"MODELING, ANALYSIS, AND FABRICATION OF SOLID ROCKET MOTOR"

Submitted in partial fulfillment of the requirements of the degree of

Bachelor of Technology
in
Aerospace Engineering
By

STUDENT NAME	PRN NO.
SANKET BANSODE	190101051007
VAISHNAVI SOGALAD	190101051020
MITALI JADHAV	190101051028
PRANAY MALEWAR	190101051030
UTKARSH NINAWE	190101051045

Under the Supervision

of

Dr. Ravi Krishna Swami Garigipati

(Assistant professor)

SANDIP UNIVERSITY
UGC Recognised

Department of Aero Engineering
School of Engineering and Technology
Sandip University Nashik

AY 2022-2023

SANDIP UNIVERSITY NASHIK SCHOOL OF ENGINEERING & TECHNOLOGY

Department of Aero Engineering

Recommendation

This is to certify that the dissertation entitled **"Modelling, Analysis, and Fabrication of Solid Rocket Motor"** submitted by **Sanket Bansode (190101051007) Vaishnavi Sogalad (190101051020) Mitali Jadhav (190101051028) Pranay Malewar (190101051030) Utkarsh Ninawe (190101051045)** has been carried out under my guidance and supervision. The dissertation is approved for submission towards partial fulfillment for the award of the degree of **Bachelor of Technology** in **Aerospace Engineering.**

It is further certified that this work has not been submitted for the award of any other degree or diploma to my knowledge.

Prof. Dr. Ravi Krishna Swami Garigipati
Supervisor

Prof. Dr. Vishal N Sulakhe
Professor & Head Aero,
SOET, SUN

Dr. Prakash Burade
Associate Dean
SOET, SUN

Date-
Place-Sandip University, Nashik

Department of Aerospace Engineering
School of Engineering and Technology

SANDIP
UNIVERSITY

Certificate

This is to certify that

Sanket Bansode
(190101051007)
Vaishnavi Sogalad
(190101051020)
Mitali Jadhav
(190101051028)
Pranay Malewar
(190101051030)
Utkarsh Ninawe
(190101051045)

Students of B. Tech with specialization in "Aerospace Engineering" was examined in a dissertation entitled

"Modelling Fabrication and Analysis of Solid Rocket Motor"
on

/06/2023

at

Department of Aero Engineering

School of Engineering and Technology, Sandip University, Nashik

Internal Examiner **External Examiner**

Date: -
Place: - Sandip University Nashik

Department of Aero Engineering
School of Engineering and Technology

SANDIP
UNIVERSITY

Candidate Declaration

I declare that this written submission represents my ideas in my own words and where other's ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated, falsified, or plagiarized any idea/data/fact/source in my submission. I understand that any violation of the above may cause for withdrawal of my degree by the institute and can also evoke penal action from the sources which have not been properly cited or from whom proper permission has not been taken when needed.

Sanket Bansode (190101051007)

Vaishnavi Sogalad (190101051020)

Mitali Jadhav (190101051028)

Pranay Malewar (190101051030)

Utkarsh Ninawe (190101051045)

Acknowledgment

First of all, I am very thankful to Sandip University (SOET), Department of Aero Engineering for giving us the opportunity to work on this project. I would like to thank our Head of the Department Prof. Dr. Vishal N Sulakhe for all his guidance and tireless efforts and for inspiring us with his knowledge. I would also like to convey my deepest thanks and gratitude to our project guide **Prof. Dr. Ravi Krishna Swami Garigipati** for guiding us through the entire project. His immense knowledge and plentiful experience have encouraged us in all the time of our project research and daily life.

I am extremely grateful to our faculties for their invaluable advice, continuous support, and patience during the entire project. Their review sessions and valuable feedback helped us to achieve our final results. I also want to convey thanks to all the faculty members for their guidance and support even at the times of pandemic. I am grateful for all your efforts. I would also like to thank my parents for providing me with all the necessities and for their constant support. Finally, I would like to convey my lovable thanks to my friends too for their good cooperation and support.

Sanket Bansode
(190101051007)

Vaishnavi Sogalad
(190101051020)

Mitali Jadhav
(190101051028)

Pranay Malewar
(190101051030)

Utkarsh Ninawe
(190101051045)

Dedicated to my Professors for their constant Guidance and Support. And to my Parents for their love and inspiration

Abstract

Solid rocket propellant is storable and is relatively safe to handle also it is reliable and its cost effective compared to the liquid fueled engine. Solid fueled rocket is essentially a single single use item. The motor cannot be ignited, and specific impulse is rather low because of the low chemical energy of solid propellant. Project focuses on the modeling and fabrication and analysis of the solid rocket motor. The basic design and analysis of casing and nozzle was conducted. have accomplished the flow analysis of CD Nozzle with pressure and velocity contour. Also performed the premeasured calculations using the software namely Open Motor which led to the exact outcome of various parameters like Peak Pressure, as well as Peak mass flux. Selection of the propellant and the materials used for the casing of the motor were selected based on the research and theoretical data.

The use KNSU i.e. Potassium nitrate/Sucrose as our main propellant components. There is no need for the binder since the potassium nitrate itself works as a Oxidizer + Binder. The O/F ratio for the propellant is 65/35. We have designed a CD Nozzle in SolidWorks using appropriate dimensions. A slurry Caramelized mixture has been found by adding both the potassium nitrate and sucrose which are highly inflammable. Because the mixture is supposed to be handled very carefully. Also run a test simulation on software called Open Motor which led us to the conclusion for the grain type. Furthermore, we get the results of the aerodynamic analysis of the CD nozzle where the pressure and velocity variations with 1500 iterations using Ansys.

Table Of Contents

List of Tables

List of Figures

List of Symbols and Abbreviations

DB	**Double-base propellants**
NC	**Nitrocellulose**
NG	**Liquid Nitroglycerine**
EDB	**Extruded double-base**
CDB	**Cast double-base propellant**
RDX	**Research Department Explosive (Cyclotrimethylenetrinitramine)**
AP	**Ammonium perchlorate**
A1	**Aluminum**
CMDB	**Composite-modified double-base propellant**
HTPB	**Hydroxyl-terminated polybutadiene**
As	**Exit cone area**
At	**Nozzle throat area**
HMX	**High melting explosive (cyclotetramethylene tetranitramine)**
AN	**Ammonium nitrate (NH_4NO_3)**
KNSU	**Potassium Nitrate-Sucrose**
SLS	**Sodium Lauretha Sulfate**
O/F ratio	**Oxidizer/Fuel ratio**
KNO_3	**Potassium nitrate**
NO_3^-	**Nitrate ions**

CHAPTER 1

INTRODUCTION

1.1 Introduction

Solid propellant rocket motors (SRM) are commonly employed in satellite launch vehicles, according to reports. Solid rocket motor are made up of three separate structural materials: solid propellant, liner, and casing materials. In the construction of tiny spacecraft, the solid rocket motor (SRM) plays a crucial role. However, vortical flows can sometimes be caused by a propellant inhibitor, which produces pressure oscillation. The rocket motor case is a non-energy-contributing missile component; the design goal is to make the case as light as possible while staying within technological and economic constraints.

The Solid rocket motor various physical and chemical processes that occur in an actual rocket motor during operation are highly complex. These processes include the complex chemical reactions that occur during combustion; the manner in which "consumption" of the propellant grain occurs during burning; the behaviour of the flow of exhaust gases as they form at the burning surface, travel through the chamber, and exit through the nozzle; the interaction between the exhaust gases and condensed particles (smoke).

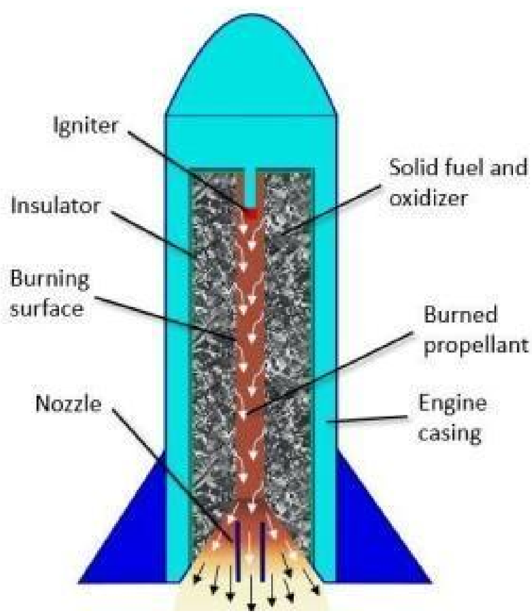


Figure 1.1 Basic components of solid rocket motor

Rocket engines simultaneously contain the fuel required for propulsion and oxidizers required for combustion. Therefore, they are different from other engines; they can work both in the Earth's atmosphere and in space where oxygen is absent.
Solid propellant rocket engines contain fewer components and have simple-structure than liquid and hybrid propellant rocket engines. Therefore, they have relatively low production costs, ease of storage and transportation. This situation makes the solid fuel engine to be preferred as an propellant engine in defense and space systems. Another advantage of solid propellant is that a thrust is relatively stable and can therefore be produced and stored for future use. Moreover, they can burn very quickly and have no sensitive to shock, vibration and acceleration.
The theoretical analysis of a solid rocket motor necessitates certain simplifications, that is, the assumption is of an ideal rocket motor. An ideal rocket motor assumes the following:
The propellant combustion is complete and does not vary from that assumed by the combustion equation.

- The combustion products obey the perfect gas law.
- There is no friction impeding the flow of exhaust products.
- The combustion and flow in the motor and nozzle is adiabatic, that is, no heat loss occurs to the surroundings.
- Unless noted otherwise, steady-state conditions exist during operation of the motor. This means that the conditions or processes that occur do not change with time (for a given geometric conditions) during burning.
- Expansion of the working fluid (exhaust products) occurs in a uniform manner without shock or discontinuities.
- Flow through the nozzle is one-dimensional and non-rotational.
- The flow velocity, pressure, and density is uniform across any cross-section normal to the nozzle axis.

Chemical equilibrium is established in the combustion chamber and does not shift during flow through the nozzle. This is known as "frozen equilibrium" conditions.
Burning of the propellant grain always progresses normal (perpendicular) to the burning surface, and occurs in a uniform manner over the entire surface area exposed to combustion.
Any further assumptions that may be required are stated as necessary in the following analyses.

Although it seems like a lot of simplifying assumptions must be made, in fact, these are all reasonable and can be expected to reflect the actual behaviour of the rocket motor fairly closely

Solid Rocket Motor will be used for a spread of applications that need a good range of casting. This project focuses on the event of solid rocket design modelling and fabrication. The analysis of the flow of the nozzle makes it one among the key elements of a solid rocket motor and its analysis development perform. Unlike different liquid rocket engines, a solid rocket and its key part can't be tested before, as testing can cause nozzle throat erosion and particle congestion which will jeopardize engine performance. For manufacturing of nozzle and the casing the material used is mild steel. the fabrication of the case motor and nozzle is done by the welding machine. It will be accustomed simulate the interior combustion characteristics and visualize the combustion flow similarly as predict the performance. By doing thus, improvement of the motor performance will be relinquished having to create and check innumerable real rocket motors.

Thus, a significant cost-saving will be achieved. A brand-new technique that is that the IR experimental approach has additionally been developed. The nozzle style is conducted by victimization SolidWorks 2019. Once the look has been completed, the CFD simulation is performed.

1.2 Overview of solid rocket motor

Solid rocket motors are used in launch vehicles, missiles, and spacecraft. In a solid propellant rocket, the propellant to be burnt is contained within the combustion chamber or in case.

The propellant charge or the grain contains the chemical elements for complete burning. Once ignited, it burns at a designed rate till the propellant is completely consumed. Solid rockets are relatively simple as compared to the other systems.

Solid rocket engines are used on air-to-air and air-to-ground missiles, on model rockets, and as boosters for satellite launchers. In a solid rocket, the fuel and oxidizer are mixed together into a solid propellant which is packed into a solid cylinder. A hole through the cylinder serves as a combustion chamber. When the mixture is ignited, combustion takes place on the surface of the propellant. A flame front is generated which burns into the mixture. The combustion produces great amounts of exhaust gas at high temperature and pressure. The amount of exhaust gas that is produced depends on the area of the flame front and engine designers use a variety of hole shapes to control the change in thrust for a particular engine. The hot exhaust gas is passed through a nozzle which accelerates the flow. Thrust is then produced according to Newton's third law of motion. The amount of thrust produced by the rocket depends on the design of the nozzle.

According to Fuller, a solid rocket motor at its core is a relatively simple device with no moving parts. It includes an outer cylindrical casing, solid propellant with a hole often star-shaped down the centre, called "the grain", an igniter to light the propellant and a nozzle to exhaust the combustion gases.

Suppose we have several rocket motors with identical structures and nozzles and loaded with different propellant grains. A comparison of their performance is easily done by measuring the intensity of the thrust F obtained by each of the motors during operation. All things being equal, the various compositions of propellant grains can be compared by dividing thrust(F) obtained by the weight flow rate of propellant burned. This ratio - the thrust obtained versus the weight flow rate for a given rocket motor allows us to determine the intrinsic characteristics of the propellant grain used.

Initially the propellant is ignited and it burns at a rapid rate producing gases. These gases develop pressure inside the combustion chamber and this pressure force the gases to pass through the only exit available, which is the nozzle. Nozzle first reduces the area of exit in order to increase the velocity of exhaust gases and gases reach supersonic velocity at the nozzle throat. Now the area is increased to further increase the velocity, as according to supersonics increase in area produces increase in the velocity.

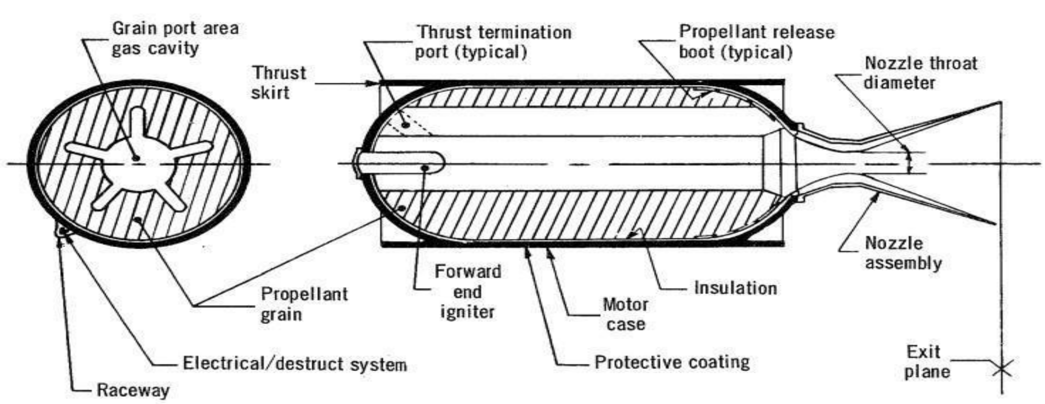


Figure 1.2 Solid rocket motor

The fabrication of SRMs involves several techniques, depending on the specific components and requirements. Some common fabrication methods include:

a. Case Manufacturing: The motor casing or case is typically made using techniques such as filament winding (wrapping composite fibres impregnated with resin around a mandrel), autoclave molding, or hand lay-up.

b. Propellant Casting: Solid rocket propellant is often cast into the motor casing using methods like gravity casting or vacuum-assisted casting. The casting process involves carefully pouring the propellant mixture into the casing and allowing it to cure.

c. Nozzle Manufacturing: Nozzles are typically fabricated using materials such as carbon carbon composites, metals, or ablative materials. Techniques like machining, molding, or additive manufacturing (3D printing) can be employed to manufacture the nozzle with the desired geometry and material properties.

d. Igniter Fabrication: The igniter, which initiates the combustion process in an SRM, can be fabricated using techniques like machining, welding, or incorporating pyrotechnic materials.

e. Assembly: Once the various components are fabricated, they are assembled to form the complete SRM. This involves precision alignment, bonding or fastening of components, and integration of subsystems such as the igniter, nozzle, and propellant grain.

1.2.1 Classification of Propellant:

Propellants can be classified as:

1. **Double -based propellants**
2. **Composite propellants**
3. **Composite modified double-base propellant**
4. **Nitramine propellants**

1. Double based propellants:

Double-base (DB) propellants form a homogeneous propellant grain, usually a nitrocellulose (NC*), a solid ingredient which absorbs liquid nitroglycerine (NG) plus minor percentages of additives.
Both the major ingredients are explosives and function as a combined fuel and oxidizer.

Both extruded double-base (EDB) and cast double-base (CDB) propellant have found extensive applications, mostly in small tactical missiles folder design. By adding crystalline nitramines (HMX or RDX) the performance and density can be improved; this is sometimes called cast-modified double-base propellant.
These four classes of double base have nearly smokeless exhausts. Adding some solid ammonium perchlorate (AP) and aluminum (A1) increases the density and the specific impulse slightly, but the exhaust gas is smoky. The propellant is called composite-modified double-base propellant or CMDB.

2. Composite Propellants:

Composite propellants form a heterogeneous propellant grain with the oxidizer crystals and a powdered fuel (usually aluminum) held together in a matrix of synthetic rubber (or plastic) binder, such as polybutadiene (HTPB).
Composite propellants are cast from a mix of solid (AP crystals, A1 powder) and liquid (HTPB, PPG) ingredients. The propellant is hardened by crosslinking or curing the liquid binder polymer with a small amount of curing agent, and curing it in an oven, where it becomes hard and solid.
In the past three decades the composite propellants have been the most commonly used class.

3. Composite modified double-base propellant :

Composite modified double-base propellant (CMDB propellant) is a type of solid rocket propellant that falls under the category of double-base propellants. Double-base propellants are a class of solid propellants that consist of a mixture of two energetic compounds, known as the

binder and plasticizer.
In the case of CMDB propellant, the binder is typically nitrocellulose, which is a highly energetic material. Nitrocellulose provides the fuel component of the propellant, contributing to its energy content. The plasticizer used in CMDB propellant is usually nitroglycerin, which acts as both a plasticizer and an oxidizer.

4. Nitramine propellants:

Nitramine propellants are a class of solid rocket propellants that use nitramine compounds as the primary ingredient. Nitramines are a group of highly energetic materials that contain both fuel and oxidizer components within their molecular structure. These compounds provide high energy content and contribute to the performance of the propellant.
The most common nitramine compound used in propellants is cyclotrimethylenetrinitramine, commonly known as RDX (Research Department Explosive). RDX is a powerful explosive with high density and excellent stability. It serves as both the fuel and oxidizer in nitramine propellants.
Nitramine propellants are typically formulated by combining RDX with a binder material, such as hydroxyl-terminated polybutadiene (HTPB), and various additives. The binder provides structural integrity and holds the propellant grains together, while the additives may include burn-rate modifiers, plasticizers, stabilizers, and curing agents to tailor the propellant's characteristics.

The reaction can be classified as smoking, reducing smoking, or smoking less (essentially smoke less) based on the intensity of the smoke in the exhaust. Aluminum powder, an ideal gas component, oxidizes to alumina, producing a small amount of smoke seen in the exhaust.
Propellants can be classified according to some of their main production uses. Bulk propellants a re produced by mechanical mixing of solid and liquid components, followed by pouring and curi ng; this is the most common method for composite fuels. Many cast irons harden by reaction of b inder and curing agent at high temperature (45 to 150 °C); However, some of them work at low t emperatures (20 to 25°C) or crystallize etc.

1.2.2 Nozzle

The general shape of a nozzle (Fig. 1.1), called the nozzle profile, includes three major parts:

- The convergent zone of the nozzle, which channels the flow of propellant Combustion gases
- The throat: selection of throat dimensions determines the operating point of the rocket motor
- The exit cone of the nozzle, which increases the exhaust velocity of the gases in their expansion phase, consequently improving the propulsive effect.

Currently, the shape and complexity of a nozzle depend on the expected level of performance and on the field of application of the rocket motor (space, ballistic missiles, tactical missiles). Its design requires knowledge of the following parameters. Internal operating pressure of the motor, which affects the structural indignity of the nozzle and the ablation of the thermal materials.

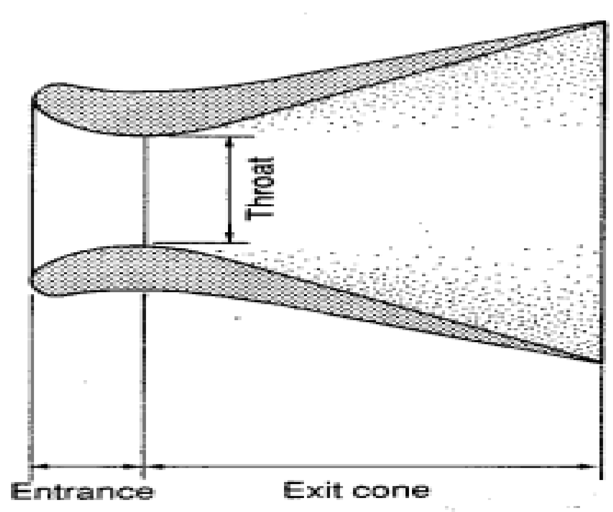


Figure 1.3 Nozzle

Burning time, often negligible for small rocket motors (a few seconds) but in the case of large rocket motors (measured by the minute) an essential factor in the determination of the thickness required to withstand thermal transfer. Throat diameter, which will determine the operating pressure.

Type of propellant used, the gases and the propellant's burning temperature determine the selection of the thermal materials. Space available; often a function of equipment necessary for the guidance of the missile; for example, the nozzles located at the end of a blast tube on some tactical engines.

Expansion ratio exit cone area As versus nozzle throat area At,

$$\text{i.e. } e\bullet = As/At$$

must allow pressure in the exit section on equal to the ambient pressure to allow maximum efficiency. Because space is usually limited on ballistic missiles, the concept of the extendible nozzle exit cone (during flight) permits an increase in this ratio during operation. Submergence of the nozzle into the burning chamber defined as the ratio of the integrated length versus total length. to minimize the external part of the nozzle. This technology is used particularly on ballistic and space.

Here are some nozzle types:

Convergent Nozzles: Convergent nozzles have a reduced cross section at the outlet inlet. It is used to move water or gas by converting heat or pressure into kinetic energy. Convergent nozzles are often used in rocket engines, jet engines and gas turbines.

Convergent-Divergent (CD) Nozzles: Convergent-divergent nozzles, also known as De Laval nozzles, have an intersection followed by a divergent nozzle. The convergent section accelerates the flow and the divergent section expands the flow to supersonic speed.CD nozzles are used in supersonic and hypersonic propulsion systems, including rockets and supersonic aircraft.

De Laval Nozzle: The De Laval Nozzle is a special type of convergent-divergent nozzle. It is designed to operate at supersonic speeds and is used in rocket engines to effectively remove gases at high speeds. De Laval nozzles are usually bell-shaped to maximize airflow.

Plug Nozzle: The plug nozzle is a type of CD nozzle with a cylinder plug in the throat. By changing the position of the plug, the area ratio and expansion characteristics of the nozzle can be adjusted to improve the performance of different heights or planes. Plug nozzles are frequently used in some rocket engines.

Aerospike Nozzle: The Aerospike Nozzle is a special nozzle design that uses an aerodynamic structure instead of a physical nozzle cover. It has a central peak surrounded by a donut. As the fluid passes through the spikes and chambers, it expands and creates thrust. Aerospike nozzles are used in some experimental rocket engines to improve performance at higher altitudes. These are just a few examples of different nozzle types used in different applications. Each type of nozzle is designed to suit specific conditions, environments and operations

1.2.3 Casing

The rocket motor casing is a typical energy transfer system where the chemical energy in the fuel is changed over into thermal energy accompanied by high pressure, producing gases pass through the nozzle where the internal energy is converted to kinetic energy that generates the propulsive force (thrust). The Solid propellant rocket motor is one of the family of the rocket engine where is the fuel and oxidizer are mixed in a single solid it is the most commonly used compared with the other rocket motors due to its simplicity in design, easy manufacturing and its high reliability.

Fuel and oxidizer are mixed and stored in the combustion chamber which allows SRM to perform its function without air dependence. The simple configuration of rocket motor consists of a dome, Igniter, motor case, insulation, propellant and nozzle. The rocket motor case is considered a significant structure in SRM. The motor case structure should have enough strength and lightweight, where the combustion takes place producing high temperature of 2000 to 3500 ˚C and operating pressure of 3 to 30 MPA. The structural material for the solid rocket motor case is divided into two main types:

(1) conventional materials such as high resistance steel or high strength aluminum and titanium alloys.

(2) composite materials (carbon, Kevlar, glass). Composite materials are used in the majority of the new rocket motor cases due to its high strength to weight ratio, high impact strength and design flexibility which contributes in the development of the rocket engine industry.

Made either from metal (high-resistance steels) or from composite materials by filament winding (glass, Kevlar, carbon), the case must be capable of withstanding the internal pressure resulting from the motor operation, approximately 3-25 MPa, with a sufficient safety coefficient, usually of the order of 1.4.

The propellant grain is a cast, molded, or extruded body and its appearance and feel is similar to that of hard rubber or plastic. Once ignited, it will burn on all its exposed surfaces to form hot gases that are then exhausted through a nozzle. A few rocket motors have more than one grain inside a single case or chamber and very few grains have segments made of different propellant composition (e.g., to allow different burning rates). However, most rockets have a single grain.

There are two methods of holding the grain in the case, Cartridge-loaded or freestanding grains are manufactured separately from the case (by extrusion or by casting into a cylindrical mold or cartridge) and then loaded into or assembled into the case. Cartridge-loaded grains are used in some small tactical missiles and a few medium-sized motors.

In case-bonded grains the case is used as a mold and the propellant is cast directly into the case and is bonded to the case or case insulation. Free-standing grains can more easily be replaced if the propellant grain has aged excessively.

They often have a lower cost and are easier to inspect. The case-bonded grains give a somewhat better performance, a little less inert mass (no holding device, support pads, and less insulation), a better volumetric loading fraction, are more highly stressed, and often somewhat more difficult and expensive to manufacture.

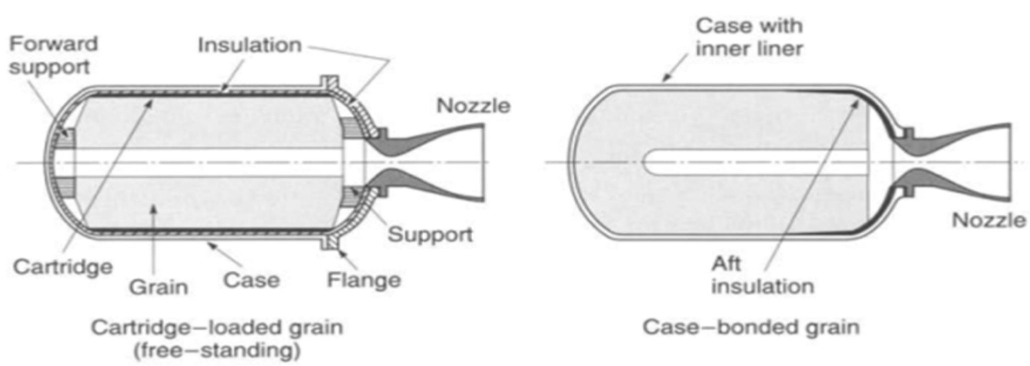


Figure 1.4 Cartridge Loaded and case bonded grain

The casing may be constructed from a range of materials. Cardboard is used for small black powder model motors, whereas aluminium is used for larger composite-fuel hobby motors. Steel was used for the space shuttle boosters. Filament-wound graphite epoxy casings are used for high-performance motors.

The casing must be designed to withstand the pressure and resulting stresses of the rocket motor, possibly at elevated temperature. For design, the casing is considered a pressure vessel.

The material is organized around the major tasks in case design:

(1) Case configuration (case characteristics as related to the motor and vehicle requirements) (2) Material selection (case loading, mode of failure, fatigue, fabrication, configuration, environmental effects)

(3) Case design (safety factor, end closure, case attachments, case loads, structural analysis, structural dynamics)

(4) Case fabrication

(5) Inspection and testing (inspection plan, destructive and non-destructive testing, and hydrostatic test).

To protect the casing from corrosive hot gases, a sacrificial thermal liner on the inside of the casing is often implemented, which ablates to prolong the life of the motor casing.

Motor case design is governed by the motor and vehicle requirements, such as performance characteristics (including motor propellant grain design), envelope constraints, mission profile, and other components within the individual stage and the vehicle. These factors are interdependent in their influence on the case design. In some programs, the basic case design parameters, including length-to-diameter ratio, external constraints, internal pressure, motor case flight loads, and propellant mass fraction, are specified

1.2.4 Grain Geometry

Solid rocket fuel deflagrates from the surface of exposed propellant in the combustion chamber. In this fashion, the geometry of the propellant inside the rocket motor plays an important role in the overall motor performance. As the surface of the propellant burns, the shape evolves (a subject of study in internal ballistics), most often changing the propellant surface area exposed to the combustion gases. Since the propellant volume is equal to the cross sectional area times the fuel length, the volumetric propellant consumption rate is the cross section area times the linear burn rate , and the instantaneous mass flow rate of combustion gases generated is equal to the volumetric rate times the fuel density.

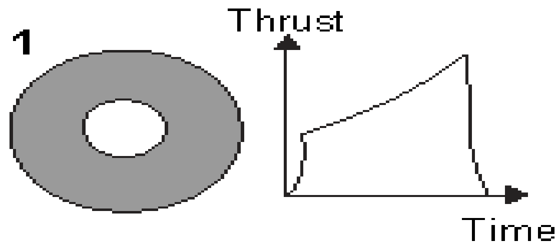


Figure 1.5 Tubular Grain Geometry

Regardless of the composition, however, all propellants are processed into a similar basic geometric form, referred to as a propellant grain. As a rule, propellant grains are cylindrical in shape to fit neatly into a rocket motor in order to maximize volumetric efficiency. The grain may consist of a single cylindrical segment or may contain many segments. Usually, a central core that extends the full length of the grain is introduced, in order to increase the propellant surface area initially exposed to combustion.

Grain configuration can be classified according to their web fraction, their length to diameter ratio, and their volumetric loading fraction. These three independent variables are often used for selecting a grain configuration in the preliminary design of a motor for specific application.

The core may have a wide variety of cross-sections such as circular, star, cross, dog-bone, wagon-wheel, etc., however, for amateur motors, the most common shape is circular. The core shape has a profound influence on the shape of the thrust-time profile.

The grain geometry plays a crucial role in determining the burning rate, thrust profile, and overall performance of the rocket motor. The selection of grain geometry depends on factors such as desired thrust profile, specific impulse, structural considerations, and manufacturing constraints. Each grain geometry defines its thrust profiles depending on the geometry shape and design.

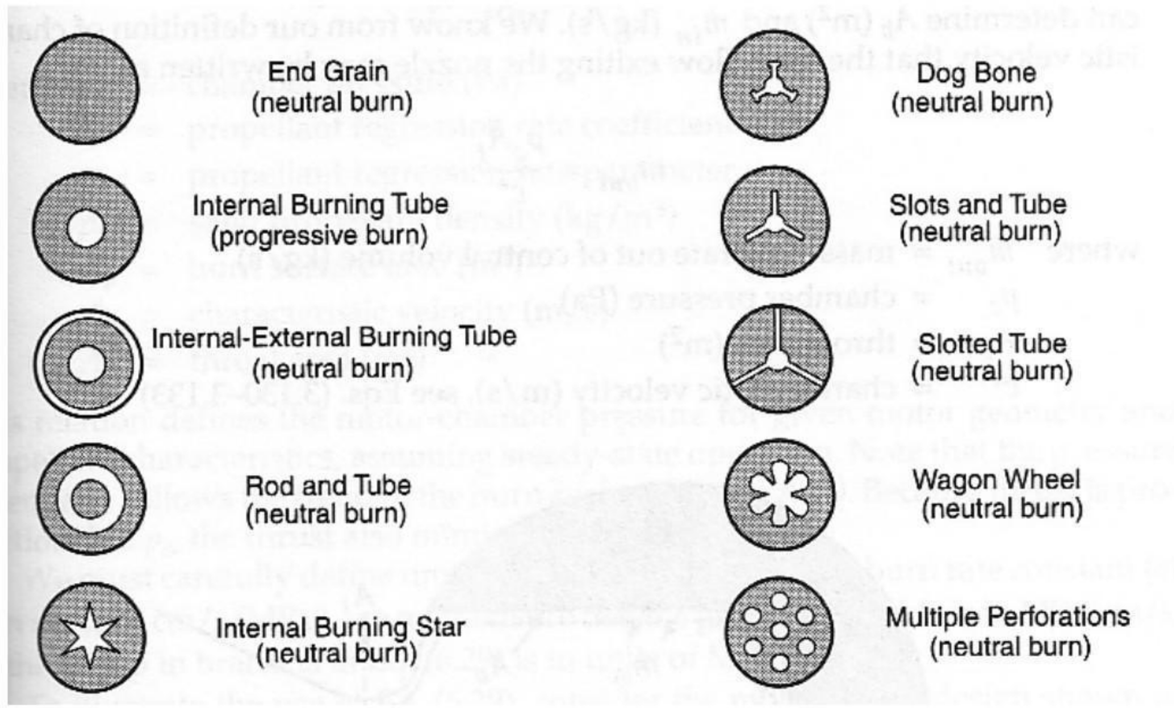


Figure 1.6 Types of grain geometry

The neutral burn is the most desired one in any mission the neutral burning provides greater efficiency in delivery of total impulse, as a nozzle operates most efficiently at constant chamber pressure. There are other burning such as regressive which is defined as burn time during which thrust, pressure and burning surface decreases with respect to time. Progressive burn is the burn time burn time during which thrust, pressure and burning surface increases with respect to time. To get the desired thrust different grain geometry are used depending on the requirements of the mission.

1.2.5 Ignitors

There are two classes of igniters in the SRM: pyrotechnic igniters and pyrogenic igniters. Thefirst type uses explosives such as black powder or small devices that, once ignited, create a lr ge area to burn. The heat from this process ignites the mother grain. This mode is mainly used for small and medium sized SRM.

The second type consists mainly of small rockets with high-velocity pellets.

When ignited, the flame spreads over the entire air space. The hot gas of the flame then reactsand damages the material. This type of igniter is more common in larger SRM. For both type, the igniter is usually on the opposite side of the nozzle, at the front end. even if other configurati ons are available.

The shape of the igniter is often dependent on the ignition method and application. However, sin ce the igniters appear small relative to the main elements, the first approach of modeling them as simple cylinders is obtained.

Grain designs need to satisfy several requirements such as:

1. Rocket motor requirements including total impulse, desired thrust-time curve and tolerance, motor mass, ambient temperature limits during storage and operation, available vehicle volume or envelope, desired location or movement of rocket motor's center of gravity and acceleration caused by vehicle forces.
2. Grain geometry must fit the motor requirements – it must be compact, use the available volume efficiently, have an appropriate burn surface versus time profile to match the desired thrust-time curve, and avoid or predictably control erosive burning. Any remaining unburned propellant slivers, and the shift of center of gravity during burning should be minimized.
3. Propellant must be selected on the basis of its performance (characteristic velocity), mechanical properties (strength), ballistic properties (burning rate), manufacturing characteristics, exhaust plume characteristics, and aging properties.
4. Grain structural integrity (its liner, insulator) must be analyzed to ensure that the grain does not fail due to stress or strain under all conditions of loading, acceleration or thermal stresses.
5. Any internal cavity volume made of perforations, slots, ports and fins increase with burning time. These cavities need to be evaluated for resonance, vibration, damping and combustion stability.
6. The processing of the grain and the fabrication of the propellant should be repeatable, simple, low cost and only cause acceptable thermal stresses. Grain geometry is crucial in its design. For a neutral burning grain (nearly constant thrust), the burning surface area has to remain sufficiently constant, however with a regressive burning grain, the burning surface area needs to diminish with time. Hence, a trade off needs to be done.

1.3 MOTIVATION

A solid fuel-oxidizer mixture (propellant) is packed into the rocket, with a cylindrical hole in the middle. An igniter combusts the surface of the propellant. Strong rockets are much less used than rocket-propelled rockets. However, there are some advantages, which can make strong propellants compatible with liquid protectors in other military applications.Once ignited, a simple solid rocket motor cannot be shut off, because it contains all the ingredients necessary for combustion within the chamber in which they are burned. More advanced solid rocket motors can be throttled, and also be extinguished, and then re-ignited by control of the nozzle geometry, or through the use of vent ports. Further, pulsed rocket motors that burn in segments, and that can be ignited upon command are available. Some of the benefits of strong propellants are:

Easy to maintain and hold and also easy to work with as compared to the liquid propellant

They have a few parts. There is no need for a separate combustion chamber and turbopumps to pump propellants into the combustion chamber. The solid propellant is fired directly into the propellant storage casing. A simple solid rocket motor consists of a casing, nozzle, grain (propellant charge), and igniter. This motivated us to design manufacture the solid rocket motor.

1.4 OBJECTIVE

Objectives planned to the project:

1. To design and manufacture solid rocket motor.
2. To conduct flow analysis of solid rocket motor.
3. To design the solid motor using the solid works software.
4. To conduct simulations in ansys software.
5. To prepare the propellant grain for solid rocket motor and conduct testing.
6. To analyses and study the experimental analysis conducted.
7. To obtain maximum thrust for tubular grain geometry design of solid rocket motor.

CHAPTER 2

LITERATURE REVIEW

2.1 Literature Review

A literature review is a critical assessment and analysis of the available literature (books,essays, articles, conference proceedings, etc.) related to a topic or research question. It Involves analysing and synthesising the data, ideas, arguments and findings presented in these resources to identify patterns, gaps, inconsistencies and areas that require further research.

If we talk about our project with the help of some data researches that give us information about the materials and compositions we knocked, such as KNSU combustion rate measurement, propellants obtained by mechanical presses: Solid Propellant Rockets CD nozzle, Calculations and analysis: Material rocket engine shell tension, etc. we will consider in detail. Rocket propellants (SRMs) are primarily used in satellite launch vehicles. An SRM consists of three separate structural components: product propellant, lining and fabric. Solid rocket engines (SRMs) play an important role in the construction of micro spacecraft. But sometimes eddies can be caused by the Propellant Inhibitor, which causes pressure swings. The rocket engine is a non-rocket; The design goal is to make light as good as possible while maintaining commercial and industrial limitations. Thermal and pressure loads during transportation, storage and ignition are considered the most important characteristics that define the long-term behaviour of electric motors. At the loading, the tension and dissipation of the rocket were determined. The maximum ring strain at the propellant surface and the bond stress on the liner-insulator interface were evaluated as an indication of spokes breakage and deboning of the liner-insulator interface, respectively.

1. Burning Rate Measurement of KNSu Propellant Obtained by Mechanical Press:

(It was published by **Foltron A.C Moro in the year of APRIL 2015**)

The potassium nitrate (KNO_3)/sucrose ($C_{12}H_{22}O_{11}$) propellant, known as KNSU, is traditionally used in rocket studies by amateur groups. Both components are easy to buy, their combustion products are non-toxic and this propellant can produce relatively high specific impulse, with values aim of this paper was to provide the propellant grains production in a simple way, consisting only on grinding and mixing the components, in absence of a heating process used security recommendations were basically the ones relative to chemical products manipulation higher than the ones obtained by black gunpowder commonly used in model .

In this paper, however, an alternative methodology for cold manufacturing was studied. It involves the grinding and mixture of components, as well as the preparation of propellant grain by compaction of components in a die with the use of a hydraulic press machine. The propellant components used for sample manufacture were potassium nitrate and refined sugar. Each component was milled in an individual mill with rotary blades. Each mill was carried up to 90% of maximum volume and used by 30 saver grinding, the components were stored in individual pots. e chemical composition adjustment was made by measuring the components' masses in a scale with 0.01 g resolution. The components were then placed in a third hermetic pot and each 100 g of propellant were manually shaken for 15 min. The burning surface is not clear because of the fact that traces of glue layer did not burn as easily as the propellant. Since the Same front is not completely homogeneous, it is difficult to decide exactly when it achieves the initial and final positions. Because of this, each measurement was repeated three times. his strategy allowed the evaluation of uncertainty ranges for the burning rate, based on the Student distribution with 95% confidence level. The highest interval was observed for sample 6 and presented 0.20 mm/s of amplitude, i.e. 8.4% with respect to the average of sample For some samples, the burning rate was spoiled by the inhibitor inefficiency, which conducted to the burn process in faces other than the one activated by the black gunpowder. Sometimes the same did not uniformly begin in all activated surfaces, as expected, or it presented some delay points. Material failure is the most concerning of the numerous modes of rocket motor failure. This could be due to minute fissures in the material or something that happened during the production process. The characteristics that cause structural failure include ultimate tensile strength and material thickness. The square root of the crack length is inversely proportional to the fracture strength of classical brittle material. When the material & stress intensity factor reaches a critical value, known as the critical stress intensity factor, it fails as a brittle fracture. It is a material attribute that determines which material is best for a rocket motor.

It lowers as the thickness of the material increases. The maximum circumferential stress caused by propellant gas pressure should be less than two-thirds of the material yield strength. The governing factor in determining the appropriate material for a rocket motor is the critical stress intensity factor Kc. It is also beneficial to choose a material thickness that will not fail under plane strain and will only fracture under plane stress. A case containing solid propellant and with standing internal pressure when the rocket is operating. The solid propellant charge (or grain), which is usually bonded to the inner wall of the case and occupies before ignition the greater part of its volume. When burning, the solid propellant is transformed into hot combustion products.

2. Computational Analysis of CD Nozzle for Solid Propellant Rocket:

(It was published by **mohammed ilyas in the year Aug 2016)**

Why does the use a mixed-divergent nozzle to achieve high speed and make it more powerful? In convergent nozzles, the speed of sound is the highest speed achieved at the extremity with h = enthalpy (kj/kg) point at the throat, while in converging-diverging nozzles is the speed of sound at the back of the throat due to the increased volume. In the divergent field, the density causes your descent rate to increase to, or even a supersonic increase. By controlling the decision variables, such as area ratio and back pressure, the Mach number at the nozzle tip can be obtained. An important aspect of combining different nozzles is aerodynamics, especially in high-speed jet or rocket engines. They play an important role in supersonic air tunnels, where they draw air and even compressed air from tanks that will be in atmospheric conditions. This work provides experimental results for the expansion of flow in a typical supersonic convergent-expanding nozzle. The simulation was performed by ANSYS FLUENT, where geometric meshes were created using ANSYS WORKBENCH. Two different turbulence models, k- and k-ω, were used for the solution. In addition, the turbulence model, comparison of different networks and calculation methods have been reviewed and even compared with experimental data, similar applications will be developed in the future. The results of this study show that there is sufficient cooperation between experimental data and simulation results for 3D density rather than 2D.

The nozzle directs the output of combustion products and, thanks to its shape, accelerates them to supersonic speed. The igniter may be an electronic device or a small rocket that activates the rocket after receiving an electrical signal. With the help of finite element analysis, the actual stress distribution of different parts of the rocket engine shell is investigated. It has been shown that the dimension affects the finite element analysis results, but does not affect the analysis results after a certain element dimension stresses obtained for cylindrical shells and hemispherical domes were analysed. Stress analysis helps us to know the stress of different elements which are difficult to calculate from correlation. The difference between finite element results and analytical method results is less than 3%. The positive voltage is less than the voltage of the material, and the design is a safe constrictor diffuser nozzle that plays an important role in supersonic missiles and rockets,and is also used in retro rockets. The air reaches the sonic conditions of the throat because the pressure returns from the convergence section These conditions cause the flow to continue across the gap to flow, where the Mach flow increases using the pressure difference. It can be adjusted by controlling different parameters such as Mach number, area ratio and back pressure. In the current study, full simulation studies of flow in a typical supersonic convergent-divergent nozzle were performed. At the respective nozzle, the water immediately contracts at one point and then widens behind the throat. The Nozzle is a balanced device, specifically a tube design, that directs hot gas and Fast Gas through it. The space shuttle uses a divergent section with sections following a fixed link, as the nozzle configuration is designed in various applications. , scramjets and rockets. The design determined its competitive value due to different nozzle models, many parameters For example, the size is sufficient, the pressure of the motor and the output voltage will be different,

Depending on the configuration, the nozzles can be divided into three types:

1) Conical and Linear Conical Nozzle

2) Contoured, Shaped and Classical Convergent-Divergent Bell Nozzle

3) Spiked, Spiked, Plug, Extended and Extended Deflected Circular Nozzle. Each of the nozzles mentioned has advantages and disadvantages over the others, and each of the nozzles will give different results depending on the configuration. The nozzle configuration, which is the focus of this study, is a converging-diverging nozzle.

3. Stress analysis of solid rocket motor case:

(It comes under International Research Journal of Engineering and Technology (IRJET), Published by **Nevin Nelson in the year March 2020)**. Solid rocket motors are used as boosters for satellite launchers. In a solid rocket motor, the fuel and oxidizer are mixed together into a solid propellant, which is packed into the motor case. When the mixture is ignited by the igniter, combustion takes place on the surface of the propellant. A flame front is generated which burns into the mixture. The combustion produces great amounts of exhaust gas at high temperature and pressure. There exists thermal insulation between propellant and motor case to limit the temperature of the motor case. The hot exhaust gas is passed through a nozzle which accelerates the flow. Thrust is then produced according to Newton's third law of motion.

Because of the complicated shape of the rocket motor case, stress analysis done by any other method is difficult, so the finite element method is obviously the best choice. Hence finite element technique has been selected for the analysis purpose. There are different types of commercial FEM softwares available in the market. ANSYS FEM software is one of the most popular commercial software and is used for the Finite Element Analysis of the rocket motor case. After 60% of nozzle length the air flow continues to decelerate proximate to the wall at a great extent. To make a reduction of this undesired phenomenon at the nozzle wall the length of the wall may be reduced to 50%, but there is a main problem if the reduction in nozzle. Length is made up to 50% it will also make a reduction in nozzle efficiency. This will also create a huge exhaust noise at the end. The turbulence contour specifies an introduction of Heavy turbulence at 70% of the nozzle length nearer to divergent wall. Eliminating or making a reduction in this type of turbulent flow can improve the nozzle efficiency. To improve the Nozzle efficiency, it’s almost impossible to reduce more than 40% of its length. This will also cause a sharp fall in efficiency of the nozzle along with a huge noise creation at exhaust. Conventional composite propellants usually contain between 60 and72% ammonium

Perchlorate (AP) as crystalline oxidizer, up to 22%aluminium powder (A1) as a metal fuel, and 8 to 16% of elastomeric binder (organic polymer) including its plasticizer. Modified Composite propellant where an energetic Nitra mine (HMX or RDX) is added for obtaining a

little more performance and also a somewhat higher density. Modified composite propellant where an energetic plasticizer such as nitroglycerin (used in double-base propellant) is added to give a little more performance. A high-energy composite solid propellant (with

some aluminium), where the organic. Elastomeric binder and plasticizer are largely replaced

by energetic materials (such as certain Explosives) and where some of the AP is replaced by

HMX. Some of these are called Elastomer-modified cast double-base propellants (EMCDB).

Most are experimental Propellants. The theoretical specific impulse can be between 270 and

275 sec at standard Conditions.

A lower-energy composite propellant, where ammonium nitrate (AN) is the crystalline

Oxidizer (no AP). It is used for gas generator propellant. It is used for gas generator Propellant. If a large amount of HMX is added, it can become a minimum smoke propellant with fair performance.

4. Design and Analysis of Solid Rocket Propellant Motor and its Applications :

(It was Published by **Shaik Muzib in the year August 14,2019**)

The aim of each project is to publish new results in scientific journals to disseminate knowledge about new inventions worldwide. Research articles on nozzle design techniques for rocket propellants are also extensive, as many journals have more than one. The project includes the creation of nozzles that can be used in Control Control (RCS), a technique used by rockets to control them after reaching an airless altitude. So there is also a nozzle system. Due to the lack of air, the initial power of the is almost impossible to use the control centre to control and control the rocket. Therefore, in the use of pressure and velocity control systems, we can create nozzles for controlling rockets, calculate and compare their initial values.

5. Grain Configuration of Solid Rocket Motor

(It was Published by **Pawan Hiteshbhai Jethwa in the year 2022)**

In this research paper, the results are divided into four different sections as follows. The mean crack propagation appears to be highly correlated across various stress intensities. Second, the failure properties are classified from A to D using the morphology of the crystalline crack face caused by the failure surface morphology. These results proved that the fault (intermediate fault) using the AC potential has no limit and does not affect its overall development.

That is, intergranular fractures (Type D) propagate faster than intergranular cracks. Particle alignment benefits from a larger combustion area without sacrificing volumetric performance. The star design increases volumetric efficiency. Both volumetric efficiency and Isp increase the overall effect. The star prevents flow separation at the nozzle and reduces the chamber pressure, preventing the pressure vessel from bursting. Low chamber pressure and rocket acceleration increase the likelihood of payload. Starburst can provide an average return burn. The average regression combustion curve follows the ambient pressure curve for maximum efficiency. All these benefits increase the performance and competitiveness of the rocket.

6. Design and Structural Analysis of Solid Rocket Motor Casing Hardware used in Aerospace Applications

(It was published by **shishira nayana B in the year 2016**)

Rockets had a significant change: an iron tube was used to contain the burning powder . The rocket propulsion system is a non-breathing system in which thrust or thrust is obtained by changing the energy of the body. They do not contain air and do not act as oxidising agents. As the name suggests, the motor engine is solid.

The oxidant and fuel are premixed and captured and stored directly in the combustion chamber . Because the propellant consists of fuel and oxidizer, the propellant rocket can operate in any environment. Compared to other types of fireworks, electric fireworks are simple in design, easy to use and require very little maintenance. Rocket engine propulsion can be classified according to the type and configuration of support of the rocket propulsion unit used in a particular vehicle, the method of generating thrust. Although there are many types of rocket propulsion, only chemical rocket propulsion is commonly used.

Other rocket propulsions have disadvantages in terms of weight considerations and power generation. Further advances in technology could lead to the use of other nuclear weapons in the future.

7. Conceptual Design and Structural Analysis of Solid Rocket Motor Casing

(it was published by **B.K Chaitanya in the year February 2017)**

This article focuses on the design of a 100 kg solid rocket engine with preliminary results for a combustion velocity of 100 mm/s, a thrust of 240 s and a chamber pressure of 1000 psi. It is limited by the choice of materials and basic elements of the rocket engine and their performance in static tests. A rocket engine is a general purpose device consisting of metal castings, ablative liners and propellant particles. Also determine the rocket engine design and burst pressure. Preliminary designs provide important results that will later be refined and evaluated in the final design. A theoretical analysis of small-scale electronic devices was performed using Ansys to understand the energy performance of various oxidant/fuel-specific densities. A significant improvement in engine performance appears to have been achieved by changing the nozzle design. The results show the importance of determining the effect of energy consumption on the size of rocket fuel. The best oxidizer/oil ratio was found to be 70/30. Considering the ease of production, the conical nozzle turns into a very interesting design. An increase in nozzle efficiency can be achieved by reducing the converging or diverging angle.

2.2 GAP

According to these research papers, we found that some of these contents have their certain limitations and gaps that are analysed further, likewise during the burning of propellant KNSU:

Lack of standardised measurement techniques: There might be a lack of universally accepted standards or protocols for measuring the burning rate of KNSU propellant. Variability in sample preparation: The way the propellant samples are prepared can significantly affect the burning rate measurements. Variations in the mixing process, particle size distribution, and compaction density of the propellant can introduce inconsistencies and affect the burning rate results.

Influence of environmental conditions: Burning rate measurements can be sensitive to environmental conditions such as temperature, pressure, and humidity. According to next research paper about the designing and analysis of the nozzle.

Turbulence modelling: Accurately modelling and predicting turbulence is a key challenge in computational analysis. Turbulence has a significant impact on the flow behaviour inside the nozzle, affecting factors such as boundary layer development, separation, and shock structure.

Heat transfer modelling: The transfer of heat between the nozzle walls and the flow can have a significant effect on nozzle performance. Properly accounting for convective and radiative heat transfer is crucial for accurate analysis. Grid resolution and meshing: The quality and resolution of the computational grid used in simulations play a critical role in achieving accurate results. However, obtaining an optimal mesh that captures the flow features properly while maintaining computational efficiency can be challenging. The third Research paper is all about the analysis of Stress functions and its effects on their nozzle, and the designing factor.

Material characterization: Accurate characterization of the material properties of the rocket A motor case is crucial for reliable stress analysis. However, obtaining precise and comprehensive information.

Manufacturing defects and variability: Rocket motor cases can have manufacturing defects, such as voids, inclusions, or variations in material properties. These defects and variability can significantly affect the structural integrity and performance of the case. Material data, especially for composite or non-homogeneous cases, can be challenging. Nonlinear behaviour: The stress-strain relationship of rocket motor case materials can exhibit nonlinear behaviour, especially at high strain levels or under extreme environmental conditions.

If we focus on how our project i.e solid rocket motor is different from other types, you can clearly see from its configuration and designing of the model. As we know that solid rocket motor are basically be divided according to its shape structure and their properties, some of them are:

1) According to number of motors use
2) Composite propellants
3) Grain geometries
4) Case bonded motors.

From the above such types we decided to use and finalise on grain geometries from which we stood up on a circle or round type grain structure. When deciding on the type of solid rocket motor to use for a particular application, several factors come into play. Here are some key considerations and gaps that can influence the choice:

a) Performance Requirements: The performance requirements of the mission, such as desired thrust, specific impulse, burn time, and payload capacity, play a crucial role in determining the type of solid rocket motor.

b) Cost and Affordability

c) Reliability and Safety

d) Manufacturing and Supply Chain Considerations: The availability of manufacturing facilities, expertise, and the reliability of the supply chain for the chosen solid rocket motor are essential factors to consider.

2.3 CONTRIBUTION

Our basic idea of the project is Design, Modelling and fabrication of solid rocket motors, overall it's a project with various parts and modules where each part is assigned to individuals of the group, so it seems like their contribution to the work. Developing a solid rocket motor using potassium nitrate sugar propellant (KNSU) requires expertise in propellant formulation, motor design, and manufacturing processes.

1) Propellant Formulation: Research and experiment with different ratios and compositions of potassium nitrate and sugar to optimise the propellant formulation. This involves understanding the combustion characteristics, burn rate, specific impulse, and stability of the propellant. Conduct experiments to measure these properties and refine the formulation accordingly. Includes with the mixing of Propellants, firstly melt them with their respective melting points, properly stir them and with the help of scooping method, fill the propellants in the PVC pipe.

2) Performance Analysis: Perform theoretical calculations and simulations to analyse the performance parameters of the solid rocket motor, such as thrust, specific impulse, and burn time. This involves using software tools and mathematical models to predict the motor & performance under different operating conditions. For this section we use software like ANSYS, open motor, and try to analyse the flow variations.

3) Motor Design: Contribute to the design of the solid rocket motor, including the selection of appropriate motor casing materials, nozzle design, and igniter system. Consider factors such as structural integrity, heat transfer, pressure containment, and ignition mechanisms during the design process, here for the designing part we use Solid works software, and approaches to bottom up method.

4) Manufacturing Processes: Investigate manufacturing techniques suitable for fabricating the motor components. This includes casting or moulding the propellant grains, assembling the motor casing, and integrating the igniter system. Develop efficient and reliable manufacturing processes that can be scaled up for production, picking up all the materials together and for using the lathe machine we completed with manufacturing part of case and nozzle, with mild steel material.

The use KNSU i.e. Potassium nitrate/Sucrose as our main propellant components. There is no need for the binder since the potassium nitrate itself works as a Oxidizer + Binder. The O/F ratio for the propellant is 65/35. We have designed a CD Nozzle in SolidWorks using appropriate dimensions. A slurry Caramelized mixture has been found by adding both the potassium nitrate and sucrose which are highly inflammable. Because the mixture is supposed to be handled very carefully. Also run a test simulation on software called Open Motor which led us to the conclusion for the grain type. Furthermore, we get the results of the aerodynamic analysis of the CD nozzle where the pressure and velocity variations with 1500 iterations using Ansys.

CHAPTER 3

METHODOLOGY

3.1 Introduction

Methodology refers to the systematic approach or set of procedures used to conduct research, investigation, or any systematic study in a particular field. It outlines the overall framework and steps followed to achieve the objectives of a study or project. Methodology provides a structured and organized way to gather data, analyze information, and draw conclusions.

Basic methodology for project:

Design Requirements

↓

Define mission objectives and payload specifications.
Identify target performance parameters (e.g., thrust).
Determine constraints and safety considerations (e.g., weight, cost)
Develop a system preliminary design concept.

Propellant Formulation

↓

Conduct research on suitable propellant types (e.g., liquid, solid, hybrid).
Perform testing of propellant components.
Optimize the propellant formulation for desired performance characteristics

Casing Design

↓

Determine structural requirements and environmental constraints.
Conduct stress analysis and finite element modelling.
Select appropriate materials for the rocket casing.
Design the casing geometry, including wall thickness, diameter, and length.
Perform thermal analysis to assess thermal protection requirements

Stress Analysis/Ignition System

Determine structural requirements and environmental constraints.
Conduct stress analysis and finite element modelling.
Select appropriate materials for the rocket casing.
Design the casing geometry, including wall thickness, diameter, and length.
Perform thermal analysis to assess thermal protection requirements

Manufacturing Assembly

Prepare detailed manufacturing plans and procedures.
Fabricate individual rocket components (e.g., propellant grains, casings)
Conduct quality control inspections at each manufacturing stage.
Assemble components into a complete rocket system.
Perform integration checks and tests to ensure proper functionality

Performance Analysis

Define performance metrics and simulation objectives
Conduct computer-aided analysis and simulation (e.g. CFD)
Validate performance predictions through ground testing.
Analyse test data and refine design parameters as necessary

Integration and Launch

Conduct system-level checks and compatibility tests.
Coordinate with launch personnel and obtain necessary approvals.
Perform final safety inspections and pre-launch tests.
Execute the launch and monitor the rocket's performance.

Figure 3.1 Methodology Steps

Manufacturing methods for solid rocket motors used in small, fast flight vehicles were developed using the KNO3 (Potassium Nitrate) & Sucrose test motor this chapter will describe the methods used for manufacturing the propellant and liner for this configuration. Additional considerations for extending the motor manufacturing process to cast multi-segment propel-lant grains and flight-like motor geometries are then described.

<u>We have started the work on the project as follows: -</u>

1. Searched for different topics for the capstone project.
2. Discussed with our project guide the topics that we have searched for.
3. Finalized the topic "Modeling, Fabrication and Analysis of Solid Rocket Motor".
4. We had a discussion on the finalized topic with our project guide.
5. Collected different research papers on Solid rocket systems.
6. Shortlisted some informative papers which are related to our project.
7. Collected the required information for designing our project.
8. Worked on the design parameters which are related to our project.
9. From the above information, we proposed our project.
10. Started working on the actual design of the missile.
11. In this paper the missile is designed using Dassault Systemes (SolidWorks 2019) software (Open Source). The first step was to create a 2D
12. For the first draft design we have created a rough nozzle to kick start our project work. This design made us realize the errors and the calculation behind the design.
13. As the nozzle was going to be manufactured on LATHE there were so many restrictions on the nozzle model.
14. So, we created the nozzle part separate and the casing part separate soo that there is no harm to the model.
15. After creating the parts, the flange and the nozzle was welded with the TIG welding.
16. Motor case was also manufactured the same way a pipe GI was taken separately and the flange was welded separately to avoid any harm to the case.
17. After Manufacturing we Proceed towards the Making of propellants part, where we take KNSU as our Propellants.

18. We started melting them, in their suitable temperatures, in the fixed proportion ratio of 65:35 as an Oxidiser to fuel ratio.

19. For testing we tried in an PVC small pipe , after getting suitable results, we proceeded with the same propellants. And according to the results we get the parameters.

21. The parameters were put in the open-source like Open Motor to know the capability of the (SRM) solid Rocket Motor after finalizing the nozzle.

22. To cross-check we have tested with another software named Meteor.

23. After a lot of changes in design and parameters we've come to the concluded design which satisfies every condition.

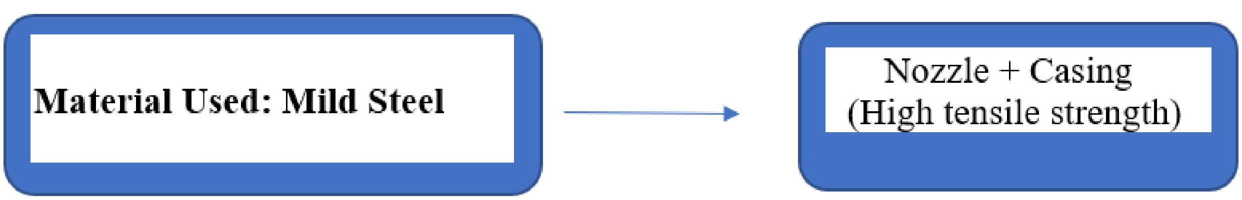
24. After completion of designing work, we further did the analysis.

25. The following chart shows the CFD analysis procedure, detailed information is given further in the analysis section

26. Finally, after the simulation process, we compared obtained graphs for the desired output and results.

27. Prepared the final report and presentation for the evaluation of the guide.

3.2 Materials Used:



During the fabrication of our model , the material used is mild steel , High tensile strength.

High impact strength. inspite of nozzle, we also provide them with a mild steel pipe for the casing (The motor case generally consists of a steel or aluminum tube; it has a head-end dome that contains an igniter and an aft-end dome that houses or supports the nozzle. It's important to note that mild steel may not be suitable for high-temperature applications or environments where corrosion resistance is critical. In such cases, alternative materials like stainless steel, brass, or specialized alloys with higher temperature and corrosion resistance should be considered.

Before selecting mild steel for a specific nozzle application, it is advisable to carefully evaluate the operating conditions, including temperature, pressure, fluid characteristics, and any specific environmental factors, to ensure that mild steel meets the required performance and durability criteria.

Now In terms of Use of Propellants, Its totally based on how Thar chosen Propellant works , How much it gives the efficiency, What type of combustion Energy Equation It follows and The most important thing is Thrust , As our aim, is to burn the propellants as in the manner so that we will able to get more thrust. It's important to note that the specific formulation and composition of solid rocket propellants can vary depending on the application, desired performance parameters, and safety requirements. Propellant manufacturers and rocket motor designers carefully select and optimize the propellant formulations to meet the specific needs of the mission or application.

Handling and manufacturing solid rocket propellants require strict safety protocols and specialized facilities due to their high energy content and sensitivity to ignition. Therefore, it is essential to follow established guidelines and work with trained professionals when working with or developing solid rocket propellants.

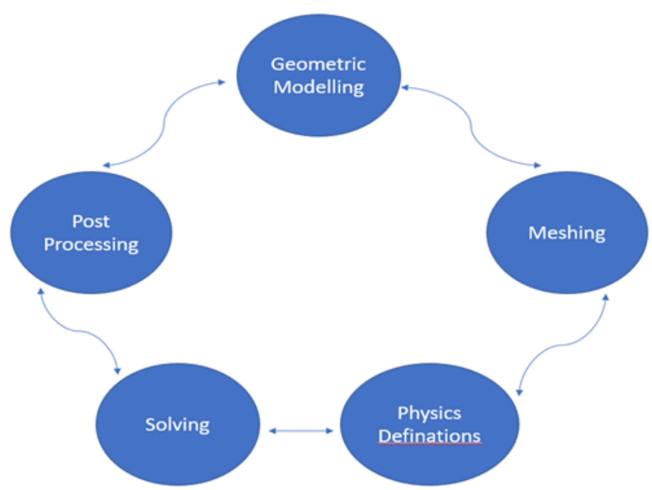


Fig no.3.2 : Steps to perform CFD Analysis

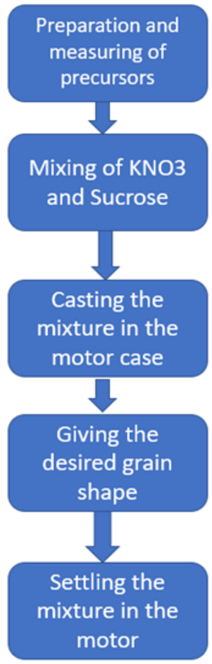


Figure 3.3 Manufacturing Process of the propellant

Composite propellant which is heterogeneous in nature and has an conventional properties.

As we know that,

<u>OXIDIZER + FUEL + BINDER/ PLASTICIZER/CURING AGENTS</u>

makes an appropriate propellant for the motor.

This chapter will discuss the methods used for manufacturing of nozzle and casing and the selection of the propellants.

We have started to work on the project as follows:

1. Searched for different topics for project.
2. Finalized the topic and discussed it with the guide.
3. Collected research papers for our topic.
4. Worked on design parameters of nozzle and the casing.
5. Conducted the analysis.
6. Selection of propellant
7. Selection of the grain design

8. Material selection
9. Manufacturing the casing and nozzle
10. Prepared the propellant.
11. Casting of the propellant

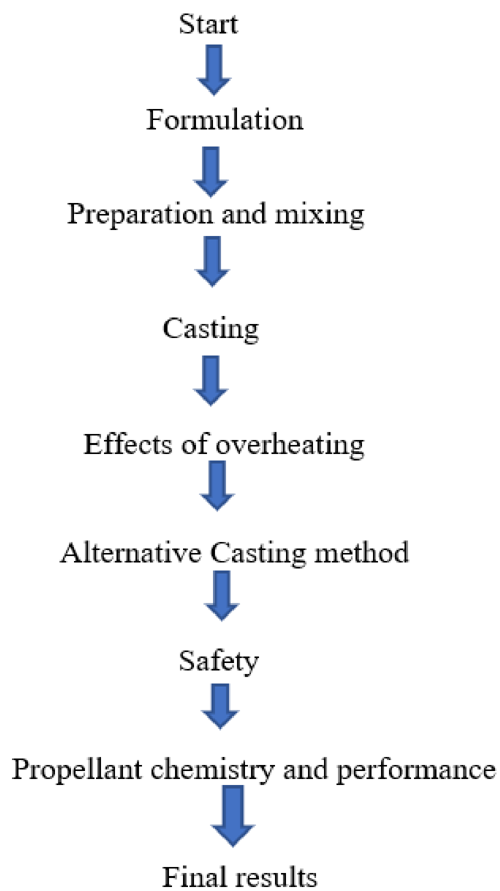


Fig No. 3.4 : Algorithm of Project

3.3 PROPELLANTS

(1) POTASSIUM NITRATE:

Potassium nitrate is a chemical compound with a sharp, salty, bitter taste and the chemical formula KNO_3.This alkali metal nitrate salt is also known as Indian saltpeter (large deposits of which were historically mined in India). It is an ionic salt of potassium ions K+ and nitrate ions NO3 and is therefore an alkali metal nitrate. It occurs in nature as a mineral, niter, It is a source of nitrogen, and nitrogen was named after niter. It is a source of nitrogen, and nitrogen was named after niter. Potassium nitrate is one of several nitrogen-containing compounds collectively referred to as saltpeter.

Major uses of potassium nitrate are in fertilizers, tree stump removal, rocket propellants and fireworks. It is one of the major constituents of gunpowder, In processed meats, potassium nitrate reacts with hemoglobin and myoglobin generating red color.

Fig no. 3.5 : Potassium Nitrate (KNO3)

Potassium nitrate is also sold as 14-0-45 fertilizer at farm supply stores, typically 98-99% pure. This is by far the most economical form, and the performance is generally no different than purer grades. Sadly, nowadays the sale of potassium nitrate has had restrictions placed on it, making it more challenging for prospective rocket engineers to carry on their calling. That it is not difficult to synthesize potassium nitrate from a commonly available, non-regulated fertilizer. Powdered sorbitol tends to form hard clumps in storage. Caked clumps may be reduced to a fine powder by using a flour sifter or by rubbing inside a strainer.

(2) SUCROSE:

Sucrose, a disaccharide, is a sugar composed of glucose and fructose subunits. It is produced naturally in plants and is the main constituent of white sugar. It has the molecular formula $C_{12}H_{22}O_{11}$ For human consumption, sucrose is extracted and refined from either sugarcane or sugar beet.

Sugar mills – typically located in tropical regions near where sugarcane is grown – crush the cane and produce raw sugar which is shipped to other factories for refining into pure sucrose. Sugar beet factories are located in temperate climates where the beet is grown and processed directly into refined sugar. The sugar-refining process involves washing the raw sugar crystals before dissolving them into a sugar syrup which is filtered and then passed over carbon to remove any residual color. The sugar syrup is then concentrated by boiling under a vacuum and crystallized as the final purification process to produce crystals of pure sucrose that are clear, odorless, and sweet. Sucrose, a disaccharide, is a sugar composed of glucose and fructose subunits .

Fig no. 3.6 : Granular Sucrose

Fig no.3.7 : Powdered Sucrose

Fig no. 3.8 : Liquified KNSU

3.4 BINDERS:

Provides the structural glue or matrix in which solid granular ingredients are held together in a composite propellant.

- Polyether's, polyesters, and polybutadiene are three types of binders.
- After they are mixed with the solid ingredients, they form a hard rubber like mat that constitutes the grain.

They get oxidized in combustion process. As we are using simple sucrose and potassium nitrate as an propellants, their mixtures gives the finely particles which are mixed properly, so there is no need for binder.

3.5 FUEL:

Sucrose:

- · Ethanol is produced from glucose via fermentative consumption of pyruvate. Glycolysis is a metabolic process that converts glucose to a partially oxidized product, pyruvate, while supplying ATP for biomass production.
- · As a clean, affordable, and low-carbon biofuel, sugarcane ethanol has emerged as a leading renewable fuel for the transportation sector. Ethanol contributes to decarbonization transport when it is used in its pure form, or when it's blended with gasoline.
- · Sugar is, of course, extremely easy to oxidize and is a good source of energy, as you know if you've ever eaten a candy bar. Table sugar, or sucrose, is flammable under the right conditions, just like wood (which is made of cellulose, or lots of sugar molecules linked together).
- · Bioethanol fuel is mainly produced by the sugar fermentation process, although it can also be manufactured by the chemical process of reacting ethylene with steam. The main sources of sugar required to produce ethanol come from fuel or energy crops.

3.6 OXIDIZERS:

The oxidant most frequently employed in the preparation of our motors is nitrate (KNO3). Alternative oxidizers are often used also, like atomic number 11 and metal nitrates also as mixtures of atomic number 11 and nitrate. KNO_3 are often non heritable by getting a granular "stump remover" from stores that carry garden supplies. Alternatives seldom used oxidizers are unit ammonia and metallic element salt.

3.7 INSULATION:

The solid insulating materials are fibrous, ceramic, mica, glass, rubber, and resinous. The liquid insulating materials are mineral oils, synthetic oils, transformer oils, and miscellaneous oils. The gaseous insulating materials are air, hydrogen, nitrogen, and Sulphur hexafluoride.

For the project we finalized to use the insulation material as corrugated boards with grease as an insulation coating on it, Also known as dielectric grease, use insulating grease to lubricate and protect electrical systems. It resists water and corrosion. This grease can be used on most rubber and plastic.

WD-40 Specialist:

High-Temp Grease is a lithium-based grease built to perform in high temperature

and high-friction mechanical loads. It was engineered to meet the demands of protecting high-speeds bearings in applications involving high temperatures and heavy mechanical loads. The high-temperature Super-Lube synthetic grease is recommended by Aerotech for lubricating the threads on reloadable motors as they are assembled. This makes it easier to take the motors apart after the flight, and much easier to clean the casing.

1. Grease functions as a sealant to minimize leakage and to keep out contaminants. Because of its consistency, grease acts as a sealant to prevent lubricant leakage and also to prevent entrance of corrosive contaminants and foreign materials. It also acts to keep deteriorated seals effective.
2. Grease is easier to contain than oil. Oil lubrication can require an expensive system of circulating equipment and complex retention devices. In comparison, grease, by virtue of its rigidity, is easily confined with simplified, less costly retention devices.

3. Grease holds solid lubricants in suspension. Finely ground solid lubricants, such as molybdenum disulfide (moly) and graphite, are mixed with grease in high-temperature service or in extreme high-pressure applications. Grease holds solids in suspension while solids will settle out of oils.

4. Fluid level does not have to be controlled and monitored.

PREPARATION OF PROPELLANT

Measure out the KNO3 (65 parts), measure out the Sorbitol (35 parts). We have used
a scale accurate to 0 grams; they can be found in market or online store at very
reasonable prices just search "pocket scale". Then adding the ingredients together in
a cup or bowl, and simply mix them together until homogeneous.

Then it is time to add them to the electric induction (which is pre-heated to 250° F). now all that needs to be done is the mixture be stirred around until completely homogeneous on the pan, we've used a cheap non-stick silicone spatula. After about 5 minutes you can see the propellant is now the consistency of a very viscous fluid, much like molasses.

After partially melting of propellant, we have added the 0.1 percentage of the surfactant which reduces the surface tension and allows extra time to pour slurry propellant in casting tubes.

Now the propellant is pushed over the small hole in the griddle and allowed to fall into the casting tube(s). Finally, the propellant is cored, by inserting a Teflon rod into the center of the propellant mass while still hot. After 2 to 4 hours the propellant is fully cured and is now workable, so the coring tool may now be removed, and you are left with a perfect grain of KNSB propellant.

Types of Grains

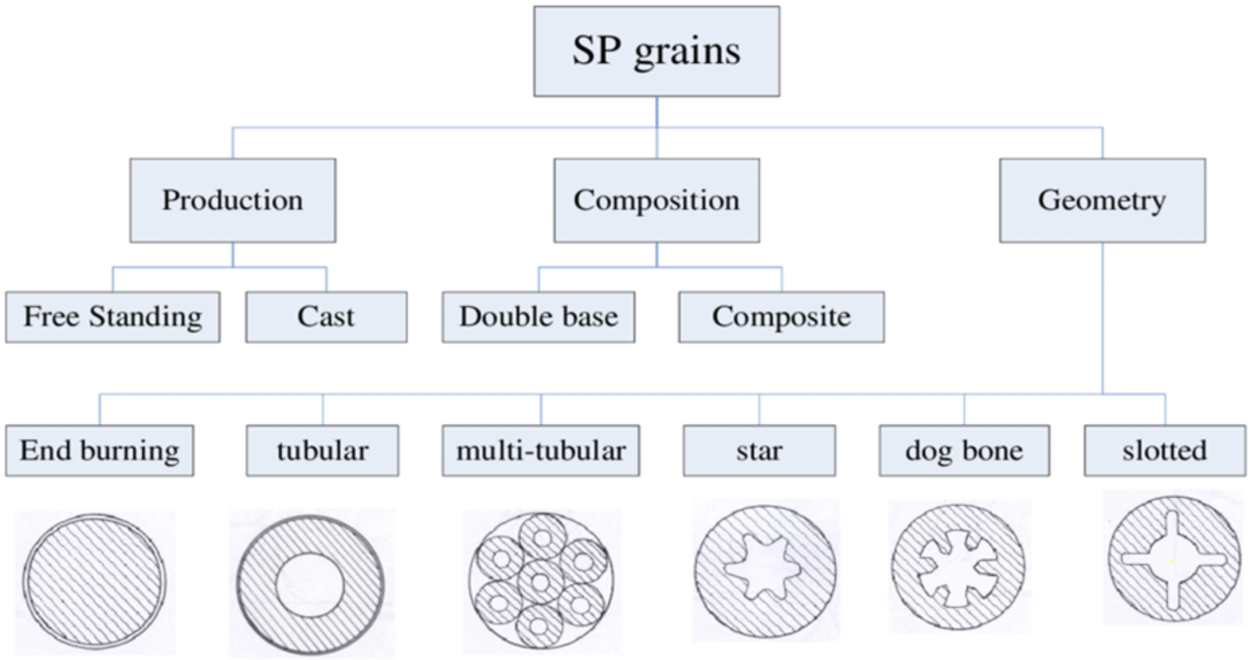


Fig no 3.9 : Types Of Grains

Grain Type Used

In solid rocket motors, the tubular grain type refers to a specific configuration of the propellant grain. The grain is the solid material within the motor that contains the fuel and oxidizer mixture. It burns in a controlled manner to produce thrust. In a tubular grain configuration, the propellant grain is shaped like a tube or cylinder. It consists of a hollow core with a cylindrical outer casing. The fuel and oxidizer mixture are packed within the annular space between the core and the casing. This configuration allows for efficient combustion and controlled burn rate.

Key characteristics and advantages of tubular grain type in solid rocket motors:

- **Surface Area:** The tubular grain provides a large surface area for combustion. The exposed inner and outer surfaces of the grain allow for more efficient burning and increased thrust.

- **Controlled Burn Rate:** The geometry of the tubular grain helps in achieving a controlled burn rate. The burning of the propellant starts at the inner surface and progresses outward, maintaining a consistent rate of combustion.

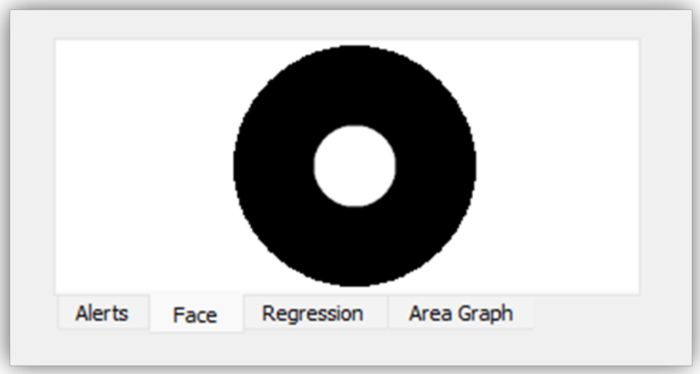


Fig no 3.10 : Tubular Grain Type

- **Regression Rate:** The regression rate refers to the speed at which the burning surface moves along the length of the grain. Tubular grains typically exhibit a relatively low regression rate, which contributes to stable and predictable motor performance.
- **Structural Integrity:** The cylindrical casing provides structural integrity to the grain, helping to maintain its shape during combustion. This stability is important for maintaining the motor's performance and preventing any structural failures.
- **Grain Design Flexibility:** Tubular grains offer design flexibility, as their geometry can be customized to meet specific performance requirements. Different configurations, such as single perforated tube or multiple-tube grains, can be employed to achieve desired thrust profiles.

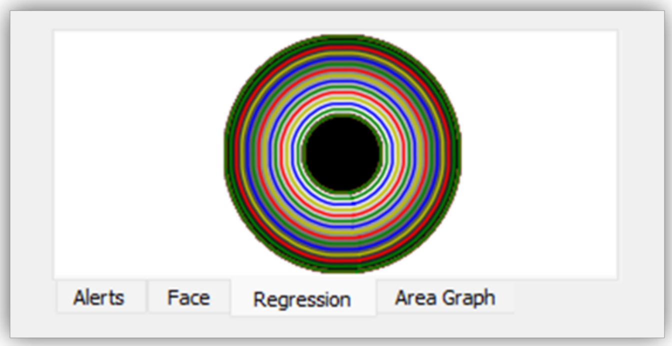


Fig no. 3.11 : Regression Burning

The design of the solid propellant grain is a decisive aspect of the solid propellant rocket motor performance. Tubular grain design is a favorable design since it produces a high neutral (time-invariable) thrust-time profile.

CHAPTER 4

Modelling

4.1 SOFTWARE USED:

For our 3D design and modelling needs, we have used Solidworks software version: 2021. SolidWorks is a popular computer-aided design (CAD) software application mainly used for creating 3D models and drawings. Dassault Systèmes developed it and is widely used in various industries, including mechanical engineering, aerospace, automotive, and product design.

Figure 4.1: Solidworks logo

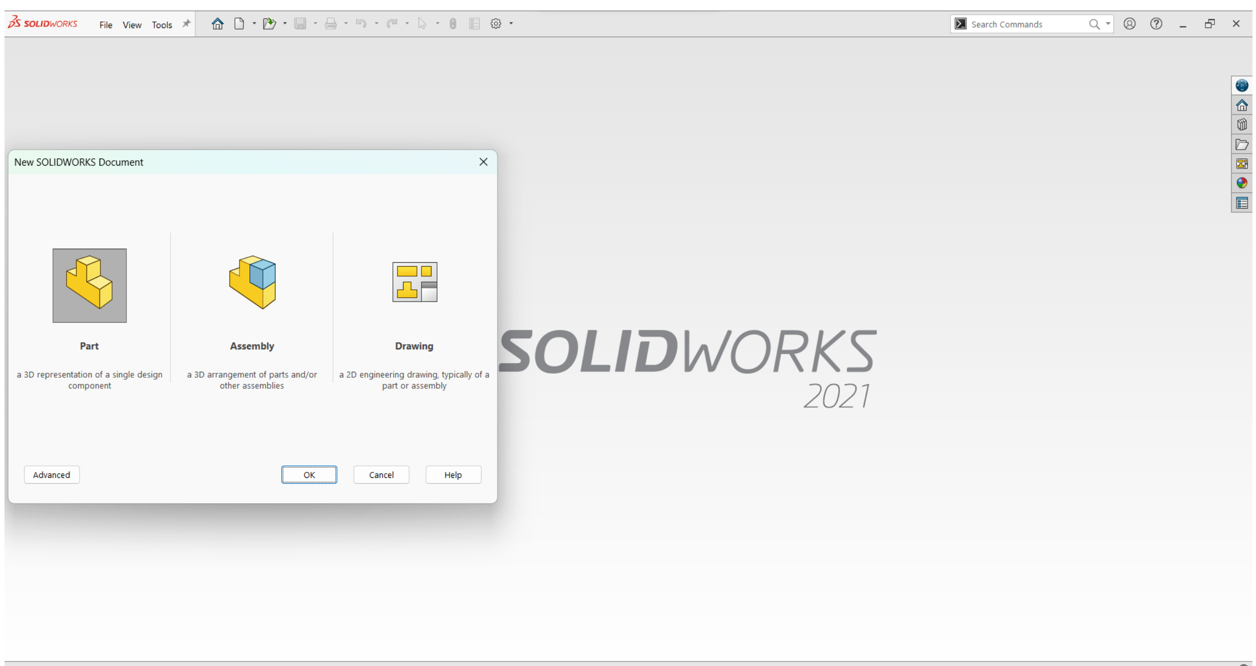


Figure 4.2: Solidworks New Window GUI

The software provides a user-friendly interface that allows designers and engineers to create, modify, and analyze complex 3D models with ease. It utilizes parametric modeling, which means that the dimensions and features of the model are defined by mathematical parameters, making it easy to modify the design and explore different iterations.

SolidWorks supports the creation of both individual parts and assemblies of multiple components. Users can define relationships and constraints between the parts, such as mating surfaces or connections, to ensure that the design functions correctly. The software also provides tools for simulating the motion and behavior of assembled components, allowing users to test their designs virtually before manufacturing.

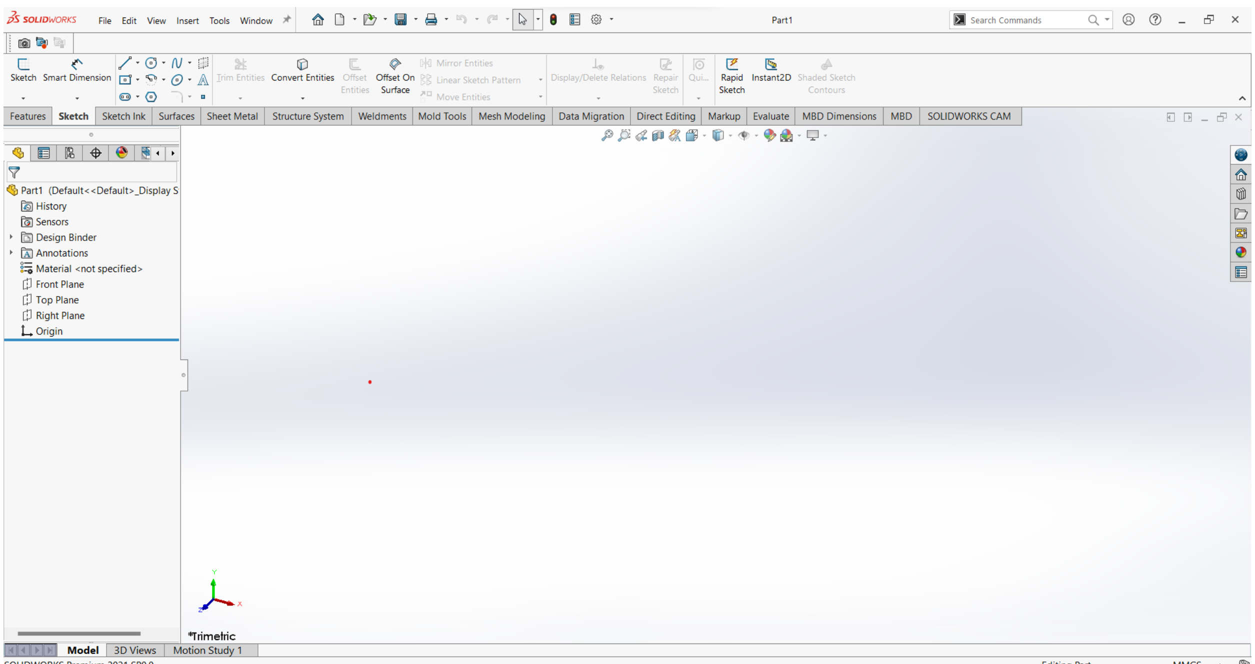


Figure 4.3: Solidworks Part GUI

One of the strengths of SolidWorks is its extensive library of features and tools. These tools enable users to create complex geometries, apply materials and textures, define precise dimensions and tolerances, and generate detailed 2D drawings with annotations and dimensions.

The software also offers simulation capabilities, allowing engineers to analyze and validate their designs for factors such as structural integrity, fluid flow, and thermal performance. This helps in identifying potential issues or optimizing the design for better performance.

SolidWorks provides various rendering and visualization options, allowing users to create realistic images and animations of their designs. These visuals are helpful in communicating design concepts to clients, stakeholders, and manufacturing teams.

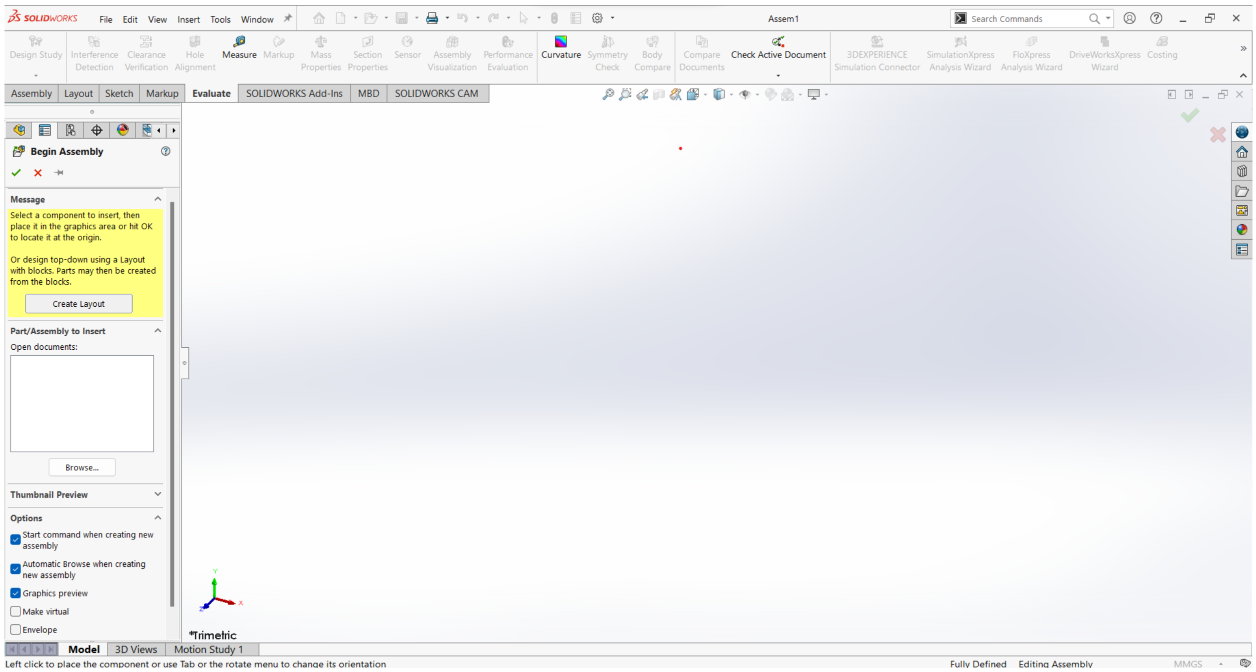


Figure 4.4: Solidworks Assembly GUI

Collaboration and data management are crucial aspects of the design process, and SolidWorks incorporates features for managing design files, version control, and collaboration among team members. It helps ensure that everyone involved in the project has access to the latest design data and can work together seamlessly.

SolidWorks is known for its extensive online resources and community support. Users can access tutorials, forums, and knowledge bases to learn and enhance their skills in using the software. The availability of training materials and certifications further enhances its appeal to professionals and organizations.

SolidWorks offers a comprehensive set of tools and features that allow users to design, simulate, visualize, and manage their product development processes. Some of its key capabilities include:

3D Modeling: SolidWorks provides a range of tools for creating 3D models of parts and assemblies. Users can create complex geometries, define relationships between components, and generate parametric models that can be easily modified.

Assembly Design: The software enables users to assemble multiple components, define their relationships and constraints, and simulate the motion and interaction between parts. It also offers features for managing large assemblies efficiently.

Simulation and Analysis: SolidWorks includes simulation tools that allow engineers to perform structural analysis, motion analysis, and fluid flow simulation to evaluate the performance and behavior of their designs under different conditions.

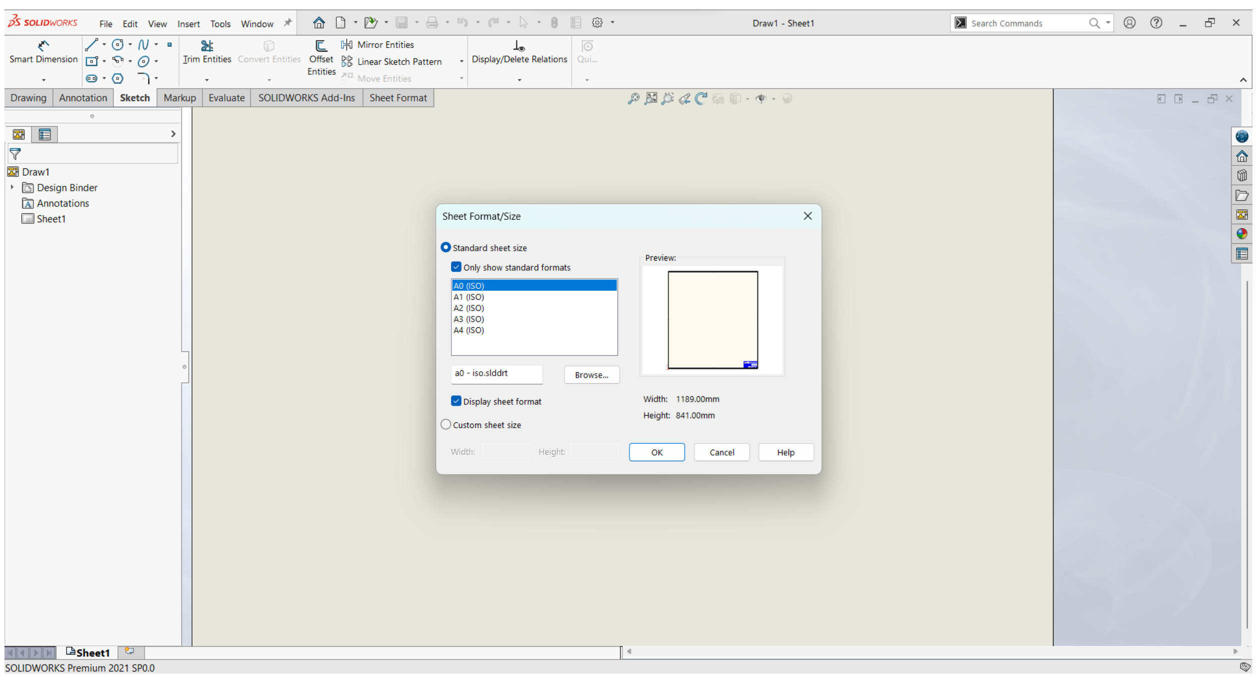


Figure 4.5: Solidworks Drafting GUI

Rendering and Visualization: Users can apply materials, textures, and lighting effects to their models to create realistic renderings and visualizations. This helps in communicating design concepts and showcasing products before they are manufactured.

Drawing and Documentation: SolidWorks offers comprehensive drawing tools to create detailed 2D engineering drawings, including dimensions, annotations, and bill of materials. It also supports the automatic generation of drawing views from 3D models.

Product Data Management: The software includes built-in data management capabilities to help users organize and manage their design files, collaborate with team members, and track changes throughout the product development lifecycle.

4.2 DESIGN AND DRAFTING:

Design and drawing are two similar professions that involve creating and documenting drawings and plans for various purposes.

Design is the process of finding solutions to problems or creating new products. It includes understanding needs, constraints, and goals, and using common sense and cognitive skills to find solutions. Design involves the creation of ideas, concepts, and features that will guide the creation of the final product.

Drawing is the process of creating detailed drawings and plans from design ideas. It involves converting the generated data into graphical representations using symbols, lines, and symbols. Drawings are often made using computer-aided design (CAD) software or traditional techniques such as drawings and tools.

The purpose of drafting is to communicate design goals and specifications in a clear and standardized manner. It provides detailed information about the geometry, dimensions, height, information, and other relevant aspects of the object representation. Design enables designs to be translated into a format that others, such as engineers, manufacturers, and designers, can understand and interpret.

Drawing plays an important role in many industries, including architecture, engineering, manufacturing, and construction. Building plans, mechanical equipment, electrical equipment, plumbing, etc. Used to create plans for These drawings is the common language that allows designers, engineers, and technicians to understand and implement designs.

With the development of CAD software, design has become more efficient and flexible. CAD systems allow designers and engineers to create, edit, and modify drawings digitally, providing greater accuracy, ease of revision, and the ability to generate multiple thoughts and feelings. CAD software can also simplify the entire product development lifecycle by integrating design information with other processes such as simulation, analysis, and manufacturing.

In summary, design and modeling are interrelated activities in the creation and presentation of drawings and plans. While design focuses on ideas and the development of solutions, the design translates these concepts into detailed information and designs that effectively communicate the brand's design plan. Planning and design are essential to bring ideas to life and ensure they are implemented correctly.

A short process of Design and Drafting:

- Create a 2D view of a rocket from the 3D model.
- Create views, dimensions, and annotations using SolidWorks drawing tools.
- Includes information such as material properties, tolerances, surface finishes, and assembly instructions.
- Use GD&T (geometric dimensioning and tolerancing) symbols and symbols as needed.
- Ensure drawings follow industry standards and recommendations.

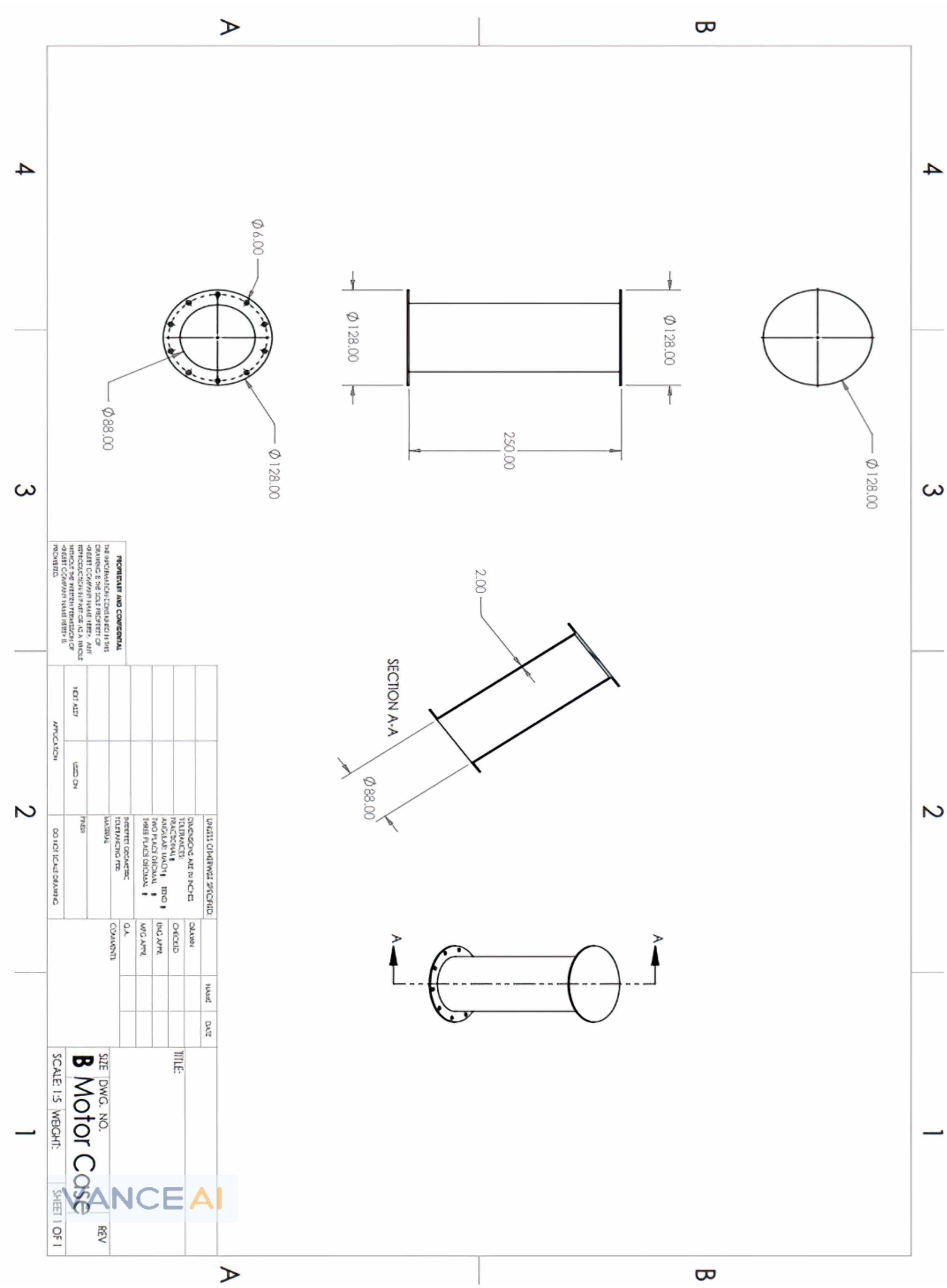


Figure 4.6: 2D Drafting- Casing

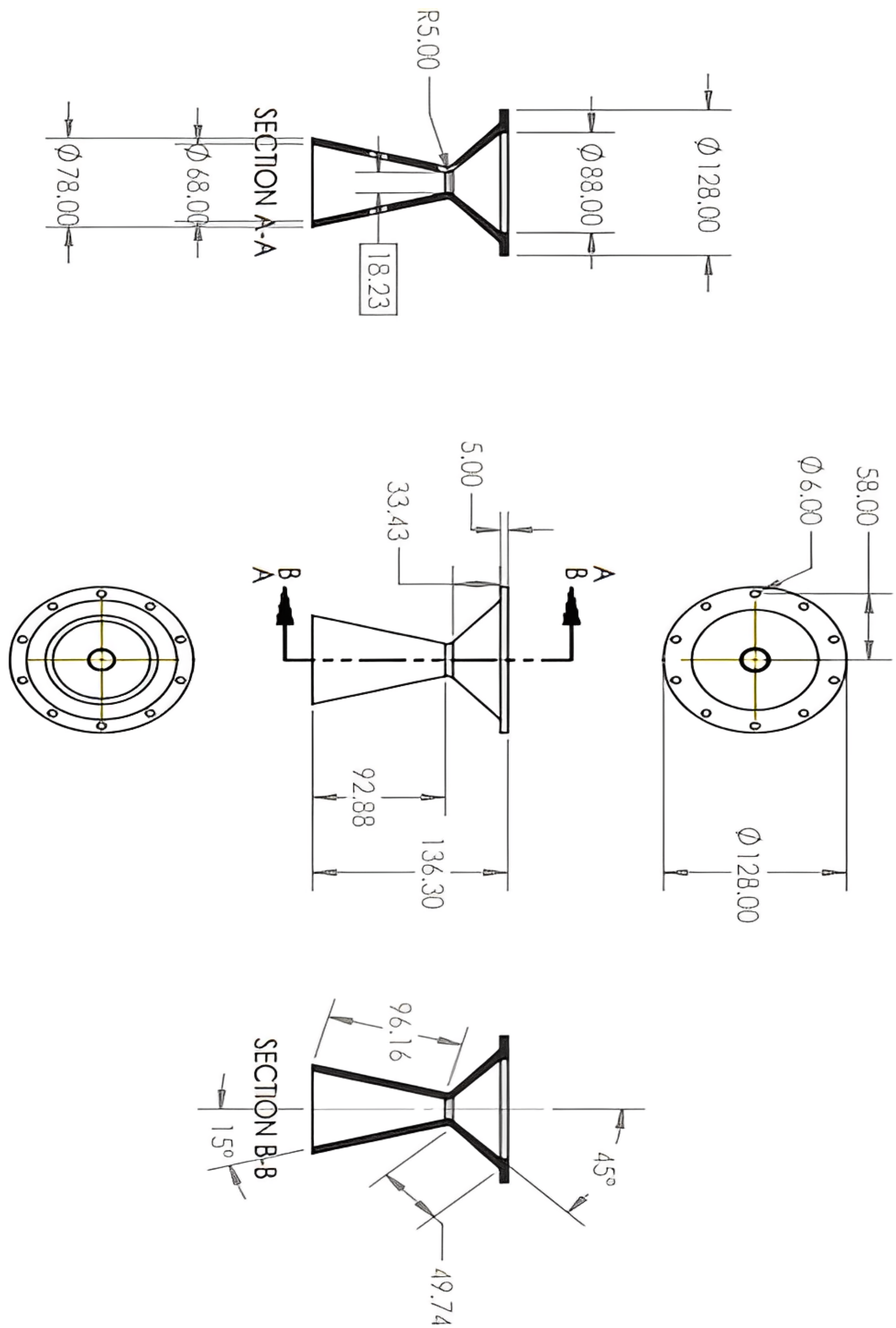


Figure 4.7: 2D Drafting- Casing

4.3 3D CAD Modelling:

3D CAD modeling or three-dimensional computer-aided design is the process of creating a digital representation of a product or specific software. It involves the creation, manipulation, and visualization of 3D geometry to accurately represent the physical properties of objects.

The 3D CAD modeling process usually includes the following steps:

1. **Design Conceptualization:** The process begins with forming an idea about the product or product to be modeled. This includes understanding the rules, limitations, and goals of design. Creative ideas can be created to show the content to start drawing or painting.

2. **Digital Modeling Environment:** 3D CAD software tools such as SolidWorks, Autodesk Inventor, or CATIA are used to create digital models. The software provides a digital workspace where designers can define the geometry and dimensions of objects.

3. **Geometric Creation:** The designer creates the basic geometry of the object using various tools provided by the CAD software. These tools include sketching, extruding, revolving, lofting, sweeping, and filleting. The designer specifies dimensions, constraints, and relationships between different geometric elements to define the shape and size accurately.

4. **Parametric Modeling:** Parametric modeling is a key feature of 3D CAD modeling. It allows the designer to associate dimensions and constraints with the geometry. By using parameters, such as length, width, or angle, the designer can easily modify the design, and the associated geometry automatically adjusts to reflect the changes. This parametric approach facilitates design flexibility and makes it easier to explore different design variations.

5. **Detailing and Refinement:** Once the basic geometry is established, the model is refined by adding details and features. This may involve creating complex curves, surfaces,

patterns, or intricate geometries. The designer can also apply textures, materials, colors, and lighting effects to enhance the visual representation of the model.

6. **Assembly and Interference Checking:** In situations where multiple components need to be designed and assembled, the 3D CAD software allows the designer to create assembly models. These models represent how the different parts fit together, their relationships, and how they move or interact. Interference-checking tools are used to detect any clashes or collisions between components and ensure proper assembly.

7. **Visualization and Rendering:** 3D CAD models can be visualized and rendered to create realistic representations of the designed object. Rendering involves applying materials, textures, lighting, and camera settings to generate high-quality images or animations that closely resemble the final product.

8. **Documentation:** In the final stage, 2D drawings and documentation are generated from the 3D CAD model. These drawings provide detailed information about the dimensions, tolerances, annotations, and manufacturing specifications required for the production of the object. The documentation includes orthographic views, section views, exploded views, bill of materials (BOM), and other necessary information for manufacturing, assembly, and quality control purposes.

Overall, 3D CAD modeling is a versatile and powerful tool for creating digital representations of objects or products. It enables designers and engineers to visualize, analyze, and communicate their ideas effectively, leading to improved design quality, faster product development cycles, and reduced manufacturing costs.

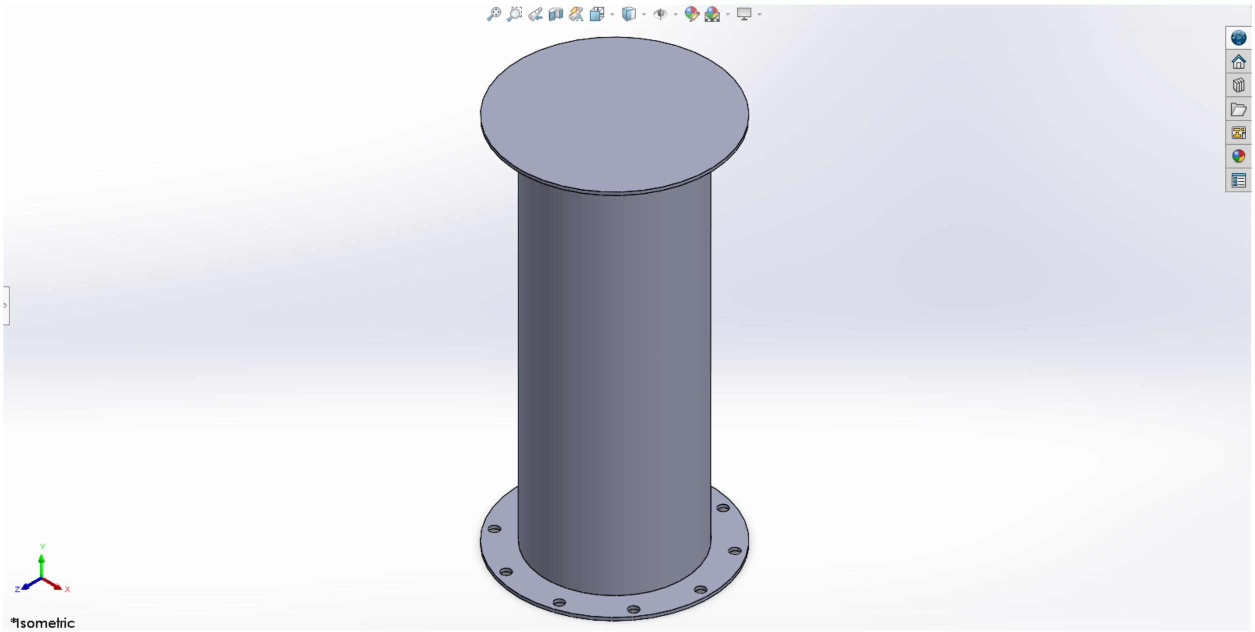


Figure 4.8: 3D CAD Model of Casing

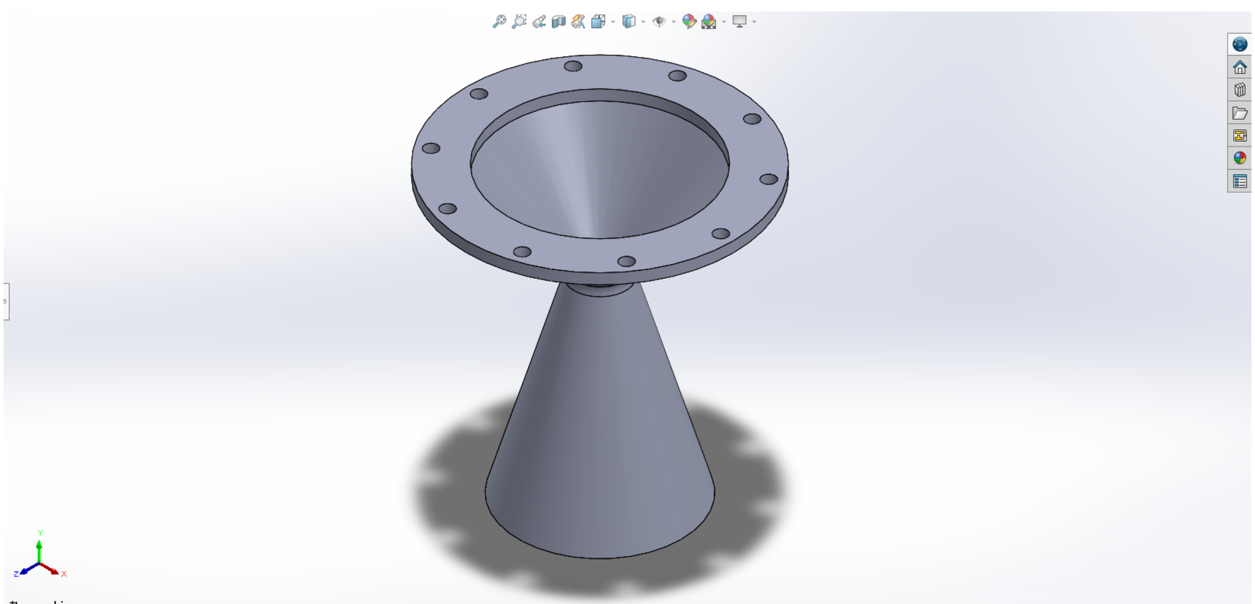


Figure 4.9: 3D CAD Model of Nozzle

4.4 CAD Model Assembly:

A 3D CAD model assembly is the process of combining multiple individual parts or components into a single cohesive model. It involves creating relationships and constraints between the parts to define their positions, orientations, and interactions within the assembly. Here is a detailed explanation of 3D CAD model assembly:

1. **Component Selection:** Identify and select the individual parts or components that will be assembled together to create the final product. These components can be existing 3D models or newly created parts.

2. **Placement and Positioning:** Position the components in their appropriate locations within the assembly. This involves defining their initial positions and orientations relative to a reference coordinate system or other components in the assembly.

3. **Constraints and Relationships:** Apply constraints and relationships to define how the components are connected and interact with each other. Constraints can include mate relationships, such as coincident, concentric, parallel, and tangent, as well as mechanical constraints like gears, cams, or hinges. These constraints ensure that the components behave as intended and move or rotate correctly within the assembly.

4. **Degrees of Freedom:** Check and control the degrees of freedom of the assembly. Degrees of freedom refers to the number of independent movements or rotations a component has within the assembly. The goal is to restrict unnecessary degrees of freedom while allowing the desired range of movement or flexibility required for the functioning of the assembly.

5. **Interference Detection:** Use interference detection tools to identify and resolve any clashes or interferences between the components. Interference occurs when two or more components occupy the same space, preventing proper assembly or movement.

Interference detection helps ensure that the components fit together properly and do not collide or interfere with each other during operation.

6. **Motion Simulation:** If required, perform motion simulation to verify the movement and functionality of the assembly. This involves defining motion constraints, such as limits, mates, and forces, and running simulations to evaluate how the components interact and move in response to external inputs or forces.

7. **Exploded Views:** Create exploded views of the assembly to illustrate how the individual components fit together and how they are disassembled or assembled. Exploded views are useful for assembly instructions, service manuals, or visual communication purposes.

8. **Bill of Materials (BOM):** Generate a bill of materials that lists all the components included in the assembly. The BOM provides details about each component, such as part numbers, descriptions, quantities, and other relevant information for manufacturing and procurement purposes.

9. **Documentation:** Create detailed 2D engineering drawings from the 3D assembly model. These drawings include orthographic views, section views, dimensions, annotations, and other necessary information for manufacturing, assembly, and quality control.

By using 3D CAD model assembly techniques, designers and engineers can visualize, analyze, and communicate the relationships and interactions between components, ensuring accurate and efficient assembly of complex products or systems.

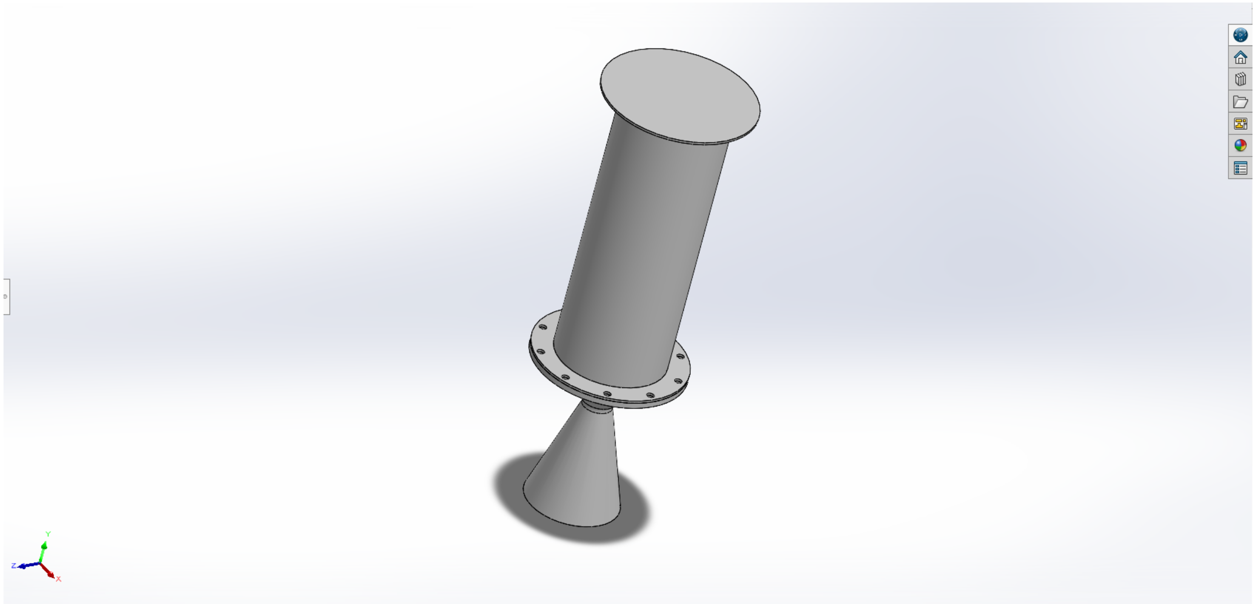


Figure 4.10: 3D CAD Assembly of Solid Rocket Motor

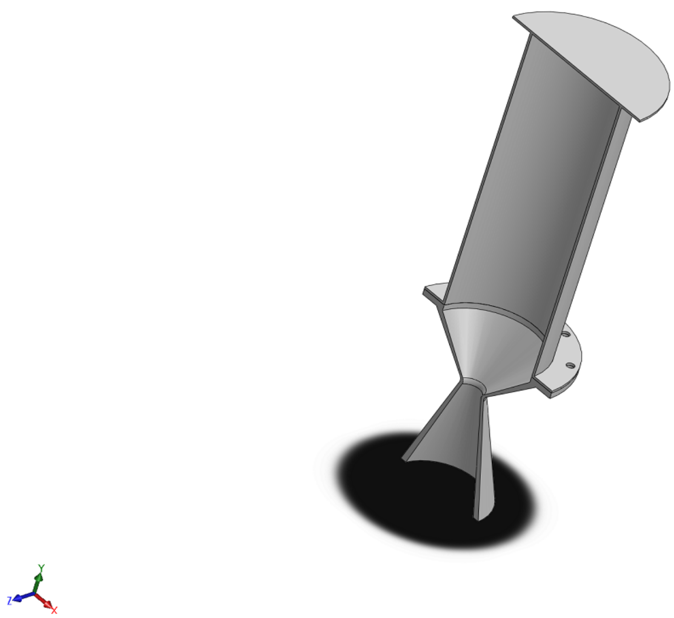


Figure 4.11: Section View- 3D CAD Assembly of Solid Rocket Motor

CHAPTER 5

FABRICATION

5.1 Introduction

The material used in making the nozzle is Mild steel, the nozzle is made on a lathe, it is easy to use and has the advantage of low cost in the later stage, it takes 2-3 days to complete the nozzle. There are some problems, but we passed the Exchange, some did not solve it and the final design was prepared as below.

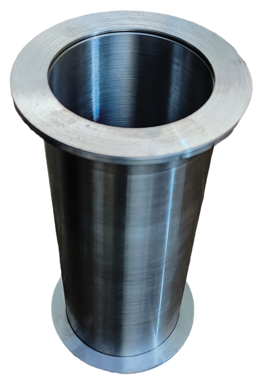


Fig no.5.1 : Mild steel Fabricated Casing

After fabricating the spout there's an external rib which was made separately so that there's no interaction between the Lathe machine jaws and spout typically since on the off chance that spine was made from the piece the jaws seem break the spout which would have been coming about within the cracked spout.

After making the external rib, the spout and rib were welded with the TIG welding which is the foremost solid and clean welding after the TIG the portion was given to penetrate the bore so that the spout seems to get connected to the engine case without any spillage.

Fig no 5.2 : Mild Steel Fabricated Nozzle

Mild steel, moreover known as plain carbon steel, is broadly utilized in construction sites. The steel contains a thickness of 7.8g/cm^3. Considering that gentle steel displays a nearly comparative impact of temperature on its quality as experienced by Stainless Steel, fetched distinction and the complex machining of spout required a flexible fabric which does not break on machine operations; mellow steel was chosen for the manufacture of nozzle.

For the engine case we got the GI (Galvanized Iron) fabric pipe which has the ID of 85mm this engine case was moreover given the external spine which was welded to the pipe with the TIG welding, and the other side of the pipe was fixed with the MS (Mellow Steel) circular sheet to shut the one conclusion.

After the fully fabricating of the nozzle and the motor case the SRM is prepared to fill with the propellant and prepared to test.

5.2 Manufacturing of nozzle and motor case

The material used is mild steel for the nozzle and casing. The total material (MS) weighed around 14.85 kg for manufacturing.

The nozzle was created by using the lathe machine which was a low-cost advantage. The nozzle manufacturing took almost 3-4 days on lathe. The outer flange was not manufactured separately to avoid the welding of the flange to the nozzle. The weight of the nozzle after manufacturing weighed 3kg.

Fig no . 5.3 : Cylindrical casing Model ***Fig no . 5.4 : Nozzle-Flange Model***

Mild steel is a type of carbon steel with a low amount of carbon – it is also known as "low carbon steel." Although ranges vary depending on the source, the amount of carbon typically found in mild steel is 0.05% to 0.25% by weight, whereas higher carbon steels are typically described as having a carbon content from 0.30% to 2.0%. If any more carbon than that is added, the steel would be classified as cast iron. The steel has density around 7.8g/cm^3.

Mild steel is not an alloy steel and therefore does not contain large amounts of other elements besides iron; you will not find vast amounts of chromium, molybdenum, or other alloying elements in mild steel. Since its carbon and alloying element content are relatively low, there are several properties it has that differentiate it from higher carbon and alloy steels.

Less carbon means that mild steel is typically more ductile, machinable, and weldable than high carbon and other steels, however, it also means it is nearly impossible to harden and strengthen through heating and quenching. The low carbon content also means it has very little carbon and other alloying elements to block dislocations in its crystal structure, generally resulting in less tensile strength than high carbon and alloy steels. Mild steel also has a high amount of iron and ferrite, making it magnetic.

Fig no 5.5 : Case-Nozzle Assembly

Mild steel, also known as low-carbon steel, is one of the most widely used steel. It is used in the construction and automotive industries, and for fencing, signs, and innumerable other applications. It is valued for its weldability, machinability, and Ductility.

Mild steel is used because of its impact strength ratio, and due to its high malleability, it will be easy to change its form of shape, during fabricating it, for drafting any model we use various software like open motor and solidworks where we get the proper dimensions of the convergent -divergent nozzles. the further process is manufacturing that model or design in the real world with the help of lathe machine .(a machine tool that rotates a workpiece about an axis of rotation to perform various operations such as cutting, sanding, knurling, drilling, deformation, facing, and turning) in spite of nozzle , also provide them with a mild steel pipe for the casing (The motor case generally consists of a steel or aluminum tube; it has a head-end dome that contains an igniter and an aft-end dome that houses or supports the nozzle.) for the casing part a hollow cylindrical shape pipe we used , in which the propellants will be added, at one end it will be welded completely and packed with a flange , and at the other side of it , another flange is welded with drive holes in it at an angle of 45 deg.

The whole process will take around 3-4 days of gap , where at the end the assembly model of nozzle and casing will be obtained and we can use further casting with propellants for further works.

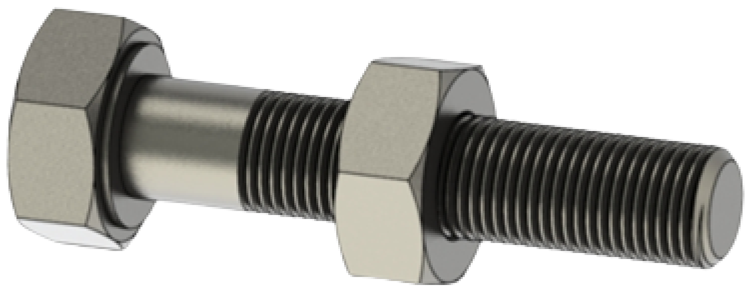


Fig no. 5.6 : M6 Nuts and bolts

For the casing part we used mild steel as we did the same for nozzles because of the availability of the material. To attach the flange to the casing we used the TIG Welding which is said to be the most strong and clean welding.

After all the manufacturing process and resolving the problems faced during manufacturing the fully manufactured solid rocket motor SRM is ready for the casting of the propellant.

M6 nuts and bolts are widely used in many applications, including rocket engines. However, it is important to note that specific hardware options may differ between rocket designs and manufacturers .The rocket engine assembly consists of several components such as the housing, nozzle, igniter, and propellant cartridge. Nut and bolt selection depends on the material, such as material, load requirements, and environment. High-power, heat-resistant materials are often preferred in rocket engines.

Stainless steel or titanium alloys are widely used because of their strength, corrosion resistance and ability to withstand heat. This material provides the necessary durability and reliability for the use of rockets. For M6 size fasteners, you will usually need an M6 bolt (or screw) and an M6 nut. The bolt will have a hex-head threaded spindle for easy tightening, while the nut will have an internal thread that matches the bolt.

It is important to ensure that the nuts and bolts used in the rocket engine comply with the instructions and standards set by the rocket manufacturer. These properties can include material properties, thread type (such as metric coarse or fine thread), and strength requirements. It is important to note that the Rocket engine is site specific and specific hardware options and assembly procedures may vary based on the capabilities of the rocket design and manufacturing facilities. Therefore, it is important to consult the manufacturer's information, engineering specifications, or an expert in the field to verify that nuts and bolts are used for a particular rocket engine.

Manufacturing Considerations:

One of the different processes that will be used to make rocket engines will be changes in the pro perties of the materials to which they are exposed. Depending on the material, the processing and the reaction of the material, the change in the product may or may not be suitable for use. The se lection of the manufacturing process for a product will be based on the advantages of this process and minimize the disadvantages. When the product's response to the manufacturing process is u nknown or too inadequate to detect, the product will be evaluated by the tests described in Sectio ns 2.4 and 2.5.

Some examples of creative thinking are discussed in the following paragraphs.

In some cases, work

related hard work can increase energy consumption, leading to the production of the product. Inc reasing the energy level can reduce the bone hardness of the material below an acceptable level. I n other cases, the hardening process involves formation (eg.For example, shear spinning) can be used in high strengthmachinable hardenable materials where pressure levels can be increased wit hout damaging the skin. Depending on the welding process used, the mechanical and physical pr operties of the material being welded are often very different. The most commonly used methods are gas tungsten arc welding (GTAW), gas metal arc welding (GMAW), electric beam (EB), submerged arc welding (sub arc welding), resistance welding (spot welding) and many variations. soldering welding. In tests using a combination of jointing and heat treatment, the welding process is chosen to produce sufficient tensile strength and fracture toughness in heat removal attack of the weld and shell material.

The higher power consumption of the electric arc welding equipment and the gas metal arc welding process (compared to the gas tungsten arc welding process) can reduce the tensile and fracture toughness of the weld and metal, and the grain structure in the weld, in the welding performance . - the affected area. When gas tungsten arc welding process requires more welding time (less coating per case than GMAW and sub-arc welding process), the best weld with good fracture toughness needs to be used. GMAW and sub-arc processes are more cost-effective than GTAW when appropriate welding (and HAZ) characteristics and performance can be achieved.

CHAPTER 6

RESULTS AND ANALYSIS

6.1 SOFTWARE USED:

We have used Ansys(version 2021R2) Simulation software for our Computational fluid dynamics analysis. ANSYS 2021, ANSYS, Inc. It is a powerful engineering simulation software package developed by engineers, designers, and researchers in various industries to simulate and analyze complex phenomena. ANSYS provides a comprehensive set of tools and capabilities for structural analysis, fluid dynamics, and electromagnetic and multiphysics simulation. Some of the key features and capabilities of ANSYS 2021 are:

Fig 6.1: Ansys logo

1. **Structural Analysis**: ANSYS allows users to simulate and analyze the behavior of structures under various loads. It provides various analysis tools such as linear and static analysis, dynamic analysis, fatigue, and compound analysis. Users can measure the strength, stiffness, and durability of products and models.
2. **Fluid Dynamics:** ANSYS can simulate fluid flow, heat transfer, and other phenomena. It includes computational fluid dynamics (CFD) capabilities to model and analyze fluid flow and heat transfer in complex geometries. Users can examine flow behavior, improve design, and measure the performance of systems such as pumps, turbines, and electrical equipment.
3. **Electromagnetic:** ANSYS provides electromagnetic simulation tools to analyze electromagnetic fields, antennas, circuits, and electromagnetic compatibility (EMC) issues. Users can examine the behavior of electronic devices, optimize antenna designs, identify integrity issues, and measure electromagnetic interference (EMI).

4. **Multi-Physics Simulation:** ANSYS allows users to combine multiple physics and perform multi-physics simulations. It has the ability to combine communication processes, fluid dynamics, electromagnetics, and other physical phenomena to simulate complex interactions and events occurring in global systems.

Fig 6.2: Types of analysis systems in Ansys

5. **Optimization and Design Exploration:** ANSYS includes optimization capabilities to help users improve designs and achieve optimal performance. It provides tools for parameter optimization, shape optimization, topology optimization, and design exploration. Users can iteratively refine designs based on simulation results and explore design alternatives.

6. **High-Performance Computing (HPC):** ANSYS 2021 leverages parallel processing and distributed computing to accelerate simulations and handle large-scale models. It supports HPC environments, enabling users to solve complex problems faster and more efficiently.
7. **Integration and integration**: ANSYS integrates with various CAD software, allowing users to import drawings and perform simulations directly on CAD models. It also provides collaboration capabilities that allow multiple users to work on the same project simultaneously and share simulation data and results.

ANSYS 2021 continues to improve functionality, performance, and user experience by enabling engineers and scientists to solve complex engineering problems and improve design across multiple industries, including aerospace, automotive, energy, electronics, and manufacturing.

ANSYS, Inc. is a well-known provider of engineering simulation software, but there are many companies that offer similar solutions and can be considered competitors. Here are some of the main competitors of ANSYS:

- Siemens PLM Software (Simcenter)
- Dassault Systèmes (SIMULIA)
- Altair Engineering (HyperWorks)
- MSC Software
- COMSOL
- Autodesk (Simulation CFD, Nastran)
- PTC (Creo Simulate)

These are just a few of the competitors in engineering simulation and virtual prototyping. It is worth noting that each company has its own strengths and areas of expertise, and the choice of software often depends on the specific needs and needs of the people or the organization.

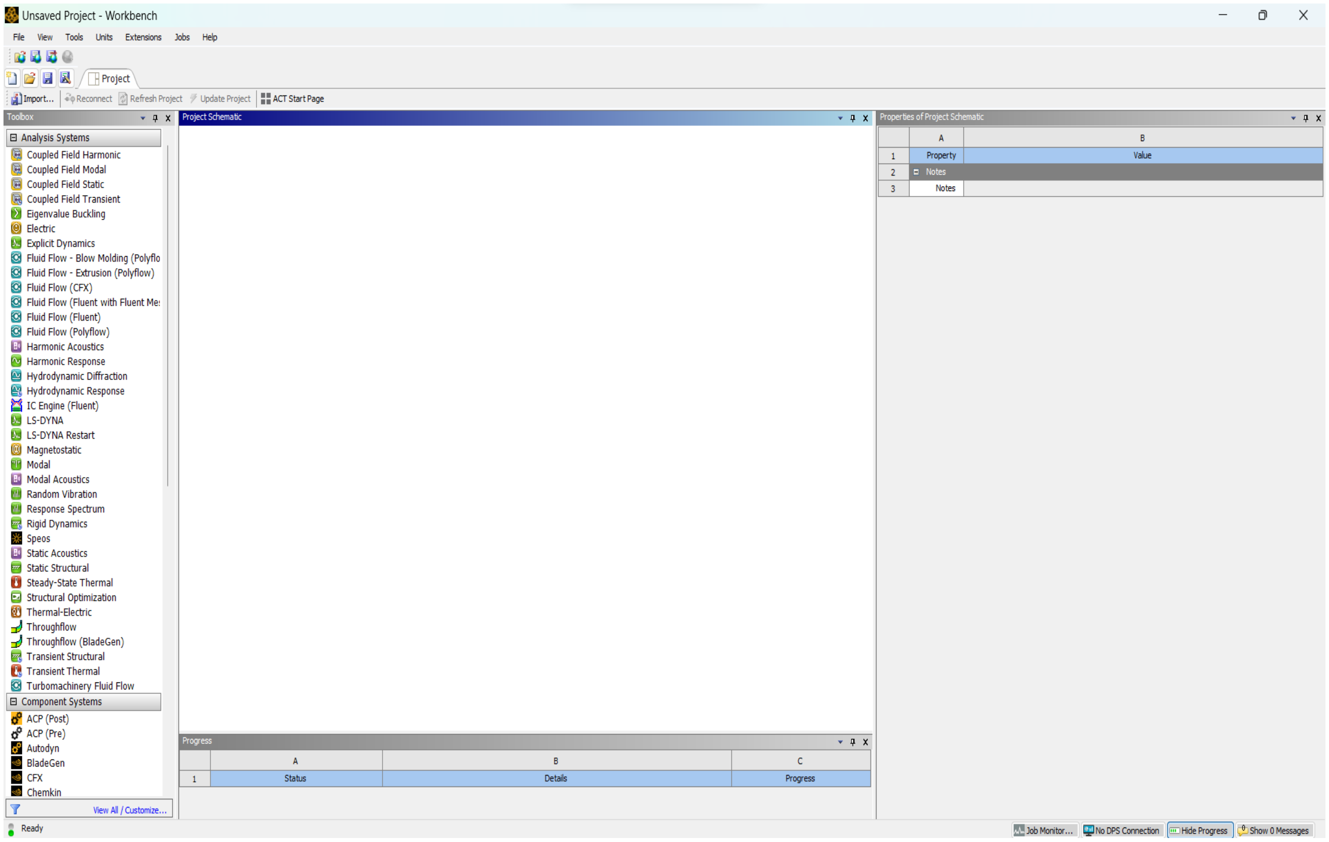


Fig 6.3: Ansys new window GUI

6.2 NUMERICAL METHODS IN ANSYS:

ANSYS primarily utilizes the Finite Element Method (FEM) for structural analysis and the Finite Volume Method (FVM) for fluid dynamics simulations. These methods are widely recognized and extensively used in engineering and computational physics.

The Finite Element Method (FEM) is a numerical technique for solving partial differential equations by dividing a complex geometry into smaller, simpler subdomains called finite elements. Each finite element represents a small portion of the overall geometry, and the behavior of the system is approximated by solving equations within each element. The FEM is commonly employed in ANSYS for structural analysis, such as stress analysis, deformation analysis, and modal analysis.

CHAPTER 7

CONCLUSION AND REFERENCE

CONCLUSION

In conclusion, our solid rocket motor has successfully completed the manufacturing of the necessary components, including the nozzle, casing, and propellant (KNSU). According to the Open motor software we have determined that the expected thrust of the motor is around 600-700 N. The design of the nozzle and its seat was modeled in the design section and assembled with the help of Solidworks. This includes determining demand, burn time and load capacity, as well as factors such as operational stability and sustainability. Propellants are generally fuel and oxidizer mixtures that must be carefully formulated to meet the desired performance. This includes the selection of the right ingredients, the balance of required energy consumption, and the addition of additives to control combustion, combustion stability and other properties.

Through propellant burn testing, we have found that the propellant (KNSU) creates smoke and residue granules when in thick mixture form but heating the mixture for 20-30 mins at around 160-250 degrees Celsius and can make the mixture more efficient for burning.

Further testing will be needed to determine the full efficiency and performance of the rocket motor, and safety precautions must be taken when working with propellants.Safety is essential for the manufacture of fireworks. Special care must be taken to secure and store power tools because they can be very powerful and potentially dangerous. The manufacturer should adhere to the lack of tight air to prevent rust, and equipment and tools should be more careful. The propellant rapidly begins to harden as it cools, requiring that the pouring operation be conducted quickly. The melted mixture is also quite sticky. Lubrication of the coring tool is necessary to prevent sticking.

The sucrose in the mixture, once heated to melting temperature, begins to caramelize which reduces the performance of the propellant. Therefore, the heating process must be conducted over the minimum possible time duration. The production process must be carefully followed from the design stage to produce engine materials, heads and machines. This will include casting or molding the propellant, machining the housing and nozzle, and assembling the various components. The overall design of the CD nozzle and housing can be easily created using a lathe. Strict quality control throughout the manufacturing process is essential to ensure the reliability and safety of the rocket. Non-destructive tests such as x-rays or ultrasound are often used to detect defects or abnormalities.

We also tested the purified potassium nitrate of Emparta and Emplura which led us to the conclusion that the Emplura is more efficient. Since it produces less amount of smoke as compared to Emparta . The rocket must be designed to withstand the heat and temperature generated during combustion.

It is usually made of strong and heat resistant materials such as steel or composite materials. Nozzles are carefully designed to optimize exercise and exhaust. The finished engine is then subjected to rigorous tests, including static fire tests, to evaluate its performance in real-world applications. When the propellant is ready for testing, it is placed in a test rig and tries to overcome its small size with maximum thrust.

REFERENCES

1. **Antonio Carlos Foltran, Diego Fernando Moro, Nicholas Dicati Pereira da Silva, Ana Eliza Gonçalves Ferreira, Luciano Kiyoshi Araki, Carlos Henrique Marchi "Burning Rate Measurement of KNSu Propellant Obtained by Mechanical Press" Journal of Aerospace Technology and Management, Universidade Federal do Paraná, May 2015**
2. **Mohammed Iliyaas .A, Dr.K.Karuppasamy "Computational Analysis of CD Nozzle for Solid Propellant Rocket" Anna University Tirunelveli Region, Tirunelveli, Aug 2016 19**
3. **Nevin Nelson, Yezhil Arasu, Kiran Kumar, Thomas Kurian "Stress Analysis of Solid Rocket Motor Case" Bishop Jerome Institute, Kerala, India, Mar 2020**
4. **Roy Hartfield, Rhonald Jenkins, John Burkhalter, and Winfred Foster "A Review of Analytical Methods for Solid Rocket Motor Grain Analysis" Aerospace Engineering Department, Aubum University, Auburn, Alabama, Jun 2012**
5. **Sidhant Singh "Solid Rocket Motor for Experimental Sounding Rockets" the University of Petroleum and Energy Studies Dehradun, India, 2013**
6. **P.G. Sutton and O. Biblarz, Rocket Propulsion Elements, John Wiley & Sons, New York, 2001.**
7. **N.D. Mundhe, "Analysis of Cracked Cylindrical Pressure Vessel by Using Experimental Approach, International Journal of Latest Trends in Engineering and Technology", Vol.2, pp.155-160, 2013.**
8. **Mr. Shaik Muzib, "Design and analysis of solid propellant rocket nozzle and its applications to RCS", Vol. 9, Issue 5, Oct 2019.**
9. **Jackson Stephenson, "Design of Nozzle for High-Powered Solid Rocket Propellant" University of South Florida, 2018**
10. **ENERGETIC MATERIALS AND METAL BORIDES FOR SOLID PROPELLANT ROCKET ENGINES**
11. **https://estesrockets.com/product/007243-black-brant-ii/**
12. **https://commons.wikimedia.org/wiki/File:Solid-Fuel_Rocket_Diagram.svg**
13. **https://aerospaceengineeringblog.com/rocket-science-101-fuel-engine-nozzle/**

14. https://www.indiamart.com/proddetail/potassium-nitrate-5112243830.html

15. https://www.indiamart.com/proddetail/sorbitol-powder-21102695173.html

16. https://meteor.open-sky.fr//motorDesign

17. Ji, S., Wang, B., & Zhao, D. (2020). Numerical analysis on combustion instabilities in end-burning-grain solid rocket motors utilizing pressure-coupled response functions. Aerospace Science and Technology, 98, 105701.

18. Greatrix, D. R. (2008). Transient burning rate model for solid rocket motor internal ballistic simulations. International Journal of Aerospace Engineering, 2008.