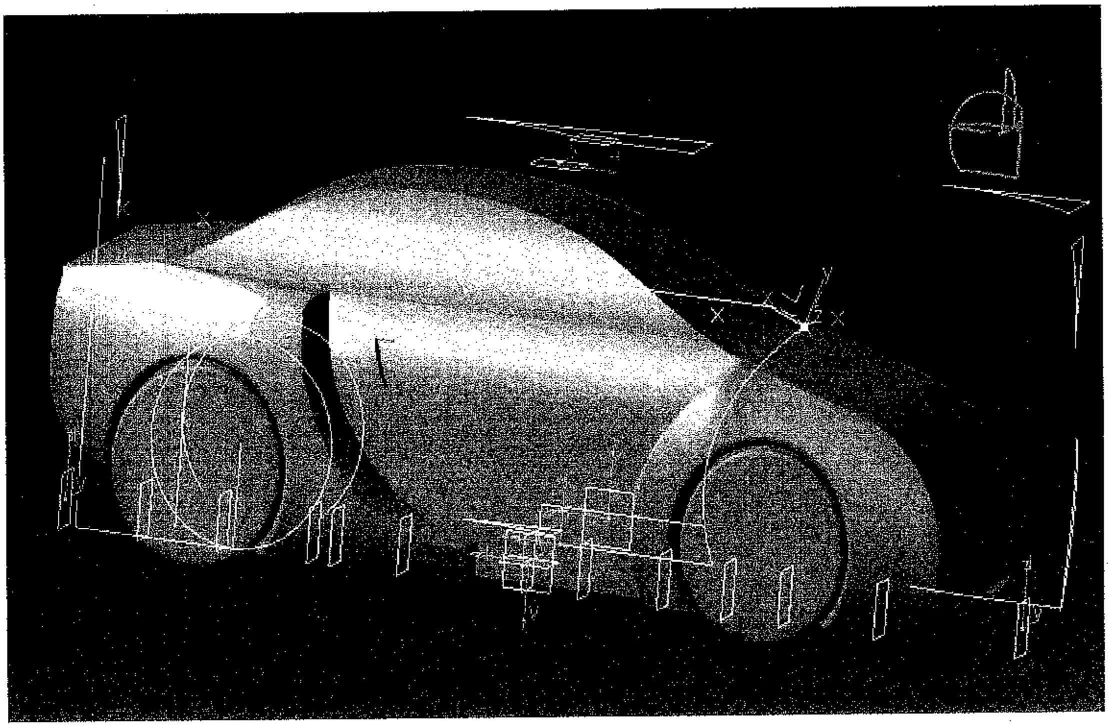


Figure 4.4: 3D Model with Updated Features

For an automobile the overall drag force is dominated by the pressure effects such as the separation observed in the tuft test rather than skin friction effects. Therefore the majority of the changes made in the body shape were aimed at reducing the size of the vehicle's pressure wake. This was accomplished by reducing or eliminating the separation caused by discontinuities in the body such as wheels, wheel wells, mirrors and door handles. In addition to reducing the pressure wake the shape of the vehicle body was modified to create pressure gradient which promotes attached flow along the entire length of the body.

Based on the models construct it shows different shape with a different characteristic. The first model has already undergone the refining process and still through the process while the other model is the resultant of a flat surfaces and sharp edges. The main purpose of having the comparison is to see the different and try to improve the shape and make it smooth as possible as to minimize the drag and pressure acting upon the body.
Based on the two models it doe shows different characteristic projected as having a different body shape which is the smooth and flat edges. Basically the changes and the suggested idea are as follows:
The nose and hood of the vehicle were altered to reduce separation and encourage smooth airflow. The front hood seam was moved below the stagnation point on the nose, creating an undisturbed surface extending to the base of the windshield. The hood gaps above the front fenders have been lowered to run along the tops of the wheel well openings thus providing a continuous surface for the air flowing along the sides of the nose toward the pillars.

With these changes the entire top half of the nose is smooth and seamless and should support a laminar boundary layer. A two dimensional flat plate approximation indicates that the flow may be laminar over the entire length of the hood. Wheels and wells add as much as 0.07 to 0.09 to the drag coefficient of a basic body shape. This is due to the interference of the unsteady flow entering and existing unfaired wheel wells with the basic body flow. The underside is suggested to be covered with a smooth surface from nose to tail to greatly improve airflow. In contrast the power train, exhaust, fuel tank, spare tire, etc. created a very irregular surface for the airflow. At the base of the rear window, the separation was due to the section just before the trunk lid. The result was that the air flow did not have enough energy to remain attached to the surface. The separation has been minimized by reshaping the rear window and trunk lid in order to reduce the rear window angle and eliminate the concave section.

These changes keep the airflow attached to the body from the nose to the rear edge of the trunk. This edge has been shaped on the top and bottom to provide a distinct separation point for the trailing vortices. The sharp edge avoids the varying separation points of a curved trailing edge. These variation lead to unsteady aerodynamic characteristics and a larger pressure wake. The tail of the vehicle has been extended so that the trunk now ends at the rear edge of the bumper. The lengthened taper of the sides of the tail created a smaller rear area and reduced the pressure wake. In addition to the extension the back surface of the tail has been hollowed out in the centre. This cavity caused a tumbling effect in the trailing wake and further reduced the size of the pressure wake.
As a final change it is noticeable that there is no side mirror on both vehicle but will be replaced with the cameras using small externally mounted lenses (suggestion). The lenses are 15% the size of the stock mirrors. Small flat screened monitors placed on either side of the steering wheel make drivers aware of their surroundings without significant head movement. In addition to improving aerodynamic, removing the mirrors eliminated the blind spot because the cameras have a 78 degree filed of view.
The significant of the body improvement can be seen clearly by referring to the sample calculation made and also the graph appearance regarding on the aerodynamic flow.

Basically the effect of the aerodynamic losses can be related to this equation:

$$P_{aero} = \frac{1}{2} \rho \, C_d \, F A V2$$

It does show that how the aerodynamic power is related proportionally to the drag coefficient, the frontal area and also the velocities acting upon the body surfaces. The main purposes of highlighting this equation id to emphasize on the drag coefficient that is totally affect the vehicle performance. Thus that's the main reason of having the body modification and fining the surfaces as to minimize the drag force as many as possible. The table below indicates the several examples of different value of drag coefficient and also the frontal area value.

First condition:	**Cd = 0.35,**	**FA = 1.6**
Second condition:	**Cd = 0.3,**	**FA = 1.2**
Third condition:	**Cd = 0.2,**	**FA = 1.0**

Table 4.1: Value of Drag Coefficient and Frontal Area

Velocity	Velocity m/s	Power loss aero 1	Power loss aero 2	Power loss aero 3
0	0	0	0	0
10	2.777777778	0.933333333	0.65	0.333333333
20	5.555555556	1.866666667	1.3	0.666666667
30	8.333333333	2.8	1.95	1
40	11.11111111	3.733333333	2.6	1.333333333
50	13.88888889	4.666666667	3.25	1.666666667
60	16.66666667	5.6	3.9	2
70	19.44444444	6.533333333	4.55	2.333333333
80	22.22222222	7.466666667	5.2	2.666666667
90	25	8.4	5.85	3
100	27.77777778	9.333333333	6.5	3.333333333
110	30.55555556	10.26666667	7.15	3.666666667
120	33.33333333	11.2	7.8	4
130	36.11111111	12.13333333	8.45	4.333333333
140	38.88888889	13.06666667	9.1	4.666666667

Table 4.2: Listed Variety Velocities and Power Loss

Based on the previous table the graph projected shows three significant linear line having a different slope with a different value of power losses. From this it is clearly seen that by having a larger value of the drag coefficient will contribute to a more power losses while the yellow line present the small coefficient acting upon the surfaces,. Hence the modification of the body surfaces does project a great impact to the vehicle performance.

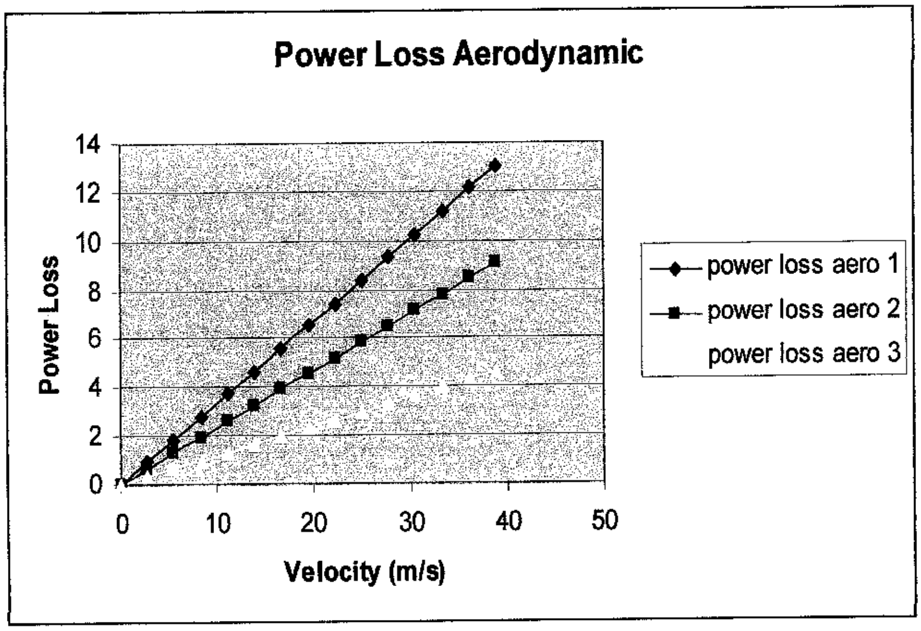


Figure 4.5: Graph of Power Loss Aerodynamic

4.3.2 Tuft Testing

During the testing, models were tested against the industrial fan as to monitor the tuft effect that acting upon the surface. Firstly, models were tested within the open air condition. Along the session when the wind flow reaches the body it blown all the threads to flow slowly just following the shape of the model. Then when the speed being increase from 1 to 2 the threads become stretched along the body and none of the turbulent effect occur but only a laminar flow was clearly identified. But when the speed was increase to the maximum, along the body its still producing the same effect which is the laminar flow but only at the certain point of the body which is at the rear part, small turbulent effect was identified and this is necessary as to put forward the car up to the maximum performance.

The bench mark of the models is referring to the flat and curvy model because it is expected that when this model being test, it will shows a turbulent effect at the certain area which is the most certain part is at the rear window and rear trunk Apart from that at the wind screen will also occur the turbulent effect and mostly along the top surfaces. The flat edges will block the wind flow to flow smoothly upon the surfaces the high velocities flow will hit the surfaces while passing the body. The thread will become ripple and this point and indicate that there are turbulent occur at that point. Thus it is not advisable to have this kind of shape that will decrease the car performance. Models were tested with and without honeycomb that was places in front the projected wind by the fan just to see the effect of the uniform air flow and it did produce uniformity flow of the wind that passing across the body.

Figure 4.6: Tuft Testing Run in the Open air

The next stage was to run test within the subsonic wind tunnel also to monitor the effect of the tuft testing. This wind tunnel can project a simulation of 40 km/h of wind velocities and with an average of tunnel turbulent intensity which is 0.6. For a good intensity the constant is 0.1 thus indicate that they might be some turbulent effect along the wind tunnel while the mesh number is 0.02 to indicate that it is a subsonic.

During the test, model was placed at the testing area and wind flow generated was at the highest point as to monitor the effect of the threads acting at the surfaces. All over the part there were no turbulent effect can be seen as the body shape is aerodynamic. The threads are just follow the wind that passes over the body and stretched it to the maximum. Because of the close tested area the turbulent effect occur only at the rear window. Thus it proves that at that point turbulent effect was needed to appear to be at that location as to help increase the performance. It can be identified by the effect of the threads that were having a small rippling condition unlike at the other parts the threads were almost stick to the body. The sticking process thus indicate that were none turbulent effect on laminar flow that is necessary to be happened at that location.

Figure 4.7: Tuft Testing Run Within the subsonic Wind Tunnel

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

This project is based on the existing car act as the main point of reference and all the design is based on the upgrading the car performance by having an aerodynamic shape and also considering the material used. Basically it is going to be a lightweight material which is now considered to be the glass fiber that can exceed the limitation of the typical hybrid vehicle. As for this project the duration takes will be one year from now in producing the body or frame of the car neglecting the engine and chassis that is currently manage by another team.

The time taken for the model constructing is based on the ability to design the required shape by using CATIA as the major tool in producing 3D model. Detail shaping process is very essential as the time taken for one year period to finish this product cannot be considered enough as they are lots of modification and alteration should be made in order to ensure the design body will completely become aerodynamic. Part Design technique is not advisable being used as the major tool of producing the 3D model because during the simulation process Star CD will detect an error due to the complex shape that might interrupt the simulation process.

Tuft testing is needed in ensuring that the body has the most aerodynamic shape because during this testing the wind flow projected by the industrial fan will blow the threads that were glued onto the surfaces and form that the flow of it can be monitor and analyze based on the comparison made from two different model; one with a fine surfaces and the other model with a rough surfaces. The effect of the turbulent an laminar flow can be seen at the back side of the back window as it is necessary to push the car forward. Any turbulent at the other part will decrease the car performance.

5.2 RECOMMENDATIONS

Basically to create the 3D design, the software used is CATIA as the major tool and there are different techniques that can be used in producing the design and one of them that is currently used to produce the model is Part Design. During the initial stage which referring to the simple design created the are no errors occur but when it comes to the complicated shape, its getting hard to create the desired shape as the profile produce will caused an errors later on when being simulated into the Star CD.

Thus another method is more effective in producing the 3D design which is the Freestyle Shape, Optimizer and Profiler. By using this technique profile can be generated layer by layer and can easily created complex shape without causing any errors afterwards. In fact it is more applicable compare to the Part Design. Currently this process will takes such a time to understand the concept and how to use each of its function.

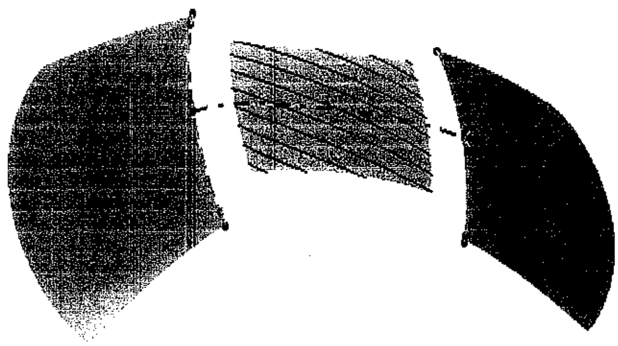


Figure 5.1: Design Model by using Surface Technique

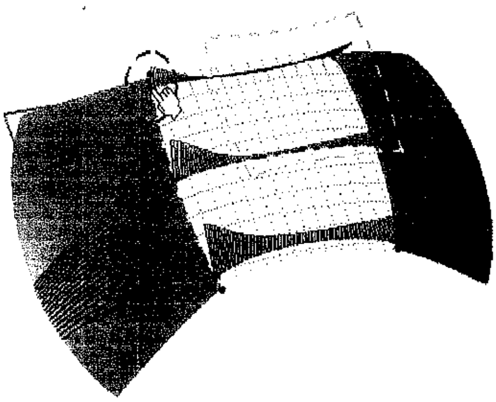


Figure 5.2: Analysis on the Surface

REFERENCES

1) Hybrid Electric Vehicle

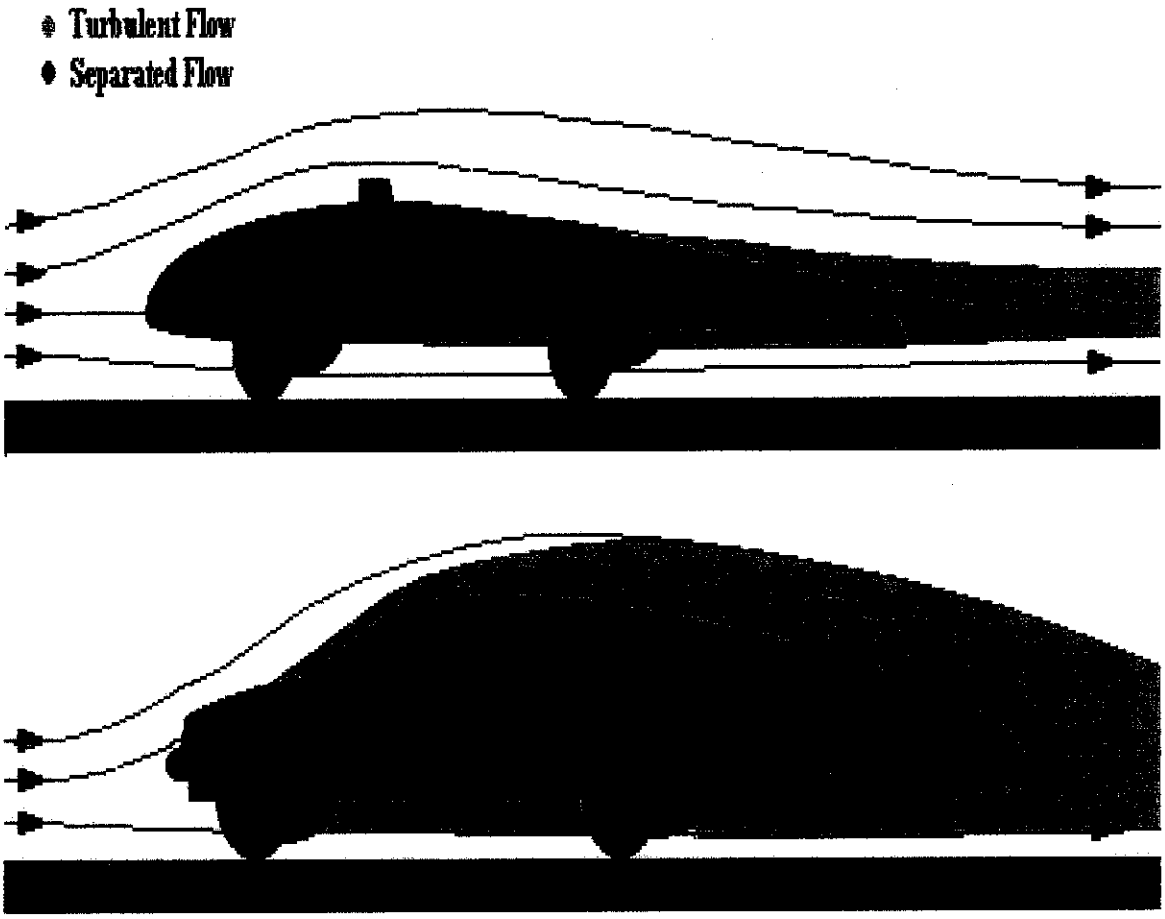
Global Mobility Database, Society of Automotive Engineers Inc.

2) Car Race Aerodynamic

3) Apart from that, the review also does involve a research trough the website such as:

- www.hev.doe.gov/
- www.toyota.com/html/shop/vehicles/prius
- www.altfuels.com/evp.php

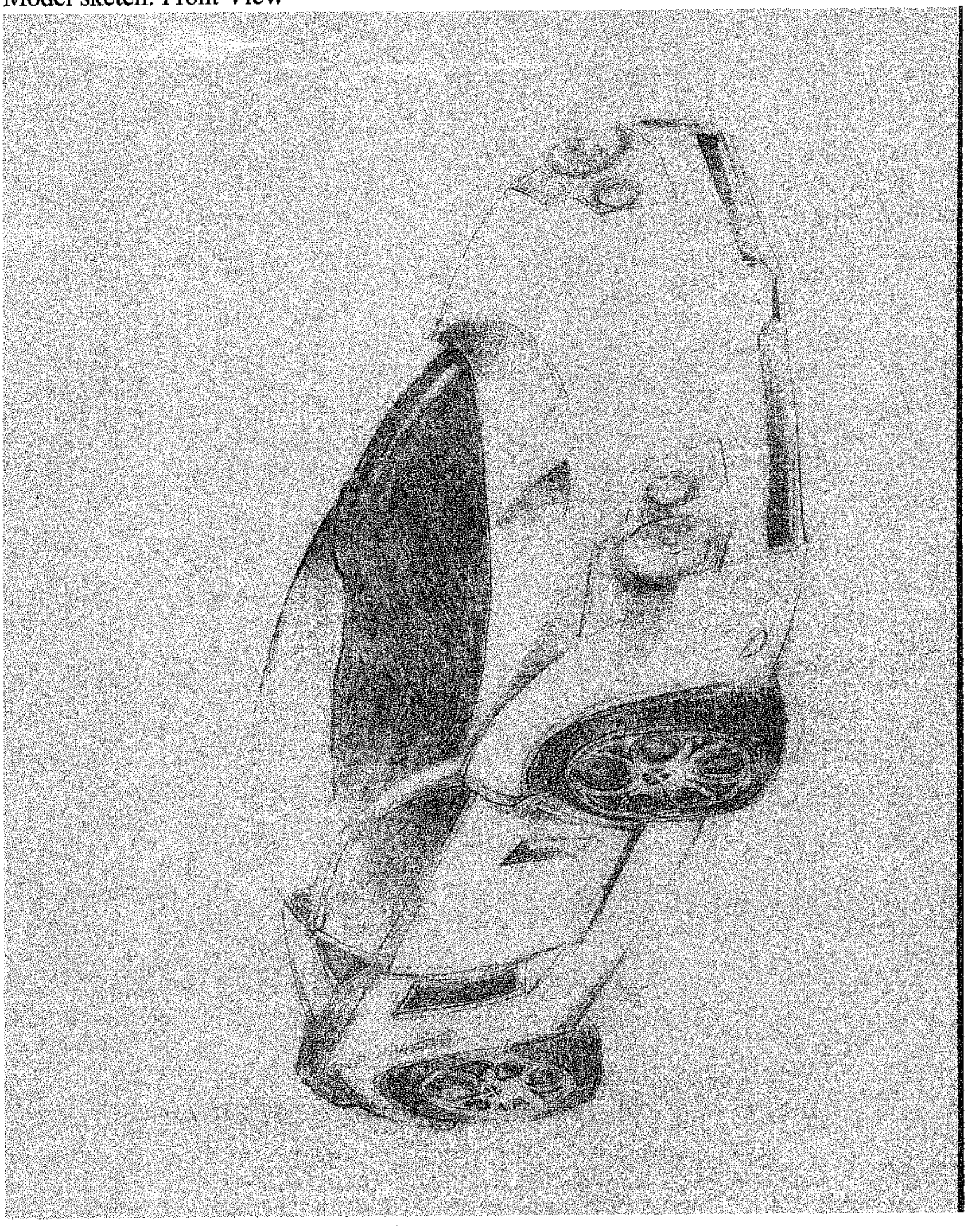
APPENDIX A: TURBULENT AND SEPERATED FLOW



Comparison of conventional and aerodynamic car that can cause different set of wind flow upon the surface due to the design structure.
Cyan shaded areas indicate turbulent air that has been slowed but is still flowing downstream. Red shaded areas indicate highly turbulent air flowing upstream, known as separated flow. The solar car had only small areas of this behind the wheels.

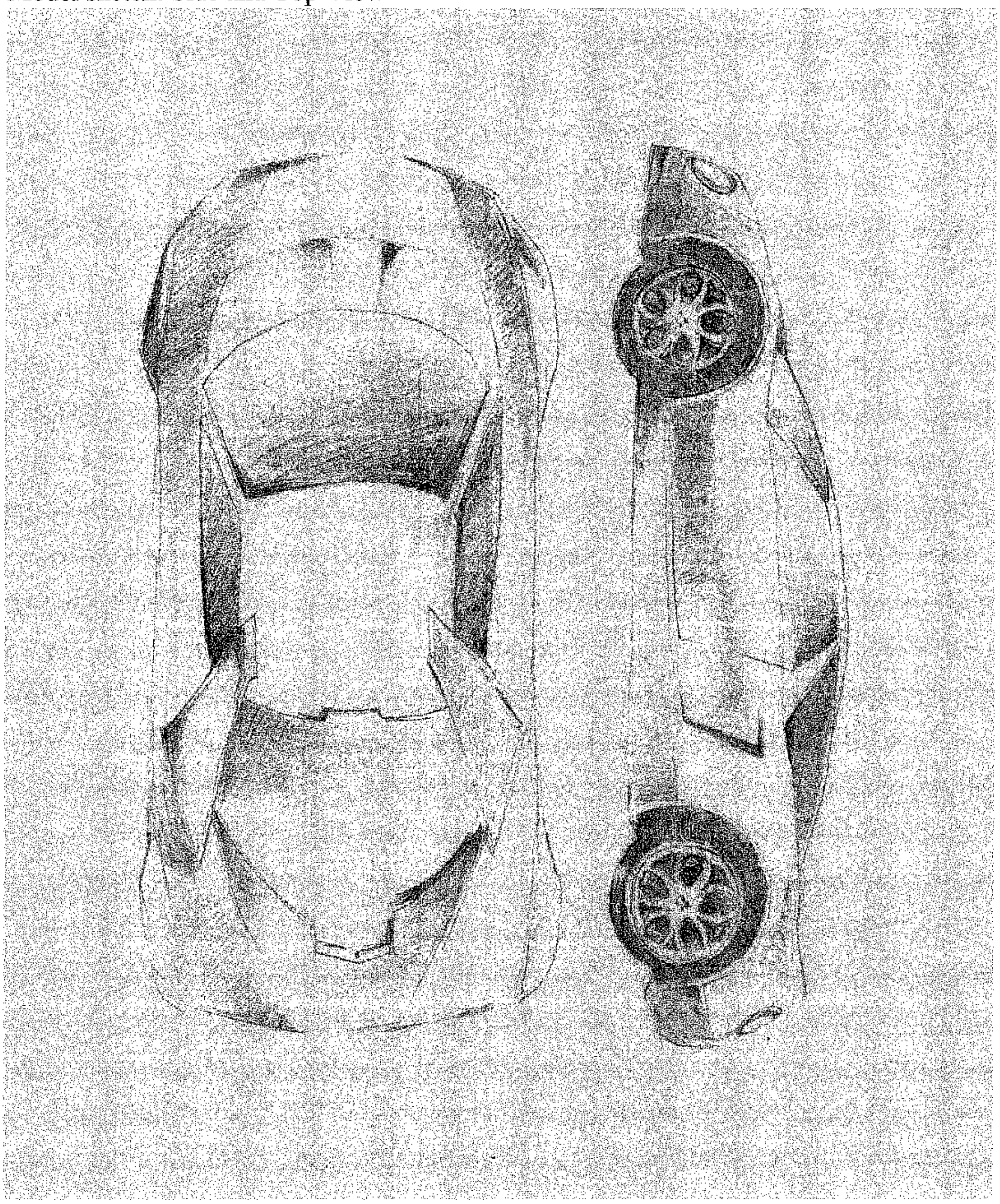
APPENDIX B: MODEL SKETCH (FORNT VIEW)

Model sketch: Front View



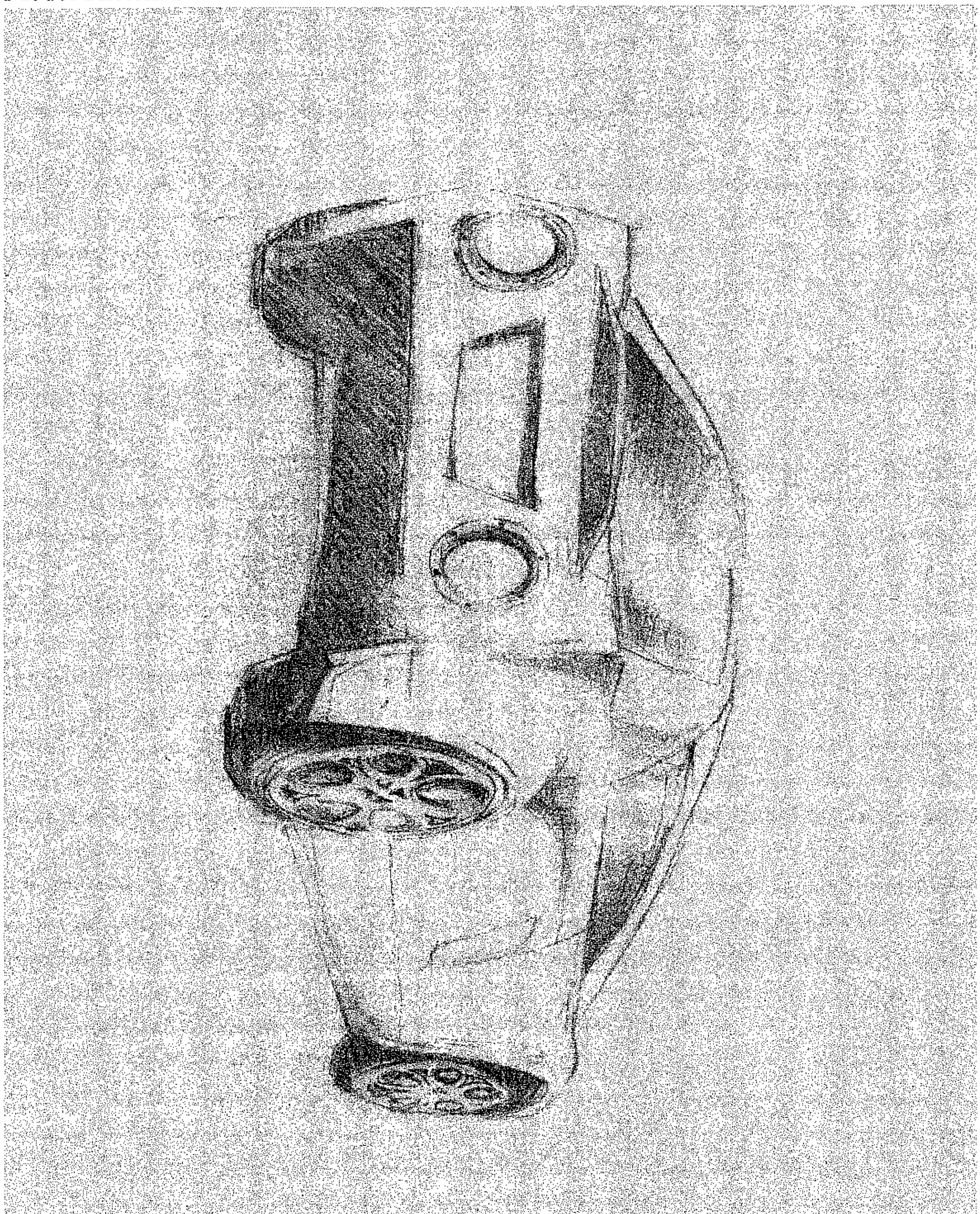
APPENDIX C: MODEL SKETCH (SIDE AND TOP VIEW)

Model sketch: Side and Top View

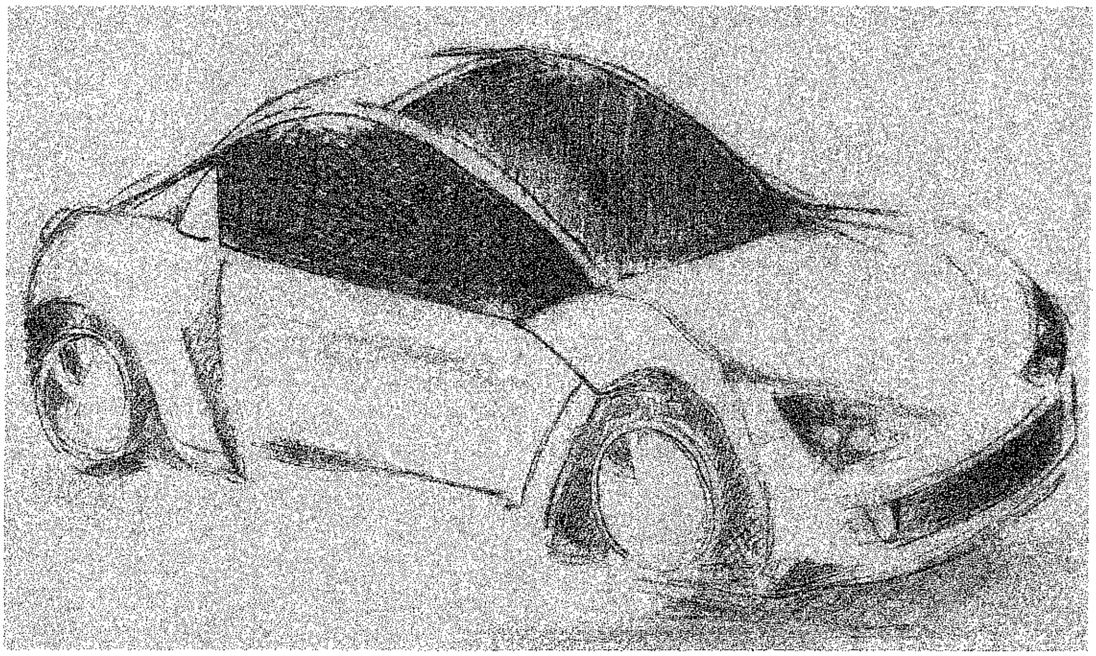


APPENDIX D: MODEL SKETCH (REAR VIEW)

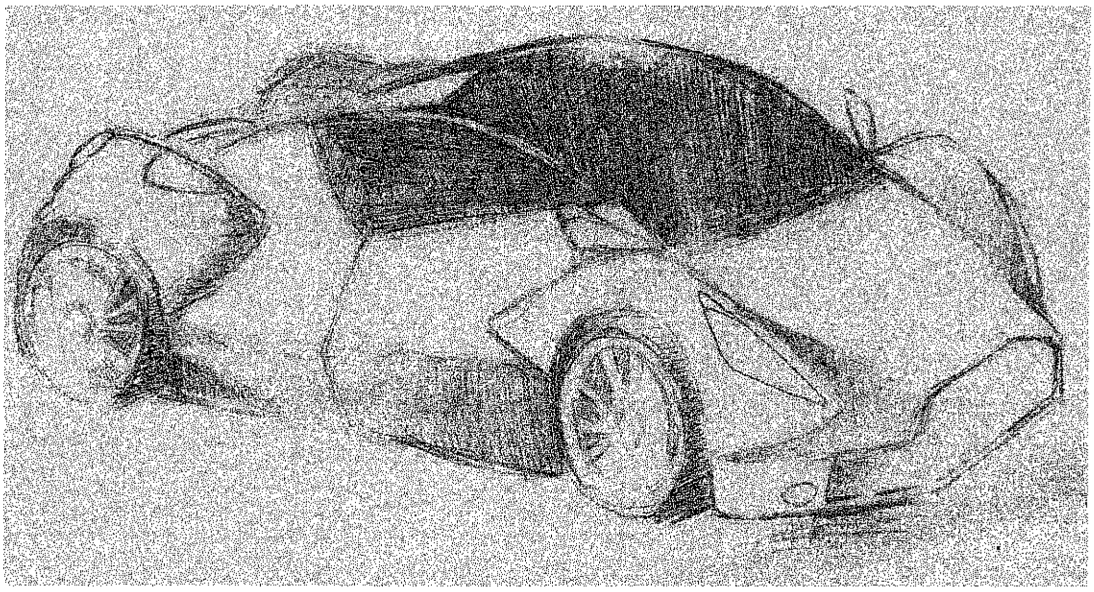
Model Sketch: Rear View



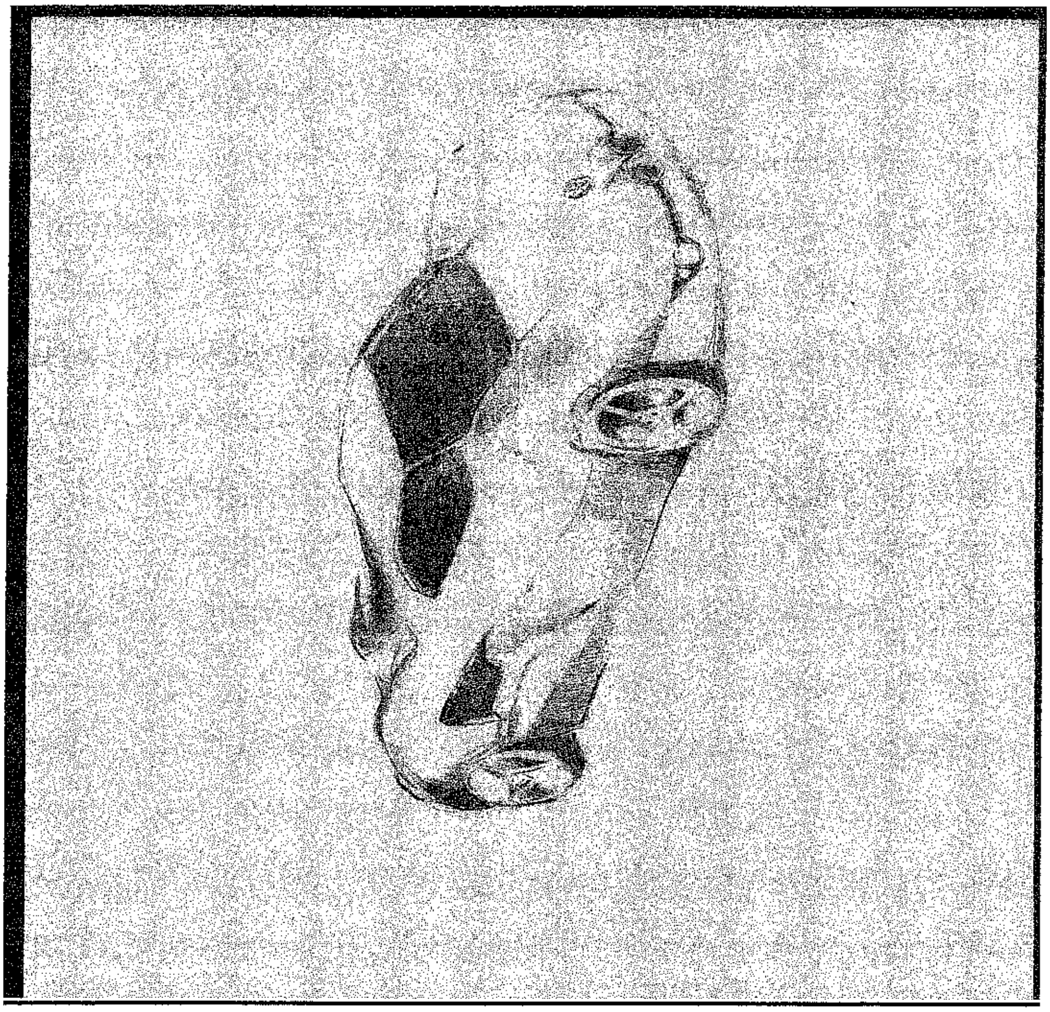
APPENDIX E: MODEL SKETCH 1



APPENDIX F: MODEL SKETCH 2



APPENDIX G: MODEL SKETCH 3

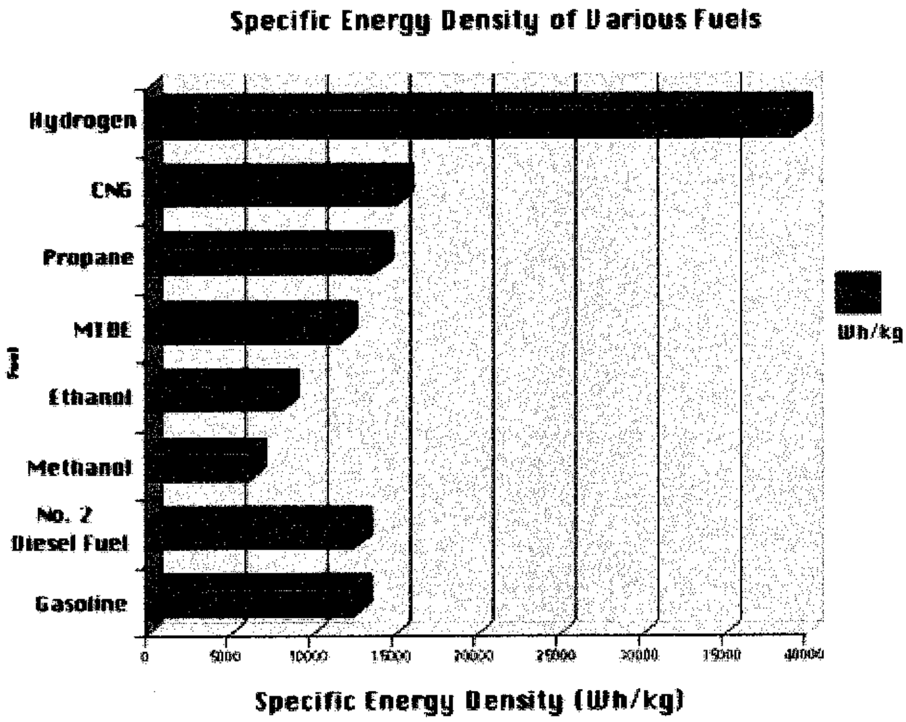


APPENDIX H: FUEL SYSTEM

Fuel Systems

The two primary fuels used in automobiles today are gasoline and diesel. The infrastructure is in place to produce, refine, truck or tank diesel and gasoline. Many of today's HEVs, and the ones that will be available in the near future, will use either gasoline or diesel to fuel the hybrid power units. However, to ensure the security of our oil supply and to address increasing environmental concerns associated with gasoline and diesel, alternative fuels are very attractive. The opportunity for fuels such as biodiesel, natural gas (CNG & LNG), ethanol, hydrogen, methanol, and propane to be used as alternative fuels for vehicles is great. Many alternative fuel vehicles are already being used effectively around the world. These fuels have the potential to be used in HEVs as well.

The following graph shows the energy density for various fuels. The graph does not take into consideration containment weight. For instance, the energy density for hydrogen and compressed natural gas is much lower than that of gasoline if the containment weight for the fuel is taken into consideration. The containment weights are not taken into consideration in the following graph due to the variability of manufacturer's containment weight estimates.



APPENDIX I: THERMAL MANAGEMENT

Thermal Management

Just as conventional gasoline engines require a cooling system, HEVs need proper thermal management of the power and energy storage units for optimum performance and durability. The type of thermal management system required will depend on the type of power and energy storage units selected. In many cases, waste heat from these components can be used for cabin air and other heating needs.

Batteries

The performance and life-cycle costs of electric vehicles (EV) and hybrid electric vehicles (HEV) depend on the performance and life of their battery packs. Each battery chemistry operates over a particular operating range to achieve optimum life and performance. Temperature variations from module to module in a battery pack could result in un-balanced pack and thus reduced performance. It is important to regulate battery pack operating temperature because it affects performance (power and capacity), charge acceptance (during regenerative braking), and vehicle operating and maintenance expenses. Battery thermal management is critical for high-power battery packs used in EVs and HEVs to maintain their battery packs within the desired temperature range. To learn more go to the DOE battery thermal management Web Site.

Power Units

Fuel cells offer highly efficient and fuel-flexible power systems with low to zero emissions for future HEV designs. There are a variety of thermal issues to be addressed in the development and application of fuel cells for hybrid vehicles. For example, solid oxide fuel cells potentially offer very high efficiencies and lower cost than PEM or phosphoric acid cells, but run hotter. Isolation of this heat from the rest of the vehicle is important not only for improved efficiency, but also passenger safety. Reducing the warmup time of fuel cells via thermal management is important to achieve quick power and minimal emissions. More standard power units such as small diesel or spark-ignition engines also need proper cooling. For more information on Fuel cells go to DOE's Fuel Cell Program page.

Exhaust Systems

60% to 80% of emissions in an auto's typical driving cycle comes from "cold start" emissions, that is, pollutants that are emitted before the catalytic converter is hot enough to begin catalyzing combustion products. The National Renewable Energy Laboratory has shown that its patented variable conductance insulation and phasechange heat storage material, can be used to keep the catalyst hot for more than 17 hours, yet allow heat to flow during peak engine loads to prevent the converter from overheating. This would allow 95% of all auto trips to begin with a hot catalyst and little or no cold start emissions. This is particularly important with many HEVs, since their power unit may cycle on and off during a trip.

Fuel System

As emissions standards tighten and exhaust control technologies improve, the issue of evaporative emissions becomes increasingly important. Thermal management of fuel tanks is one approach to reducing these emissions.

Waste Heat Utilization

Heat recovered from any of the above sources can be used in a variety of ways. For winter driving, heat recovery from HEV sources such as the power unit exhaust, propulsion motors, batteries, and power inverter can significantly improve cabin warmup. Because of their small power units, hybrid vehicles generally cannot supply enough heat to the cabin via the conventional coolant-to-air heat exchanger. Waste heat can also be converted into electricity via thermophotovoltaic devices. To learn more about how waste heat can be used for heating see the DOE auxiliary load reduction Web site.

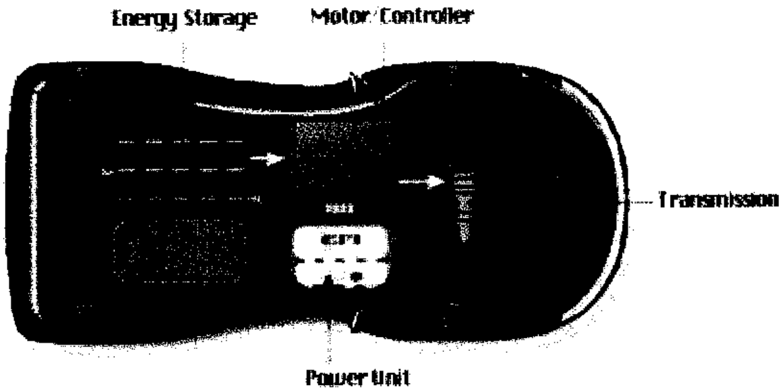
APPENDIX J: PARALLEL CONFIGURATION

Parallel Configuration

An HEV with a parallel configuration has a direct mechanical connection between the HPU and the wheels, as in a conventional vehicle, but also has an electric motor that drives the wheels. For example, a parallel vehicle could use the power created from an internal combustion engine for highway driving and the power from the electric motor for accelerating. Some benefits of a parallel configuration are:

- The vehicle has more power because both the engine and the motor supply power simultaneously.
- Most parallel vehicles do not need a separate generator because the motor regenerates the batteries.
- Because the power is directly coupled to the road, it can be more efficient.

A combination alternator/starter/"flywheel" is being considered for parallel HEVs. This is essentially an electric machine that can electronically balance the engine, start the engine, and take power from the engine and turn it into electricity. It could also provide extra power to the driveline when power assist is needed for hill climbing or quick acceleration.



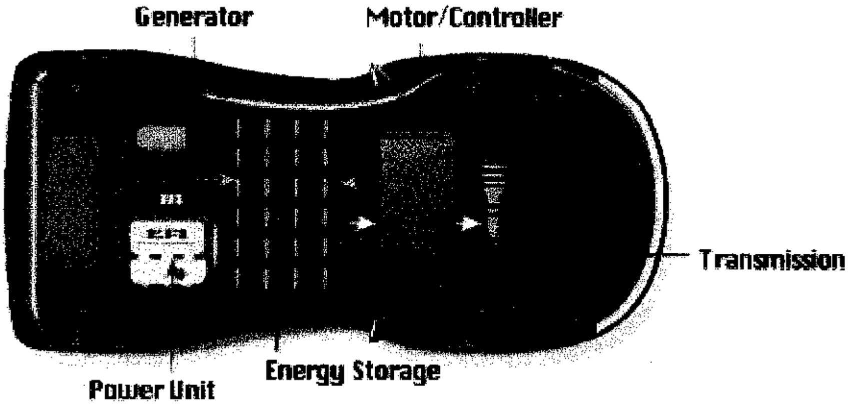
APPENDIX K: SERIES CONFIGURATION

Series Configuration

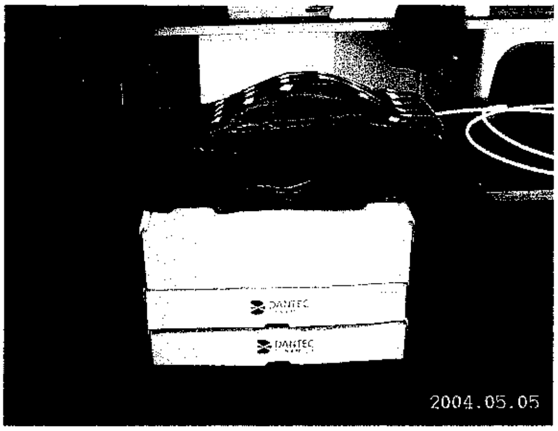
An HEV with a series configuration uses the heat engine or fuel cell with a generator to produce electricity for the battery pack and electric motor. Series HEVs have no mechanical connection between the hybrid power unit and the wheels; this means that all motive power is transferred from chemical energy to mechanical energy, to electrical energy, and back to mechanical energy to drive the wheels. Here are some benefits of a series configuration:

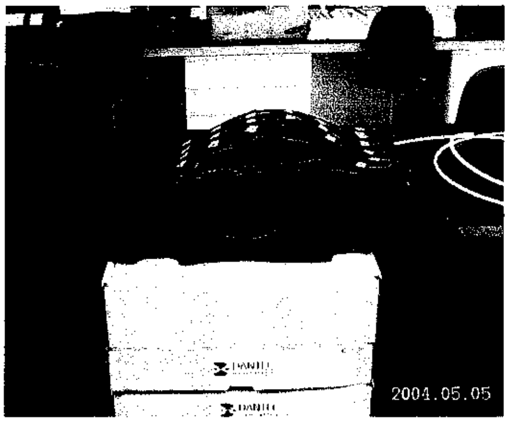
- The engine never idles, which reduces vehicle emissions.
- The engine drives a generator to run at optimum performance.
- The design allows for a variety of options when mounting the engine and vehicle components.
- Some series hybrids do not need a transmission.

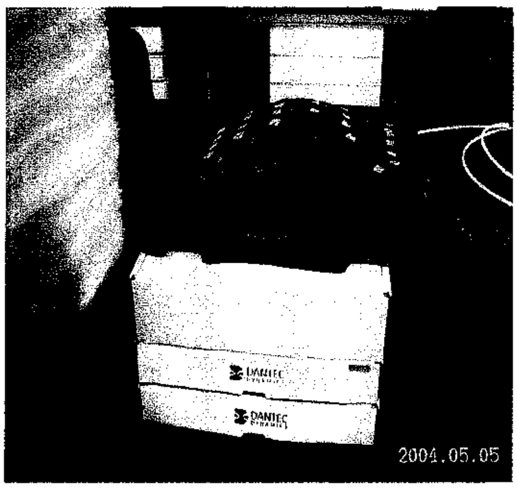
The downside is that series HEVs require larger, and therefore, heavier battery packs than parallel vehicles. In addition, the engine works hard to maintain battery charge because the system is not operating in parallel.



APPENDIX L: VISUALISATION OF TUFT TESTING





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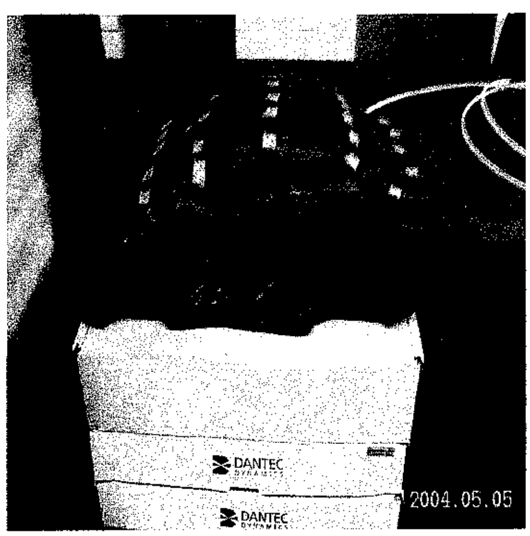
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