DESIGN AND FABRICATION OF A SOLID ROCKET MOTOR

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ABSTRACT

Rocket have been used from as early as the thirteenth century as fireworks and weapon. However, since then the usage of the rocket have been diversified. Nowadays, rocket are used from a as small as model rocketery for hobbyist to as large as a satelite launcher. Another diversified usages of rocket is as a launch vehicle for cloud seeding. This thesis examines the theoritical performance of a solid rocket motor which developed for launching small amteur research rockets. The theoritical results are presented in the form of fabrication two different throat size of nozzle, bulkhead and motor casing. Actual testing of the motor is performed utilizing a specially designed test rig in order to compare the result. As well, optimization of the motor's performance is investigate.

The theoritical performance is found to be in good agreement with the test results, providing a basis for future design of larger engines.

ABSTRAK

Roket telah digunakan seawal abad ketiga belas sebagai bunga api dan senjata. Walau bagaimanapun, sejak itu, penggunaan roket telah dipelbagaikan. Pada masa kini, roket telah digunakan dari sekecil-kecil roket untuk penggemar roket sehingga ke pelancaran satelit. Selain itu, roket juga digunakan sebagai alat untuk pembenihan awan. Tesis ini mengkaji teori prestasi roket motor pepejal yang dihasilkan untuk dilancarkan oleh pengkaji roket amatur. Hasil teori diterjemahkan dalam bentuk dua nozzle berlainan saiz tekak, dinding sekat dan sarung motor. Ujian sebenar terhadap motor dijalankan menggunakan pelnatar ujian yang dicipta khas untuk nenbandingkan keputusan. Oleh hal yang demikian, pengoptimuman prestasi motor disiasat.

Teori prestasi haruslah bertepatan dengan keputusan ujian, menyediakan asas reka bentuk enjin demi masa depan yang lebih besar.

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☐ Plan ☐ Actual

GANTT CHART

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

The purpose of this chapter is to explain about the project background, problem statement, project objectives, project scopes, flow chart of the project to show the flow and overall process for this project.

1.2 PROJECT BACKGROUND

A solid rocket motor's operation and design depend on the combustion characteristics of the propellant. The ultimate success of the motor depends significantly on knowledge of its burning rate behaviour under all operating design-limiting condition mainly pressure and temperature. However, the fundamental combustion processes within a composite solid rocket motor are very complex and not completely understood.

Thermodynamically, a solid rocket motor is identical to liquid-fuel engine. Figure 1.1 shows an example of solid rocket configuration. In comparison with the liquid rocket combustion chamber is very simple. Its consist of a casing for the propellant, which joint to a nozzle. Once the inner surface of the grain is ignited, the motor produces thrust continuously until the propellant is exhausted. [1]

The fundamental simplicity of the solid rocket propellant enables wide application that is main propulsion system for small and medium launchers. As an example, a simple and reliable third stage for orbital injection. The solid rocket propellant is storable, and is relatively safe to handle. There are two main disadvantage which is the motor cannot be controlled once ignited although the trust profile can be preset. Next, the specific impulse is rather low because of the low chemical energy of the solid propellant.[2]

As mentioned before, there are various design of the solid rocket motor and those design are based on the type of propellant and amount of propellant being use. The purpose of my project is to design and fabricate a Ballistic Evaluation Motor (BEM) for solid rocket motor.

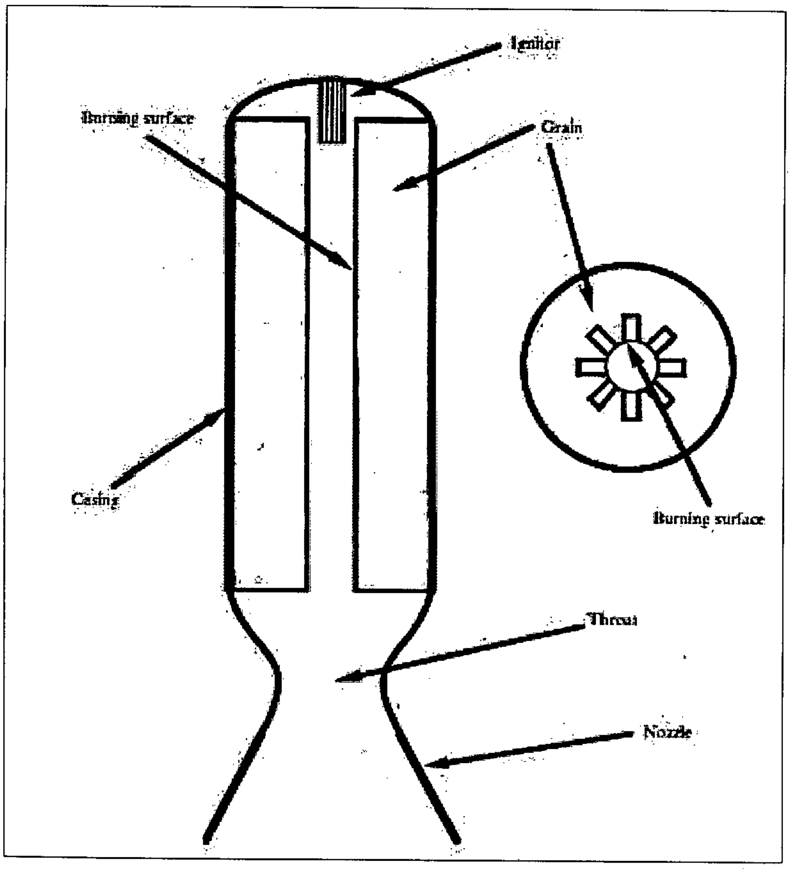

Figure 1.1 : Rocket Motor Features [2]

1.3 PROJECT OBJECTIVE

i. To design and fabricate a Ballistic Evaluation Motor (BEM) for solid rocket motor.

1.4 SCOPE OF THE PROJECT

i. To fabricate a solid rocket motor.
ii. To fabricate a solid rocket motor that use thread as a fastening.
iii. To fabricate 25 mm and 30 mm diameter of throat for nozzle.

1.5 FLOW CHART

Organization of the project is guided from the project flow, a flow chart, or a flow diagram that is graphical representation of a process or system that details the sequencing of steps required to create output. This flow chart was present steps or process of final year project that I will present this semester. Figure 1.2 shows the process of my final year project.

First of all, problems are being identified and the object and scopes are made clear. Further studies will then be conducted regarding the title of the project. This is where literature review started by reviewing the literature study by previous persons.

Then, rough idea about the title is gotten and the designing and drawing phase is then started. Designing phase is commenced by sketching using the available product in the market and editing it to become achievable. The sketching process is carried out using free hand. Then, the design is then drawn into a three dimensional drawing by using the Solid Works.

After that, the bill of material is being listed out one by one. Market surveying is then commenced. Materials listed are being searched by using all the available media. Once gotten all the materials, we can start fabricating the solid rocket motor.

Once the fabrication is done, the product is then tested. If the result is not satisfying, fabrication process has to be repeated until satisfactory result is achieved.

Finally, report everything in the final report writing and presentation slides. Presentation slides are then reviewed by the supervisor so that mistakes can be corrected. Everything regarding the project is then presented to the panels and draft report is submitted to the supervisor. Errors should be corrected and the final product is then submitted to complete the final year project.

Table 1.2 shows the project development done by week.

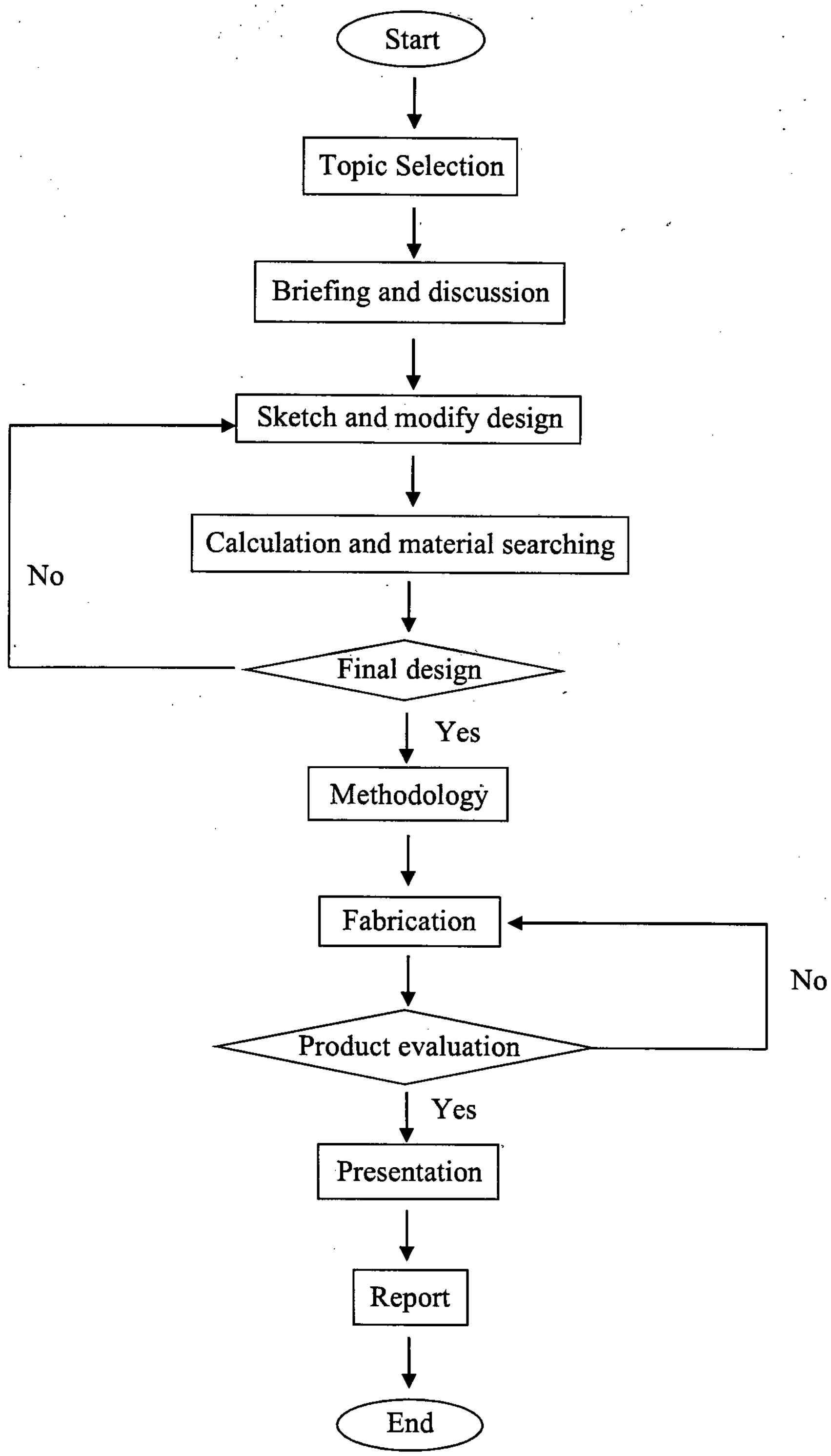

Figure 1.2 : Flowchart

1.6 THESIS ORGANIZATION

Chapter 1 would explain about introduction, problem identifications, objectives, scopes, flow chart and Gantt chart. This particular chapter planned the direction of my final year project.

Chapter 2 will then go through the literature review of the solid rocket motor. This chapter will discuss about the previous researcher about solid rocket motor. This chapter also briefly explain about the main parts of the solid rocket motor.

Chapter 3 will then enlighten about the methodology of carrying out this project from beginning to the end. The tools and machine that were used for fabrication would be discussed as well.

Chapter 4 would then study on the final produce that has been fabricated. The fabricated product would be explained part by part and the testing of it would also be shown. Not only that, discussion on the project would also be achieved.

Chapter 5 is the conclusion of the project. This specific chapter would then summarize the result related to the real world problem and recommend some suggestion for further research.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter mainly provides detail description of literature review done regarding the previous design that produce by the reseacher.

Basically, a rocket motor is a device that develops thrust by the rapid expulsion matter. The main component of rocket motor is propellant that consists of fuel and an oxidiser. Second, rocket motors have a casing to hold the components and control the systems. Next, main parts of rocket motor are igniters followed by nozzle and bulkhead. This chapter briefly explain about the previous research or design that has been tested and the five main component of solid rocket motor.

2.2 PREVIOUS RESEARCHERS

The solid rocket motor belongs to the family of the rocket engine where the thrust achieved by mass ejection and its history can be considered both ancient and recent. It is possible to consider that the black powder is the precursor of modern solid propellants that composed of natural ingredients such as sulphur, charcoal and saltpetre. The black powder has been used since 13th century in Asia to propelled darts. A lot of work has been performed since this time to improve the solid. The main developments for military that is missiles and space activities launchers started in 1945.

Regarding the space activities, the first flights were carried out by liquid propellant rockets, following the world's first successfully flown rocket on March 15, 1926 R. Goddard, USA. The first satellites have been put into orbit by a liquid propellant launcher R7 Semiorka, October 1957 and the first successful US launch Jupiter C in January 1958 used solid propellant rockets for the upper stages. The small US Scout has been the first all solid propellant launcher. Most of the first intercontinental missiles or intermediate range missiles used also liquid propellant engines, for their first generations.[3]

2.2.1 STATIC TEST [4]

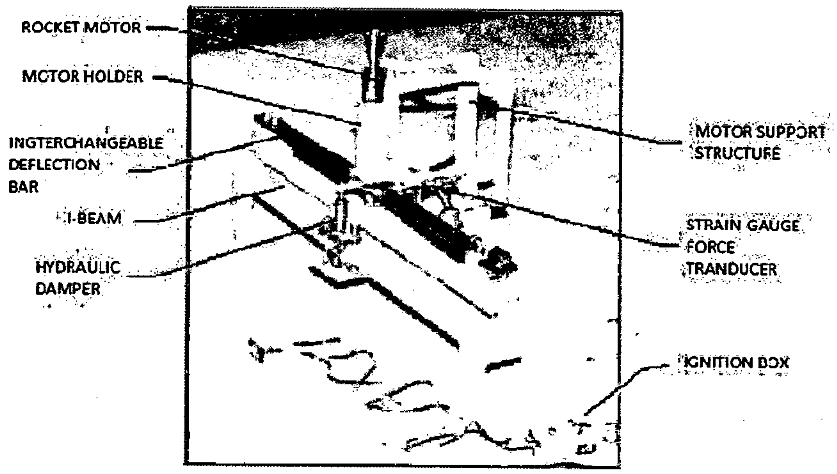

Figure 2.1 : Static Test Rig

The rocket motor was mounted vertically, with the nozzle facing upward, in a tubular holder. The bottom of the holder sat on a deflection bar which acted as a beam supported at both ends, with the load (motor thrust) acting downward at the middle of the beam. The force transducer was mounted such that it's end was in contact with the deflection bar near the middle. As the motor would fire, the thrust would force the deflection bar to deflect downward, and in doing so, also deflect the beam of the force transducer.

2.2.2 STATIC TEST STAND [4]

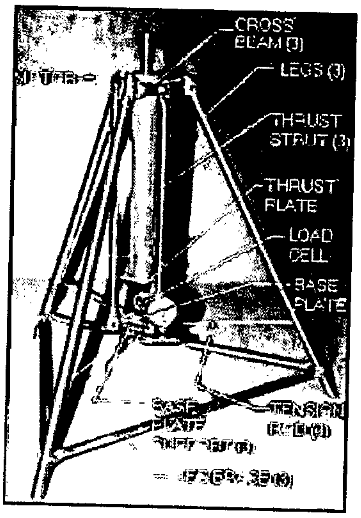

Figure 2.2 : Three Base Plate Supports

The basic structural form of the test stand is that of a tripod. A significant advantage to having three support legs is that the stand is self-leveling on any surface, with equal load distribution to each leg. The rocket motor is mounted vertically, nozzle upward, such that the thrust force exerts against the thrust plate. This plate sits atop the load cell, which bears against the Base Plate. The Base Plate is supported by a triangular arrangement of three Base Plate Supports which are attached at the ends to the three vertical Thrust Struts. These struts transmit the thrust load to the three Cross Beams. The tension load in the struts is beamed out to the three support Legs. The resulting compression load in the legs is then reacted at the ground surface. Wooden pads are placed under the foot of each leg to distribute the load in bearing.

2.2.3 LW-1 ROCKET MOTOR [5]

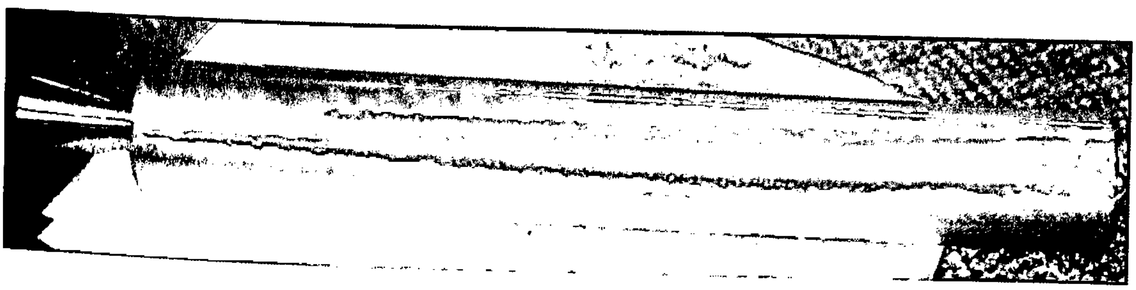

Figure 2.3 : 6061 T-6 aluminium

The 6061 T-6 aluminium was used for the casing, and mild steel for the nozzle and upper bulkhead. While the nozzle and bulkhead are still. The high strength aluminium has a tensile strength about the same as the mild steel that have worked with in the past, in fact, it has the same casing thickness as well at 0.065". While strong, the aluminium is also fairly soft, and care must be taking in the handling and machining of the metal. The biggest drawback of the aluminium is it's lack of resistance to heat. Requiring the use of a thermal barrier in the combustion chamber. The heavy walled cardboard mailing tube was used for thermal protection.

2.2.4 MB-2 ROCKET MOTOR [5]

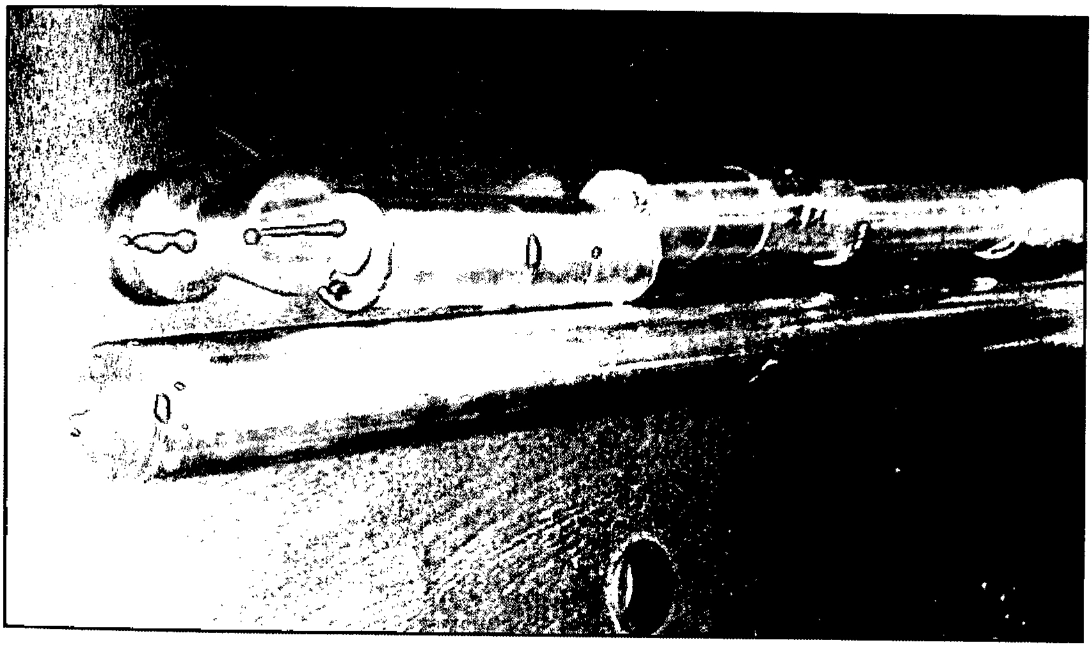

Figure 2.4 : 2" diameter casing

This motor may be pushing the limits for a 2" diameter casing. The motor design defies conventional wisdom. The length to diameter ratio is huge at 15 to 1, and the core to nozzle throat ratio is way too small. But, the initial start up phase of the motor enlarges the core diameter before the ends start burning, so the first 10 or 15 hundredths will burn up just bringing the motor to pressure.

The initial calculations have this motor holding about 4.5 lbs of propellant, assuming an Isp of 130 or so, that should should give me a motor with a total impulse of over 580 lb sec. making it a low "L" class motor. The grains are designed for a mostly flat thrust profile, even though experience has indicated it won't be a very flat profile.

This motor is going into a rocket project called Cosmo. This is also a project for the upcoming IEAS convention launch in August, so a name would be needed. There is no real significance to the name Cosmo, other than that's my Border Collie's name. The Cosmo series of rockets will all be personal best altitude attempts. So, if the Cosmo 1 makes it to say 10,000 feet AGL, Cosmo 2 will be an attempt to break his previous best.

2.3 COMPONENT OF ROCKET MOTOR

2.3.1 Motor Case

The case not only contains the propellant grain, but also serves as a highly loaded pressure vessel. Case design and fabrication technology has progressed to where efficient and reliable motor cases can be produced consistently for any solid rocket application. Most problems arise when established technology is used improperly or from improper design analysis, understating the requirements, or improper material and process control, including the omission of non-destructive tests at critical points in the fabrication process. Case design is usually governed by a combination of motor and vehicle requirements. Besides constituting the structural body of the rocket motor with its nozzle, propellant grain, and so on, the case frequently serves also as the primary structure of the missile or launch vehicle. Thus the optimization of a case design frequently entails trade-offs between case design parameters and vehicle design parameters. Often, case design is influenced by assembly and fabrication requirements.[1]

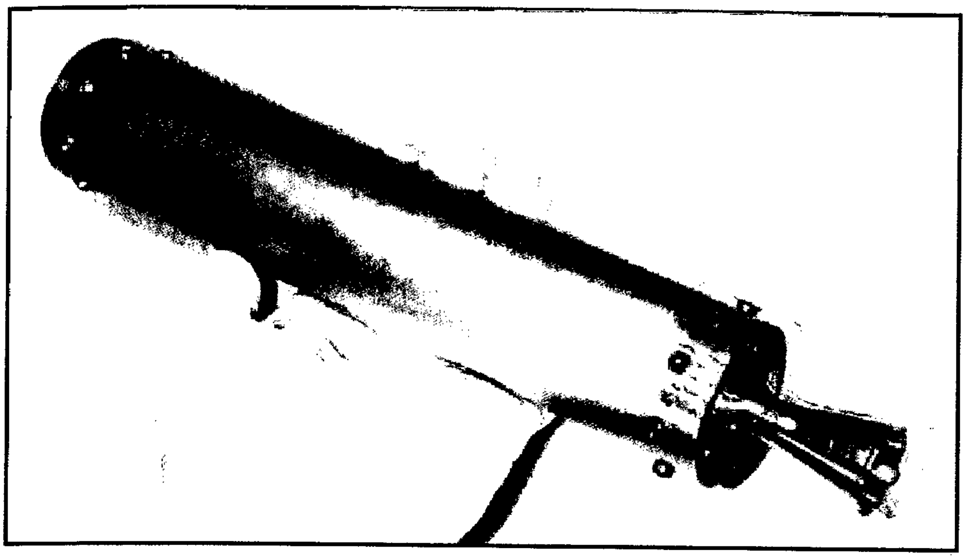

Figure 2.5 : Rocket Motor Casing

[http://www.nakka-rocketry.net/epoch/epoch2.jpg]

2.3.2 Nozzle

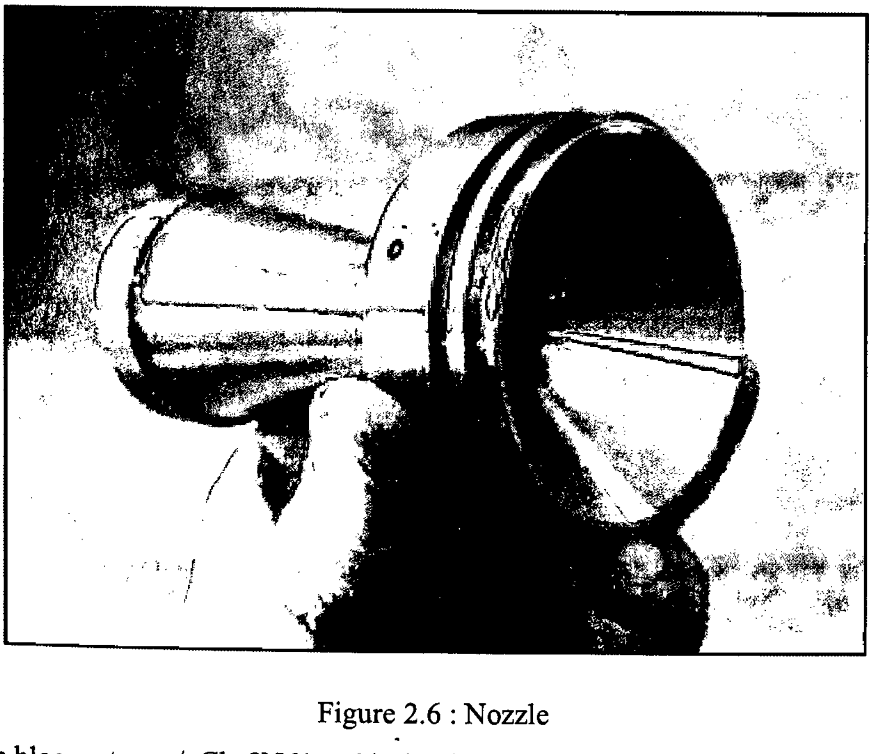

Figure 2.6 : Nozzle

[http://3.bp.blogspot.com/_Chz8N61cyvI/Ssln3d_aRKI/AAAAAAAAENc/2412bNatbmk/s320/CompletedNozzle.jpg]

The rocket nozzle can surely be described as the epitome of elegant simplicity. The primary function of a nozzle is to channel and accelerate the combustion products produced by the burning propellant in such as way as to maximize the velocity of the exhaust at the exit, to supersonic velocity. The familiar rocket nozzle, also known as a convergent-divergent, ordeLaval nozzle, accomplishes this remarkable feat by simple geometry. In other words, it does this by varying the cross-sectional area or diameter in an exacting form.

The analysis of a rocket nozzle involves the concept of steady, *one-dimensional compressible fluid flow of an ideal gas*. Briefly, this means that:

- The flow of the fluid (exhaust gases + condensed particles) is constant and does not change over time during the burn.
- One-dimensional flow means that the direction of the flow is along a straight line. For a nozzle, the flow is assumed to be along the axis of symmetry.

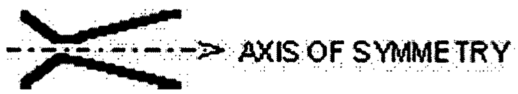

Figure 2.7 : Air Flow

- The flow is compressible. The concept of compressible fluid flow is usually employed for gases moving at high (usually supersonic) velocity, unlike the concept of incompressible flow, which is used for liquids and gases moving at a speeds well below sonic velocity. A compressible fluid exhibits significant changes in density, an incompressible fluid does not.

The concept of an ideal gas is a simplifying assumption, one that allows use of a direct relationship between pressure, density and temperature, which are properties that are particularly important in analyzing flow through a nozzle.

The goal of rocket nozzle design is to accelerate the combustion products to as high an exit velocity as possible. This is achieved by designing the necessary nozzle geometric profile with the condition that isentropic flow is to be aimed for. Isentropic flow is considered to be flow that is dependant only upon cross-sectional area which necessitates frictionless and adiabatic (no heat loss) flow. Therefore, in the actual nozzle, it is necessary to minimize frictional effects, flow disturbances and conditions that can lead to shock losses. In addition, heat transfer losses are to be minimized. In this way, the properties of the flow are near isentropic; and are simply affected only by the changing cross-sectional area as the fluid moves through the nozzle.[4]

Typical nozzle cross-sectional areas of particular interest are shown in the figure below

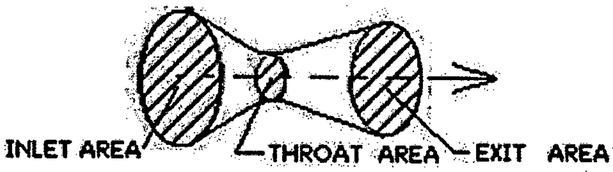

Figure 2.8 : Throat Area [4]

2.3.3 Propellant

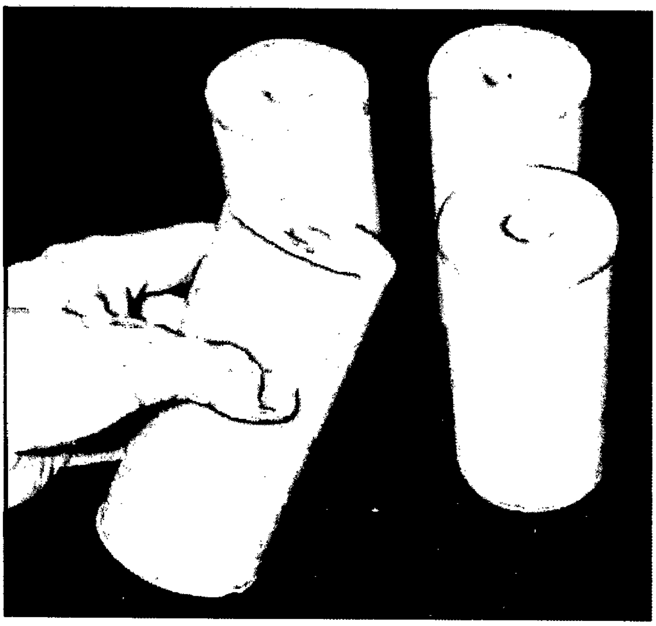

Figure 2.9 : Propellant [4]

A rocket propellant in solid form used in a solid-propellant rocket motor. It usually contains both fuel and oxidizer combined, or mixed and formed, into a monolithic grain. There are two families of solids propellants that is homogeneous and composite. Both types are dense, stable at ordinary temperatures, and easily storable.

Homogeneous propellants are either simple base or double base. A simple base propellant consists of a single compound, usually nitrocellulose, which has both an oxidation capacity and a reduction capacity. Double base propellants usually consist of nitrocellulose and nitro-glycerine, to which a plasticiser is added. Homogeneous propellants do not usually have specific impulses greater than about 210 seconds under normal conditions. Their main asset is that they do not produce traceable fumes and are, therefore, commonly used in tactical weapons. They are also often used to perform subsidiary functions such as jettisoning spent parts or separating one stage from another.

Modern composite propellants are heterogeneous powders (mixtures) which use a crystallized or finely ground mineral salt as an oxidizer, often ammonium perchlorate, which constitutes between 60% and 90% of the mass of the propellant. The fuel itself is aluminium. The propellant is held together by a polymeric binder, usually polyurethane or poly butadiene's. Additional compounds are sometimes included, such as a catalyst to help increase the burning rate, or other agents to make the powder easier to manufacture. The final product is rubberlike substance with the consistency of a hard rubber eraser.[6]

2.3.4 Bulkhead

Figure 2.10 : Bulkhead

[http://2.bp.blogspot.com/_Chz8N61cyvI/StJjb_Ieq5I/AAAAAAAAEP0/5Y9vWDRvVA8/s320/IMG_3840.jpg]