

STUDY ON TYPICAL INHIBITION RESIN MIXING EQUIPMENT TO INCREASE EFFICIENCY

Submitted in partial fulfillment of the requirements for the award of bachelor
of
Technology Degree in Chemical Engineering

by

POTTURI.BAPI RAJU (40690011)



**DEPARTMENT OF CHEMICAL ENGINEERING
SCHOOL OF BIO AND CHEMICAL ENGINEERING
SATHYABAMA**

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

Accredited with Grade "A++" by NAAC

JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI - 600 119

OCTOBER - 2023



SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)

Accredited "A++" Grade by NAAC | 12B Status by UGC | Approved by AICTE

www.sathyabama.ac.in

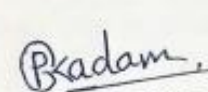
DEPARTMENT OF CHEMICAL ENGINEERING

BONAFIDE CERTIFICATE

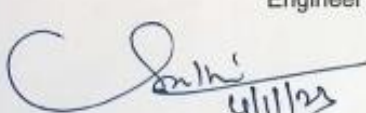
This is to certify that this Professional Training Report is the bonafide work of **POTTURI.BAPI RAJU (Reg.No.40690011)** who carried out this project entitled "**STUDY ON TYPICAL INHIBITION RESIN MIXING EQUIPMENT TO INCREASE EFFICIENCY**" under our supervision from July 2023 to November 2023.


INTERNAL GUIDE

Dr.M. KARTHIKEYAN, M.Tech.Ph.D
Assistant Professor

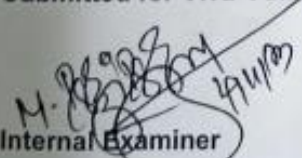

EXTERNAL GUIDE

K.PANKAJ PRAKASH M.Tech,
Engineer SD SDSC SHAR


Dr.S.SATHISH, M.E., Ph.D.,
HEAD OF THE DEPARTMENT

HEAD OF THE DEPARTMENT
DEPARTMENT OF CHEMICAL ENGINEERING
SATHYABAMA
INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)
Jeppiaar Nagar, Rajiv Gandhi Salai
Chennai - 600 119

Submitted for Viva-Voice Examination held on 4-11-23


Internal Examiner


External Examiner

DECLARATION

I, **POTTURI.BAPI RAJU** (Reg.No.40690011) hereby declare that this report entitled "**STUDY ON TYPICAL INHIBITION RESIN MIXING EQUIPMENT TO INCREASE EFFICIENCY**" done under the guidance of **Dr.M. KARTHIKEYAN, M.Tech., Ph.D.,** Assistance Professor, Department of Chemical Engineering, Sathyabama Institute of Science and Technology and **K. PANKAJ PRAKASH, M.Tech.,** Engineer, SD SDSC SHAR Sriharikota is submitted in partial fulfilment of bachelor of technology in chemical engineering

DATE : October 2023

PLACE: Chennai


SIGNATURE OF THE CANDIDATE

ACKNOWLEDGEMENT

I am pleased to acknowledge my sincere thanks to The Board of Management of SATHYABAMA for their encouragement in doing this internship and for completing it successfully. I am grateful to them.

I convey my thanks to **Dr.S.SATHISH, M.E., Ph.D.**, Head, Department of Chemical Engineering for providing me necessary support and details at the right time during the progressive reviews.

I would like to express my sincere and deep sense of gratitude to my Year coordinator **Dr. Karthikeyan. M, M.Tech., Ph.D.**, for his valuable guidance, suggestions and constant encouragement which paved way for the successful completion of my project work.

I wish to express my thanks to all Teaching and Non-teaching staff members of the Department of Chemical engineering and the staff members in industry who were helpful in many ways for the completion of the project.

POTTURI BAPIRAJU

ABSTRACT

Every successful rocket launch involves the predefined trajectory of the vehicle during its journey. The first stage solid motor performance is evaluated based on Pressure-Time (P-T) curve. In order to meet the specified P-T curve requirement for typical solid booster space booster, unwanted surface area to be masking with a inert polymeric composite material is known as inhibition resin (IR-1). It is the mixture of castor oil and silica fabrics.

In manual mixing exposure to the toxic and hazardous chemicals like TDI and Toluene. Introducing the mixing equipment to the resin mixing reduces the exposure and increases the efficiency of mixing IR-1. In this project focused on the mixing equipment and stirrers which can be adopted for the typical IR-1 and determine the optimized parameters like RPM, mixing time and preparing the samples for varies properties evaluation.

Keywords: IR-1, TDI, Toluene, propellant.

TABLE OF CONTENTS

CHAPTER NO.	TITLE	PAGE NO.
	ABSTRACT	v
	LIST OF TABLES	viii
	LIST OF FIGURES	ix
	LIST OF ABBREVIATIONS	x
1.	INTRODUCTION	1
1.1	KEY ASPECTS OF MIXING	3
1.1.1	Based on Equipment	5
1.1.2	Based on Material State	6
1.1.3	Nature of the Materials	7
1.1.4	Mixing Equipment	8
1.1.5	Operating Conditions	8
1.2	INTRODUCTION TO ROCKETS	8
1.2.1	Rocket Propulsion	9
1.2.2	Types of Rockets	9
1.2.3	Application of Satellites	10
1.3	INHIBITION RESIN (IR-1)	10
1.3.1	Flight Control	11
1.3.2	Inhibition for Radial Flow	11
1.3.3	Flow Restriction	12
1.4	PROBLEM STATEMENT	16
2.	AIM & SCOPE	18
3.	MATERIALS AND METHODOLOGY	20
3.1	PRE-MIX	20
3.2	FINAL MIX	22

CHAPTER NO.	TITLE	PAGE NO.
3.3	REACTION	24
3.4	SELECTION OF STIRRER	27
4.	RESULT AND DISCUSSION	32
4.1	STUDIES ON PREMIX	32
4.1.1	Process Difficulties with IR-1 Pre-mix While Conducting Experiment	32
4.2	EXPERIMENTAL STUDY ON INHIBITION RESIN AS FINAL MIX	35
4.2.1	Process Difficulties with IR-1 Final-mix	35
5.	CONCLUSION	43
	REFERENCES	44

LIST OF TABLES

TABLE NO.	TITLE	PAGE NO.
3.1	Raw materials for pre-mix	20
3.2	Silica fabric properties	21
3.3	Raw materials for final mix	22
3.4	Properties of Toluene	24
3.5	Properties of FeAA	24
3.6	Mechanical Properties of IR-1	25
3.7	Thermo-chemical properties of IR-1	25
3.8	Comparison of Stirrers	31
4.1	Pre-Mix Experimental Matrix	33
4.2	Final Mix Experimental Matrix	36
4.3	Final Mix Experimental Matrix	41

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE NO.
1.1	PSLV	9
1.2	Thrust Vs Time Graph	15
4.1	Premix stirrer RPM Vs Solid Content Graph	34
4.2	Premix stirrer RPM Vs Tensile Strength Graph	37
4.3	Final mix stirrer RPM Vs Elongation Graph	38
4.4	Final mix stirrer RPM Vs Density Graph	39
4.5	Final mix stirrer RPM Vs Hardness Graph	40
4.6	Final mix stirrer RPM Vs <i>Pot life</i> Graph	42

LIST OF ABBREVIATIONS

FeAA	FERRIC ACETYLE ACETONATE
IR-1	INHIBITION RESIN
TDI	TOLUNE DIISICYANATE
TCE	TRI CHLORO ETHYLENE

CHAPTER -1

INTRODUCTION

Mixing is the process of combining two or more initial separated chemicals or substances to form uniform distribution of all chemicals or substances by which new product is created for desired properties for particular application. Mixing is an important operation in many chemical and allied process industries. Mixing plays a vital and important role in industries like petroleum, polymers, cosmetics chemicals, waste water treatment, pharmaceuticals, paper and pulp industries, etc.

Based on the application variety of mixing equipment's are available. The Selection mixing equipment is very much important as it is directly associated with final product quality. Impellers are the heart of mixing equipment and properties of solids/fluids which is to be mixed is also main consideration for the selection of impellers for given mixing equipment. Different designs of impellers are used for different applications. Some of the important aspect need to be considered while mixing of new chemicals/sustenance's i.e., 1) type of mixing equipment 2) Type of raw materials 3) weightment 4) safety during mixing operation

The type of mixing equipment used depends overall on the quantity of raw materials to be handled and type of operation. This mixer consists of vessels/containers/drums, impellers for solid/liquid motion, baffles for avoiding vortex, inlet/outlet pipes and vents for samples collection.

Raw materials with suitable size are also a requirement for given mixer. Some of the chemicals/sustenance's having high viscosity and solid substances to be mixed with this type fluids so this decision is crucial as it determines the properties and characteristics of the final mixture/product.

Accurate weighing of all the ingredients/chemicals is essential to ensure that the desired proportions are maintained. This can be achieved by using standards and using calibrated weigh balances and other measuring equipment's etc.

Strictly following the safety norms by wearing appropriate Personal Protective Equipment (PPE), like gloves, vapour masks, dust masks and safety goggles. Safety is an utmost importance when working with chemicals. Personnel working in this area proper ventilation should be maintained at chemical storage area of chemicals to reduce quantum of the health risk.

For all new process/ chemical/ mixture different types of impellers are being used. Mainly two types of flow patterns that can be developed mixing impellers those are axial or radial. Radial flow impeller discharges the fluid to the vessel wall in horizontal or radial direction. If suitable baffle is placed there is a strong top to bottom axial movement also can be achieved in case of axial flow top to bottom movement of materials can be observed. Basically, mixing is the process of combining two or more chemical substances to produce a uniform or homogeneous and well-mixed mixture or to initiate a chemical reaction. Mixing may be with chemical reaction or without chemical reaction. The efficiency of mixing or mixing equipment in without chemical reaction is known through the homogeneity. In case of chemical reaction involves monitoring the concentration of reactions and products over a time can provide the progress of the mixing. Efficient mixing is important in every mixing process in order to get pure product with desired properties and less unwanted by products.

The ultimate goal of any mixing process is to get a homogenous distribution of the all the ingredients/components. In some cases, process should be done in controlled temperature to achieve required operations such as Heating or cooling or to control reaction rates in case of chemical reaction so then the mixing technique can vary depending on the chemicals or components to be mixed.

It is essential to monitor the chemical reaction if mixing involves a reaction. This can be done by temperature monitoring, periodic sampling and analysis to verify the reaction rates so reaction progress with time.

Standard operating procedure: it is to be prepared and must be followed during the entire process so that the final product meets the desired properties and specific values.

Raw materials specifications: all raw materials specifications should be strictly followed and if any deviation then that batch may be rejected

Residual management: Proper housekeeping and equipment cleaning and disposal of residue or byproducts is to be discarded safely without environment hazards

Industrial mixing processes having a wide scope. From lab, pilot plant, small scale process to large scale industry. Every process had its own procedures and precautions based of their nature and the process requirement.

1.1 KEY ASPECTS OF MIXING

Efficient Mixing: It refers to the proper utilisation of impellers/stirrers for specific chemicals. It can be controlled by changing the varies parameters like stirrer RPM, mixing time, blade configuration, Different applications require different mixing intensities.

Mode of operation: mixing processes can be performed in batch or continuous modes depends on the demand and requirement or convenient. Batch mixing refers to components charged in to the vessel after batch time, a well-mixed material will take out as a product, while in continuous process involves a continuous feeding and product delivering takes place

Viscosity and Rheology: The viscosity and rheological properties of a materials had an impact on the selection of mixing equipment and the mixing process itself. Highly viscous or non-Newtonian fluids may require customised mixing designs.

Environmental impact: Safety is utmost in chemical engineering. Proper handling of hazardous & toxic chemicals, explosion prevention techniques, and environmental impact assessment are primer aspects of chemical mixing.

Residual management system: in many chemical mixing process biproducts, residual disposal techniques create safe work environment Chemical engineers often employ optimization techniques and control strategies to ensure that mixing processes meet desired specifications and objectives efficiently.

System of reliability & Quality Control: Regular quality control helps to maintain the quality of the mixing and ensure that they meet the expected standards and specifications. Mixing is a multifaced field that requires a deep knowledge of fluid behaviour through properties, rate of reaction, chemistry of the raw materials, and laws principles. It plays a vital role in various chemical processes, from basic laboratory level to production level, and contributes significantly to product quality, process efficiency, and safety. Mixing is an important operation in various chemical industries, and it can be divided in to into varies t types based on criteria, including the nature of the materials being mixed, the purpose of mixing, and the equipment used. Here are some common categories of mixing:

Mixing for Homogenization: The objective of this type of mixing is to get a homogenised mixture throughout the vessel. It is commonly used to create turbulence which make all components are distributed evenly

Blending: Blending is the process of combining chemicals/components to obtain required exact composition or consistency. It is used to mix different powders, granules, or liquids to create a particular composition.

Reaction/Mixing: in this type of process chemical reactions takes place due to reactants are in contact with each other, either by batch reactions, continuous reactions, and polymerization.

Slurry Mixing: slurry mixing involves distributes the solid particles in a liquid medium to create a homogeneous mixture This is common in used in many chemical industries like bentonite sulphur manufacturing and inhibition resin mixing etc.

Agitators: Agitators are equipment those are used to maintain the mixtures composition uniform throughout the vessel by making shear to a fluid or material, which causes the fluid to homogenize. Mixers are differing from agitators by the action while mixer are used to mix two or more components and Agitators for maintaining homogeneity.

Gas-Liquid Mixing: it involves the Gas dispersion through the (e.g., air or oxygen) into a liquid medium. It is often used in processes like fermentation, aeration, and wastewater treatment.

1.1.1 Based on Equipment

Agitation Mixing: Agitation mixing involves the use of mechanical agitation, typically through impellers or stirrers, to promote mixing. It is widely used in both laboratory and industrial settings.

Shear Mixing: High-shear mixing uses for material with high viscous and containing solids and fines in it, so intense mixing is required for this king of materials it is commonly used suspensions, pastes, and slurries.

Powder Mixing: it is a dry mixing, predominately uses in pharmaceutical industries tumble blenders, ribbon blenders, screw blender comes in this category.

Planetary Mixing: Planetary mixers are high precision mixer which is having a combination of both rotating and revolving motions to achieve thorough mixing of materials. These are used in propellant slurry mixing

1.1.2 Based on Material State

Liquid-Liquid Mixing: In this type of mixing, two or more liquids are mixed together to get a product having expected properties within given specifications

Solid-Liquid Mixing: Solid materials are mixed with liquids to create saturated solution, suspensions, or dispersions.

Solid-Solid blending: Solid materials, often in powder or granular form, are blended together to create homogeneous mixtures or compositions. In mixed fertilizer plant this type of blending takes

These categories are not mutually exclusive, and mixing processes can often involve a combination of these types based on the specific requirements of a given application or industry. The choice of mixing method and equipment depends on the characteristics of the materials being mixed, the desired end product, and the scale of the operation.

The mixing efficiency can be depended on various factors, both intrinsic and extrinsic. Understanding these factors is important for achieving the desired outcomes in terms of product quality, reaction efficiency, and process safety. Here are some of the factors that can affect a mixing process:

1.1.3 Nature of the Materials

Chemical Compatibility: The compatibility of the chemicals being used is critical. Some chemicals may react with each other, leading to unwanted side reactions or safety hazards.

Physical Properties: Properties like viscosity, density, solubility, and particle size of the materials can impact the mixing process. Highly viscous fluids, for example, paints and emulsifiers may require more energy for effective mixing.

Reactivity: Reactive materials may require special precautions to prevent uncontrolled reactions like runaway reactions during mixing. Temperature and pressure conditions must be carefully controlled.

1.1.4 Mixing Equipment

Type of Mixer: The choice of mixing equipment and auxiliary equipment such as impellers, agitators, or blenders, depends on the specific requirements of the mixing process, based on the process requirements and nature of chemicals being used. Different types of mixers provide varying levels of agitation and shear.

Stirrer Speed: The speed at which the stirrer /impeller operates affects the intensity of mixing. Higher speeds produce more turbulence and can help faster mixing but may also increase energy consumption and heat generation.

Design of impeller: The design of agitators, including the size, shape and no. of blades or impellers, influence mixing efficiency. Proper design is key factor for achieving desired product.

Size and shape of Mixing Vessel: The size and shape of the vessel is an important parameter for better mixing. Insufficient vessel size and improper vessel shape resulting in improper mixing, while excessively large vessels may result in longer mixing times and increased energy consumption.

1.1.5 Operating Conditions

Temperature: Temperature control is essential for processes involving temperature-sensitive materials or those requiring specific temperature conditions for reactions to occur.

Pressure: In some cases, mixing processes may require pressurized vessels to maintain reactants in a specific phase or to enhance solubility.

Mixing Time: The duration of mixing can affect the degree of homogeneity and reaction completeness. Overmixing can lead to degradation or other unwanted effects.

Understanding and managing these factors is crucial for optimizing chemical mixing processes and achieving the desired outcomes in terms of product quality, process efficiency, and safety.

When dealing with viscous slurries in mixing applications, it's important to select the appropriate impeller design to achieve efficient mixing and proper fluid dynamics. The choice of impeller depends on factors such as the viscosity of the slurry, the desired mixing intensity, and the specific process requirements. Here are some types of impellers commonly used for mixing viscous slurries:

1.2 INTRODUCTION TO ROCKETS

Rocket is a vehicle which is used to insert the satellite in their precise orbit rocket engine or motor is basically works on the principle of newtons third law. Rocket engine/motor produces high thrust and temperatures by the fuel and oxidiser combustion, flue gases travel through nozzle which is having convergent–divergent section.



Figure 1.1: PSLV

1.2.1 Rocket Propulsion

Rocket propulsion is the action of pushing the object forward. or pushing an object. The word “propulsion” derived from the greek word propellere, where pro means forward and pellere means pushing action. In addition, we know that the verb “propel” means to drive or cause to move an object in a specified direction. The substance used for pushing up the rocket is called propellant. Generally liquid propellants are called as rocket engines and solid motors called as motors

1.2.2 Types of Rockets

Rocket is a vehicle that inserts the satellite in precise orbit. Based on the payload launch vehicles are divided in to following types

- **GSLV-MK3**

geosynchronous satellite launch vehicle 3.

payload 10 tons to LEO and 4 tons to GTO

- **GSLV-MK2**

geosynchronous satellite launch vehicle-2

Payload 2.5 tons

- **PSLV**

polar satellite launch vehicle

Payload 2-3 tons

- **SSLV**

small satellite launch vehicle

Pay load 500 Kg to 500 km lower earth orbit

1.2.3 Application of Satellites

- Earth observation
- Communication
- Weather forecasting
- Navigation

1.3 INHIBITION RESIN (IR-1)

In solid rocket motor especially in solid stage a controlled and pre-determined burning of propellant is required to meet the specified machine requirement. It plays a vital role for attain pressure vs time graph.

Inhibition is a non-combustible polymeric material having a very low thermal conductivity and high specific heat due to these properties it is avoiding unwanted surface area burning and prevent the propagation of flue gases and guides the travel of flue gases through the nozzle to create sufficient pressure in this case it is called as thrust. So, inhibition material pouring on the surface of propellant decreasing gradually by erosion. other hand due the compression factor inhibition used in the joint of segments of the all rockets like PSLV, GSLV and GSLV MK-3 etc.

A polyurethane is typical resin produced by reacting hydroxyl groups of castor oil reacts with the isocyanates in TDI, here silica fabrics plays a typical by acting as a reinforcements/filler material. This monomer combines together to form a polymer. Additional polymerisation takes place in this reaction.

The term "inhibition" may not be commonly used in rocketry, the control and regulation of various rocket systems are fundamental to their safe and efficient operation. These mechanisms ensure that the rocket can achieve its mission requirements by placing satellites in to the orbit to exploring the varies planets, communication spying, weather, geological surveys etc. concept of rocket inhibition is to controlling the rocket operations.

1.3.1 Flight Control

Rockets generally produces thrust through propulsion. Inhibition mechanisms controls the unwanted surface area burning to developed required thrust.

1.3.2 Inhibition for Radial Flow

In the context of fluid dynamics and flow control, "inhibition" for radial flow is not a standard term or concept. However, if you are referring to controlling or inhibiting the radial flow of fluids in a specific system or application, you may need to employ various techniques or mechanisms to

achieve this control. Here are a few methods and considerations for controlling radial flow:

1.3.3 Flow Restriction

To inhibit or control radial flow, you can use flow restriction devices such as valves, orifices, or nozzles. These components can be placed strategically within a fluid system to limit the flow rate and control the distribution of fluid in the radial direction.

In summary, controlling or inhibiting radial flow involves the use of various engineering techniques and components to manage the distribution of fluids or particles in a radial direction within a system. The specific method chosen will depend on the nature of the fluid system and the desired outcome, such as minimizing radial dispersion, optimizing mixing, or achieving other specific objectives.

Polyurethane resin, often simply referred to as polyurethane, is a versatile and widely used polymer material. It is created through a chemical reaction between polyols and isocyanates. Here are

Specific heat is a fundamental property that plays a central role in understanding how heat energy is transferred and stored in materials and substances. It is used extensively in fields like thermodynamics, heat transfer, and materials science. In the context of rockets and propulsion systems, "inhibition" usually refers to the process of preventing or controlling the ignition and combustion of propellants or explosives when they are not supposed to ignite. Inhibition mechanisms are crucial for ensuring the safe handling, storage, and transport of rocket propellants and explosive materials. Here are some key aspects related to inhibition in rockets:

Safety: In rocketry, safety is of paramount importance. Rockets and their components may contain highly reactive or explosive materials. Proper

inhibition mechanisms are essential to prevent accidental ignition and ensure safe handling.

Inhibited Propellants: Many rocket propellants, such as solid propellants, can be inhibited to prevent unintended ignition. Inhibition typically involves the addition of chemical compounds or coatings to the propellant that inhibit combustion or lower its reactivity.

Insensitive Munitions: In the defence industry, the concept of "Insensitive Munitions" (IM) is critical. IM is a set of safety standards and technologies designed to reduce the likelihood of accidental detonation of ammunition and explosives. This includes inhibition methods.

In summary, inhibition in rockets and propulsion systems is a critical safety measure that involves the use of chemical agents or mechanisms to prevent unintended ignition and combustion of propellants or explosives. It plays a vital role in ensuring the safe handling, storage, transport, and deployment of rockets in both military and civilian applications. In the context of rocket motors and solid rocket engines, the terms "radial burning" and "axial burning" refer to the patterns of combustion or burning of the propellant within the rocket motor. These terms describe how the propellant burns with respect to its geometry and orientation within the motor casing.

Radial Burning: In radial burning, the propellant burns outward from the port toward the outer surface of the motor casing. The burning occurs in a radial or outward direction, perpendicular to the axis of the rocket motor. Radial burning is often associated with grains of solid propellant that have a star-shaped or radial configuration. These grains have channels or perforations that allow the combustion gases to flow outward from the centre. This burning pattern can result in a relatively large burning surface area and a high thrust-to-weight ratio, making it suitable for certain rocket applications.

Axial Burning: In axial burning, the propellant burns along the length or axis of the rocket motor. This is also called as end burning the burning occurs parallel to the axis, from one end of the motor to the other. Axial burning is common in rocket motors with cylindrical or tubular propellant grains that do not have channels or perforations that promote radial burning. This burning pattern may result in a lower thrust-to-weight ratio compared to radial burning, but it provides more stable and predictable thrust characteristics. The choice between radial and axial burning depends on the specific requirements of the rocket design and the desired thrust profile. Engineers and designers consider factors such as thrust control, burn rate, stability, and the desired trajectory when selecting the appropriate burning pattern for a particular rocket motor.

Additionally, some advanced rocket motor designs incorporate a combination of radial and axial burning by using propellant grains with specific geometries or additives that control the burn rate along different directions. This allows for more precise control of the rocket's thrust profile and trajectory.

Ultimately, the selection of radial or axial burning is a crucial aspect of rocket motor design, impacting the performance and behaviour of the rocket during flight.

The "M-curve" in the context of solid rocket motors refers to the Mass vs. Time curve, which describes the variation in the rocket motor's total mass as it burns over time during a rocket's flight. The M-curve is a critical parameter in the design and analysis of solid rocket motors. Here's how it works:

Initial Mass (M_i): At the beginning of a rocket motor's operation, its total mass is represented by M_i . This includes the mass of the rocket motor casing, propellant, igniter, and any other components.

Burnout Mass (M_f): As the rocket motor burns, the propellant inside is consumed, and its mass decreases. The point at which the propellant is

completely burned, and the rocket motor ceases to produce thrust, is called burnout. The mass of the rocket motor at burnout is represented by M_f .

In summary, the M-curve in solid rocket motors provides a graphical representation of how the rocket motor's total mass changes over time as the propellant is consumed. It is a critical parameter used in the design, analysis, and optimization of solid rocket motors for a wide range of applications. Inhibition is a critical safety measure in rocketry, especially when dealing with energetic materials like propellants and explosives. It involves the use of specific mechanisms or agents to prevent or control the ignition, combustion,

In conclusion, inhibition in rocketry is crucial for ensuring the safe handling, transport, storage, and operation of rockets and their energetic materials. It helps prevent accidental ignition or detonation, reduces the risk of accidents, and contributes to overall safety in both civilian and military rocket applications.

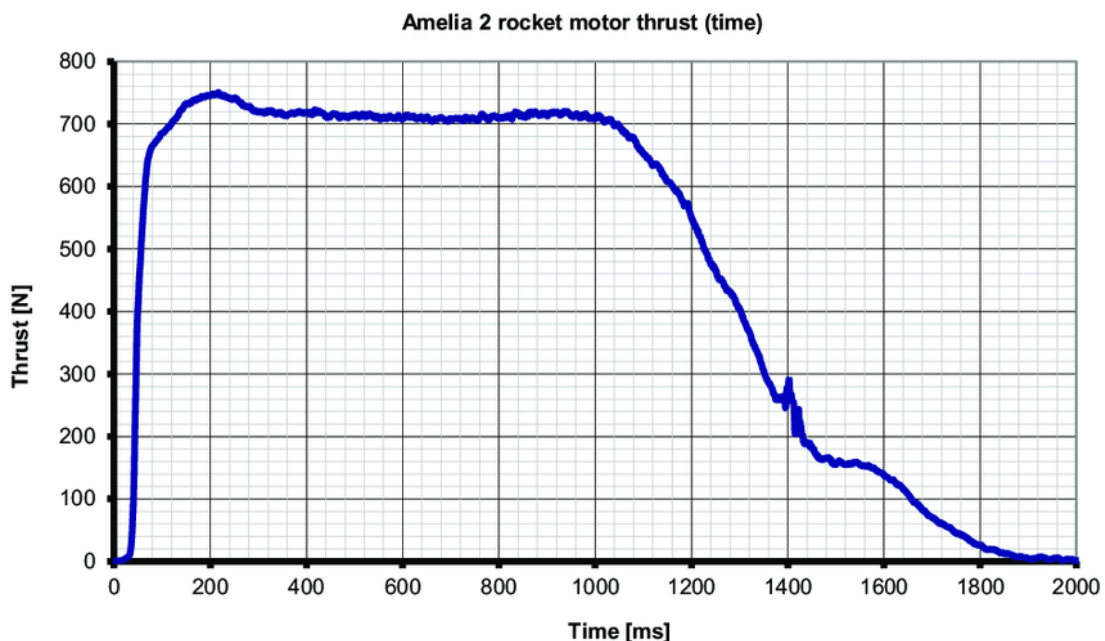


Figure 1.2 : Thrust Vs Time Graph

1.4 PROBLEM STATEMENT

Manual mixing in industrial processes can be fraught with several potential problems, which can lead to inefficiencies, safety hazards, and product quality issues. Some common problems associated with manual mixing in industry include:

Inconsistent Mixing: Human operators may have difficulty consistently achieving the desired mixing quality, resulting in variations in product quality and performance.

Operator Fatigue: Continuous manual mixing can lead to operator fatigue, which can impair their ability to maintain consistent mixing quality over time.

Safety Risks: Mixing certain substances manually can expose operators to hazardous chemicals, extreme temperatures, or physical strains. This can lead to workplace accidents or health risks.

Limited Scale and Capacity: Manual mixing processes are generally limited in terms of scale and capacity. It may not be feasible to manually mix large quantities or scale up production easily.

Time-Consuming: Manual mixing can be time-consuming, which may result in slower production rates and reduced overall efficiency.

Waste and Material Loss: Inaccurate or inconsistent mixing can lead to material waste and increased production costs.

Quality Control Challenges: Manual processes can make it difficult to monitor and control mixing parameters, making it challenging to maintain consistent product quality.

Lack of Data Collection: Manual mixing may not provide the data needed for process analysis, optimization, or quality assurance.

Non-Reproducible Recipes: Operators may struggle to reproduce specific mixing recipes accurately, leading to variations in product characteristics.

Human Error: Manual processes are susceptible to human error, which can result in costly mistakes or safety incidents.

Limited Flexibility: Manual mixing processes may lack the flexibility to adapt quickly to changing production demands or recipe adjustments.

Regulatory Compliance: Some industries, such as pharmaceuticals and food processing, have strict regulatory requirements. Manual mixing can pose challenges in meeting these requirements consistently.

To address these problems, many industries are increasingly turning to automation for their mixing processes. Automated mixing systems offer advantages such as precision, repeatability, scalability, and the ability to operate in hazardous conditions without human intervention. They also allow for data collection and process monitoring, which can aid in quality control and compliance.

However, the decision to switch from manual to automated mixing depends on factors such as the specific industry, process requirements, budget, and safety considerations. In some cases, a hybrid approach may be suitable, where automation is used for critical or large-scale mixing tasks, while manual mixing remains for smaller or less complex operations.

CHAPTER-2

AIM & SCOPE

1. Basic understanding of typical inhibition resin
2. Selection of stirrer for Pre-mix and Final mix system to achieve homogeneity of the pre-mix to achieve cure reaction between binder and curator in final mix
3. To minimize the toxic chemicals exposure to working environment like Toluene Di-Isocyanate, Toluene, Tri-Chloro Ethylene etc.
4. To achieve optimized pot life for inhibition resin
5. To carry out experimental study on stirrer configuration for premix and final mix
6. Stirrer RPM selection for premix and final mix
7. Mixing Time for Pre-mixing & Final Mixing
8. To carry out typical inhibition resin mixing (pre-mix and final mix) by using mixing equipment
9. Utilization of advanced technologies in the mixing process
10. Increases the production rate of inhibition resin mixing Decrease manpower of mixing operation

Inhibition Resin is a non- combustible inert polymeric composite material used in solid rocket motors to achieve controlled burning of propellant and meet desired mission requirements. This inhibition resin is polyurethane based and formed mainly from reaction between Hydroxyl terminated polyol as a binder and isocyanate as a curing agent and to increase the curing reaction rate accelerator is added. To increasing polymer strength solid filler is added. The resin thus prepared is applied manually on the end surfaces of

solid rocket motor. In present scenario due to increase in the size of solid rocket motors and frequency of launching, production of inhibition resin at high throughput is required, so in this project detailed study is carried out for design of mixing equipment for inhibition resin mixing. as mixing play an important and vital role in chemical reaction of heterogenous system. design of mixing equipment is considered without affecting final properties of inhibition resin. The scope of work is an implementing automation process i.e. mixing equipment foe premix and final mix inhibition resin which is applied on the solid rocket motors to avoid motor burning in axial direction and allows in radial direction In current scenario,

CHAPTER-3

MATERIALS AND METHODOLOGY

Inhibition mixing is divided in to 2 parts premix, final mix

3.1 PRE-MIX

It contains the following chemical

- 1) Castor Oil
- 2) Typical Silica Fabrics
- 3) PBNA
- 4) Fe_2O_3

Table 3.1 Raw materials for pre-mix

S.No	Chemical	Composition	Purpose
1	Castor oil	65	Binder
2	Typical silica fabrics	30	Fillers/Reinforcement
3	PBNA	4	Anti-oxidant
4	nano filler	1	Filler

Castor Oil is a naturally occurred oil extracted from the pressing the seeds of castor oil plant. It is mainly produced in Africa south America Brazil, China and India. It is a colourless liquid with a different taste and Odor.

Castor oil is the main reactant in this polyurethane reaction

Properties of Castor Oil

State	-	liquid
Colour	-	colourless or pale-yellow colour
Odour	-	oily odour
Density	-	0.961 g/cc
Viscosity	-	580 cP
Boiling point	-	313 °C
Flash point	-	229.4 °C
Hydroxyl value	-	160-168
Auto ignition temperature	-	448.9 °C
Thermal conductivity	-	4.727 (W/m°C)
Specific heat	-	0.089 (J/Kg °C)

Amorphous silica fabrics: a typical silica fabric is used as the filler. These are in the form of fibres and the matrix binds the fabrics, it plays a vital role in the product quality and curing time. Due to the fibrous nature of the particle and density differences solids settles down in a specific time period, so before final mixing, premix drum should be mixed thoroughly until the solid particles distributes uniformly throughout in the storage drum.

It is high heat resistant material. Some important thermal properties of a filler as given below

Table 3.2 Silica fabric properties

Physical state	solid fibres
Melting point	3000 (°C)
Specific gravity	2.60
Thermal conductivity	0.08 (W/m K)
Specific heat	816 (J/Kg °C)

PBNA:

N-phenyl- β -naphthylamine (PBNA) acts as a antioxidant and prevents the degradation of the materials by inhibits the activity of oxidants, such as NO_x, to prevent the degradation of energetic materials.

Synonyms : N-(2-Naphthyl) aniline

Formula : C₁₆H₁₃N

Molecular weight : 219 g/mol

Fe₂O₃: (iron oxide)

It is a nano filter. It shows both acid and base behaviour.

molecular weight - 159 g/mol

Density - 5.24 g/cc

3.2 FINAL MIX

It contains

- 1) Premix
- 2) TDI
- 3) FeAA

Table 3.3 Raw materials for final mix

S.No	Chemical	Wight in grams	Purpose
1	IR-1 PREMIX	100	resin
2	TDI	24	curator
3	FeAA	10	accelerator

IR-1 Premix: it does contain the chemicals as discussed; homogeneity and moisture content are two critical factors which affect the quality of product. to follow.

TDI: Toluene diisocyanate

It is a curing agent for the main reaction. NCO groups available in TDI will reacts with the hydroxyl groups of castor oil and to form polyurethane reaction in the presence of FeAA catalyst.

Reactivity and Handling: TDI is highly reactive and can react with moisture in the air and scale formations takes place. (white colour flakes) Therefore, it must be sealed properly after usage and at most care should be taken for storing. Proper ventilation and exhaust system is essential while handling TDI. Proper PPE is must for the manpower handling and using TDI.

Short term exposure limit is 0.002 PPM

PPE (Personal Protective Equipment)

- 1) Vapour mask
- 2) Goggles
- 3) PVC gloves
- 4) Safety shoe

FeAA solution: to increase the reaction rate an accelerator added along with reactants. The role of accelerator to increase the rate of reaction to achieve the uniform distribution of solids in order to get curing and hardness. FeAA is in solid form and reactants are in liquid/slurry form. For well mixing FeAA, it dissolves in a toluene solvent (5% w/w)

Table 3.4 Properties of Toluene

Physical State	Liquid, colourless
Odour	sweetish Odor
Vapor Pressure	28.4 mm Hg
Solubility	insoluble
Specific Gravity/Density	0.86
Molecular Formula	C ₆ H ₅ CH ₃
Molecular Weight	92.14

Table 3.5 Properties of FeAA

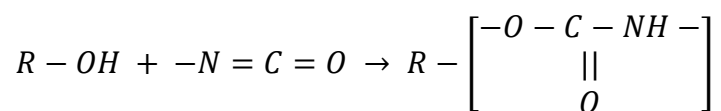
Physical state	Powder
Density	5.24 g/ml
Molecular formula	C ₁₅ H ₂₁ FeO ₆
Molecular Weight	353.17

Hazard statements

Highly flammable liquid and vapour

Inflammable Carcinogenic Causes skin irritation

3.3 REACTION



A polyurethane is typically produced by reacting isocyanate of TDI with a hydroxyl groups present in castor oil. Since a polyurethane contains two types of monomers, which polymerize one after the other, they are classed as

alternating copolymers. Both the isocyanates and polyols used to make a polyurethane contain two or more functional groups per molecule.

Table 3.6 Mechanical Properties of IR-1

Density (g/cc)	1-2
Tensile strength (Ksc)	10-15
Elongation (%)	35-45
Hardness (shore A)	40-50

Table 3.7 Thermo-chemical properties of IR-1

Thermal conductivity (W/m·K)
Coefficient of expansion
Specific heat capacity (J/Kg °C)
Erosion rate (mm/sec)

Thermal conductivity: Thermal conductivity (k) is defined as the rate at which heat energy (Q) is conducted through a unit cross-sectional area (A) of a material over a unit temperature gradient (ΔT) perpendicular to that area. The formula is given by:

$$q = -k \, dt/dx$$

k is the thermal conductivity (W/m·K)

q is the heat transferred per unit time (W)

dt/dx is the temperature gradient

Thermal conductivity is an important property of IR-1 since it is a non-combustible material it should have very low k value. During the rocket launch high temperatures occurs due to the combustion of fuel and oxidiser temperatures reaches upto 1500 °C Inhibition should be withstand that temperature to achieve controlled burning.

Coefficient of expansion: it is the change in length of a material when exposed to the temperature either heating or cooling.

$$\Delta L/L = \alpha(\Delta T)$$

ΔL =change in length

ΔT = change in temperature

Specific heat capacity: amount heat required to raise the temperature of a body to 1 °C. It is measured in (J/Kg °C).

$$Q = mC \Delta T$$

Where,

Q= heat energy

M=mass

C=specific heat capacity

ΔT = change in temperature

Erosion rate: decreasing/ losing itself with time is known as erosion,

Pot life : another important parameter in processing of IR-1 resin is pot life. It is defined as the time taken to cease the flow of IR-1 after adding curator to the pre-mix. With in pot life, the operation should complete to achieve better result of the product pot life depends on so many factors like raw material properties (since castor oil is a natural product property especially no. of

hydroxyl groups availability and other properties) and process conditions like temperature and pressure and mixing time and intensity of mixing.

Normally pot life of IR-1 ranging from 35-45 minutes

Castor oil as resin, heat resistance powder as a solid filler, Toluene Di-isocyanate as Curator and an accelerator. All chemicals are obtained from our regular suppliers and chemical analysis is carried out as per ISRO standards. Inhibition premix drum which contain 100-110 kg of inhibition resin, with stirrer motor for rotation of stirrer.

No of trails are carried out using different types of premix stirrer and final stirrer is fixed on the basis of optimization of time for mixing and RPM of stirrer.

Initially, mixing of inhibition resin i.e., premix is done for 20-30 minutes at premix station to achieve homogeneity by uniform distribution of solid content throughout the container. Process is continued in the containers based on number of containers required to meet the inhibition process.

In final mix station, after addition of curator, reaction between polyol and curator (TDI) starts and to increase reaction rate, accelerator is added and mixed.

3.4 SELECTION OF STIRRER

Selection of mixing equipment especially stirrer is an important task in the mixing process of both IR-1 Pre-mix and final mix. The slurry having 40% of fibrous solids and viscous liquids. Viscosity range of premix is around 6000 to 8000 CP. Considering the viscosity of the material the bellow stirrers has been tried for mixing

Anchor or Paddle Impeller: Anchor impellers are used for high viscous fluids and slurries and non-Newtonian fluids. Laminar mixing takes place in this type of mixing due to high viscosity. They are designed with multiple flat blades or paddles attached to a central shaft. The paddles provide a sweeping the material and through the material from walls to the centre. This impeller is used for mixing of slurries, gels, and high-viscosity fluids.

Process Difficulties:

- Laminar mixing taking place
- Low shear of material was observed
- It requires accurate design of vessel is required to avoid wear and tear
- Expensive

Helical Ribbon Impeller:

Helical ribbon impellers have a helical ribbon-like design that promotes axial flow and prevents excessive shear, making them suitable for viscous materials. They are commonly used in mixing processes involving pastes, gels, and heavy slurries, such as in the production of ceramics, polymers, and adhesives.

Disadvantages:

Less radial mixing and these impellers generally having less clearance between impeller and vessel, so accurate design required to avoid contact of impeller and vessel

Pitched Blade Turbine Impeller:

Pitched blade turbine impellers consists of blades with angle that create axial flow as well as radial flow patterns. They are suitable for viscous slurries with different types of viscosities.

The choice of impeller for mixing viscous slurries should be based on a careful evaluation of the material properties, desired mixing intensity, and process.

A pitched blade turbine, also known as a pitched blade impeller, is a type of mixing impeller used in various industrial applications to promote fluid mixing and agitation. It consists of two or more flat blades that are pitched (angled) to the central axis of the impeller. The design of the blades allows for efficient mixing of fluids, making it a common choice in chemical processing, pharmaceuticals, wastewater treatment, and other industries. Here are some key features and characteristics of pitched blade turbines:

1. **Blade Pitch:** The blades of a pitched blade turbine are inclined or pitched at an angle relative to the axis of rotation. The angle of pitch can vary, and it influences the flow pattern and mixing efficiency. Common pitch angles range from 30 to 45 degrees.
2. **Blade Geometry:** Pitched blade impellers typically have a flat, rectangular or trapezoidal shape. The width and length of the blades can vary depending on the application and the desired level of agitation.
3. **Flow Patterns:** The pitched blades induce both axial and radial flow in the fluid being mixed. This combination of flow patterns helps ensure good mixing throughout the vessel, from top to bottom and from the center to the periphery.
4. **High Mixing Efficiency:** Pitched blade turbines are known for their high mixing efficiency, making them suitable for blending, suspension of solids, and promoting chemical reactions within the fluid.
5. **Viscosity Range:** They are effective in a wide range of fluid viscosities, from low-viscosity liquids to moderately viscous materials.

6. Low Shear: While pitched blade turbines are effective mixers, they typically generate lower shear forces compared to high-shear mixers or other high-shear impeller designs. This makes them suitable for shear-sensitive applications.
7. Vessel Size: Pitched blade impellers are used in vessels of various sizes, from small laboratory containers to large industrial tanks.
8. Materials of Construction: They are available in various materials of construction, including stainless steel, plastic, and other materials, to suit the compatibility requirements of the process.
9. Versatility: Pitched blade turbines are versatile and can be used for a wide range of mixing tasks, including blending, dispersing, solid suspension, and heat transfer.
10. Blade Variations: Some variations of pitched blade turbines include three-blade, four-blade, or six-blade designs. The choice of blade configuration depends on the specific mixing requirements.
11. Motor Power: The power required to drive a pitched blade impeller depends on factors like the blade size, the fluid viscosity, and the desired mixing intensity.
12. In summary, a pitched blade turbine is an effective and versatile mixing impeller used in various industries to achieve efficient fluid mixing and agitation. Its blade design and flow patterns allow for thorough mixing of fluids with different viscosities and for various applications. The choice of impeller design and operating conditions should be tailored to the specific requirements of each mixing process

Table 3.8 Comparison of Stirrers

Impeller type	observation	Remarks/ conclusion
Anchor	1) Laminar mixing is observed 2) Axial flow of material predominately, less radial flow 3) High power consumption	At the bottom of the vessel solids are settled as a sludge.
Helical ribbon	1) Axial movement was observed 2) Due to less clearance between impeller and vessel high accurate design is required	Due to complicated design of blades cleaning is difficult
Pitched blade turbine	1) Both axial and radial movement taking place 2) Turbulence mixing takes place 3) Easy to clean	After set of trials, it is observed proper mixing of materials and homogeneity attained through lab analysis

CHAPTER-4

RESULT AND DISCUSSION

4.1 STUDIES ON PREMIX

As premix is a mixture of two different density materials i.e. hydroxyl polyol and solid content, solid content is bound to settle down over a period of time. For evaluation of mixing index, solid content is selected as performance parameter. At initial stage, during 60% of total mixing time, bottom blade is only functional and disturb the solid content settlement and provide radial mixing. Remaining time both top and bottom blades are operational where top blade provides axial dispersion and spread material uniformly. After mixing inhibition resin premix for about specified period time the samples are collected from three different zones i.e., top, middle and bottom of drum and analyze for solid content. (%) and trials matrix is shown is table 1 and results are plotted on graph

4.1.1 Process Difficulties with IR-1 Pre-mix While Conducting Experiment

Settling of Solid Particle: due to the density differences solid particles sedimentation takes place. These solids fine particles bind together to form a cluster. Due to this agitating the bottom of the drum is too difficult in order to get homogeneity of the entire drum.

Effect of Moisture: moisture reduces the purity of the premix due to these bubbles and voids formation takes place which effect the density and Tensile bond strength properties

- 1) Moisture due to the two reasons
- 2) Ageing of the premix
- 3) Exposure of the premix to the atmosphere
- 4) Drying of raw materials

Solid Particles Size: particular size of solid particles is required for premix. Deviation in size leads to off spec of parameter.

Table 4.1 Pre-Mix Experimental Matrix

Experiment No:	PM Stirrer RPM	Time of mixing (min)	SOLID CONTENT (%)		
			BOTTOM	MIDDLE	TOP
TRIAL-P1	50	20	52	30	22
TRIAL-P2	50	30	55	32.5	26
TRIAL-P3	50	40	57	36	26
TRIAL-P4	60	20	56	25	31
TRIAL-P5	60	30	54	27	31
TRIAL-P6	60	40	51	29.5	34
TRIAL-P7	70	20	34.5	35.5	35
TRIAL-P8	70	30	35	35.6	35.1
TRIAL-P9	70	40	35.1	35.8	35.2
TRIAL-P10	80	20	36.5	35.3	35
TRIAL-P11	80	30	36.1	36	36.3
TRIAL-P12	80	40	37.1	35.3	35.5

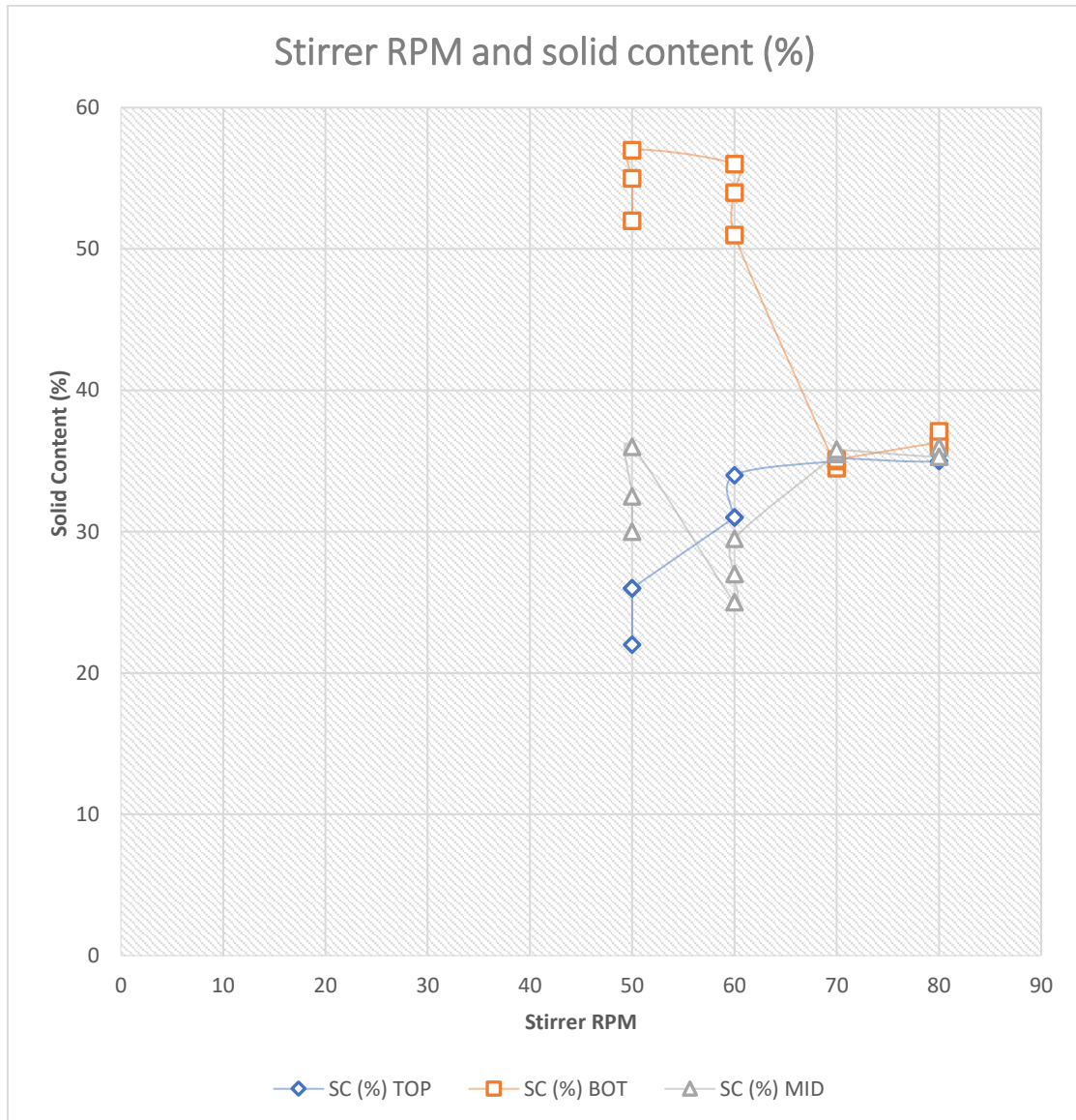


Figure 4.1: Premix stirrer RPM Vs Solid Content Graph

4.2 EXPERIMENTAL STUDY ON INHIBITION RESIN AS FINAL MIX

After achieving the inhibition resin premix homogeneity, the required quantity of material taken into container and remaining chemicals added one after other in required quantity then mixing carried out for specified time at specified final mix RPM and results are shown on graphs.

Procedure: 1 Kg of inhibition resin premix material is taken in the container this premix is mixed by selected stirrer for specified time at specified RPM to achieve complete curing after mixing, from final mix container sample were taken and slab were prepared of 150 by 150 mm and after 24 hrs i.e. complete curing of resin slabs were sent for analysis These slabs are cut into dumble shape pertaining to ASTM D-412 and test were carried out and results are noted Experiments conducted revealed that rpm of final mix stirrer RPM 140 gives pot life of 38-42 (ref fig:1) which is required for inhibition process. Further experiments are carried out at 140 RPM to study the effect of mixing time at different stages on pot life

4.2.1 Process Difficulties with IR-1 Final-mix

Exothermic Reaction: controlling this polyurethane reaction is too difficult due to the heat producing. We know that the poly addition reaction between OH groups and NCO groups is an exothermic reaction. As the isocyanate is added with the catalyst, the temperature of the reaction begins to rise gradually. The rate of the reaction proportional to the temperature and volume of reactants. As the temperature rises, the rate of the reaction will also increase.

Pot life depends on each raw material properties, castor oil is naturally occurring so every batch need to do flow trails to find pot life of that IR-1 batch. Due to less pot life 1kg material selected for processing

Interlayer porosity: porosity is an undesired property.it is having the effect on almost all properties like density, TBS, elongation etc.

Table 4.2 Final Mix Experimental Matrix-1

Experiment No:	FM Stirrer RPM	Time of mixing (min)	PROPERTIES			
			TS	Elongation	Density	Hardness
TRIAL-F1	100	3	5	53	1.05	56
TRIAL-F2	100	6	7	56	1.09	52
TRIAL-F3	100	9	8	58	1.10	52
TRIAL-F4	120	3	7	52	1.09	57
TRIAL-F5	120	6	9	54	1.11	59
TRIAL-F6	120	9	10	48	1.13	58
TRIAL-F7	140	3	12	40	1.18	62
TRIAL-F8	140	6	13.5	39	1.22	63
TRIAL-F9	140	9	13	39	1.25	63
TRIAL-F10	160	3	13	37	1.23	62
TRIAL-F11	160	6	11	36	1.26	65

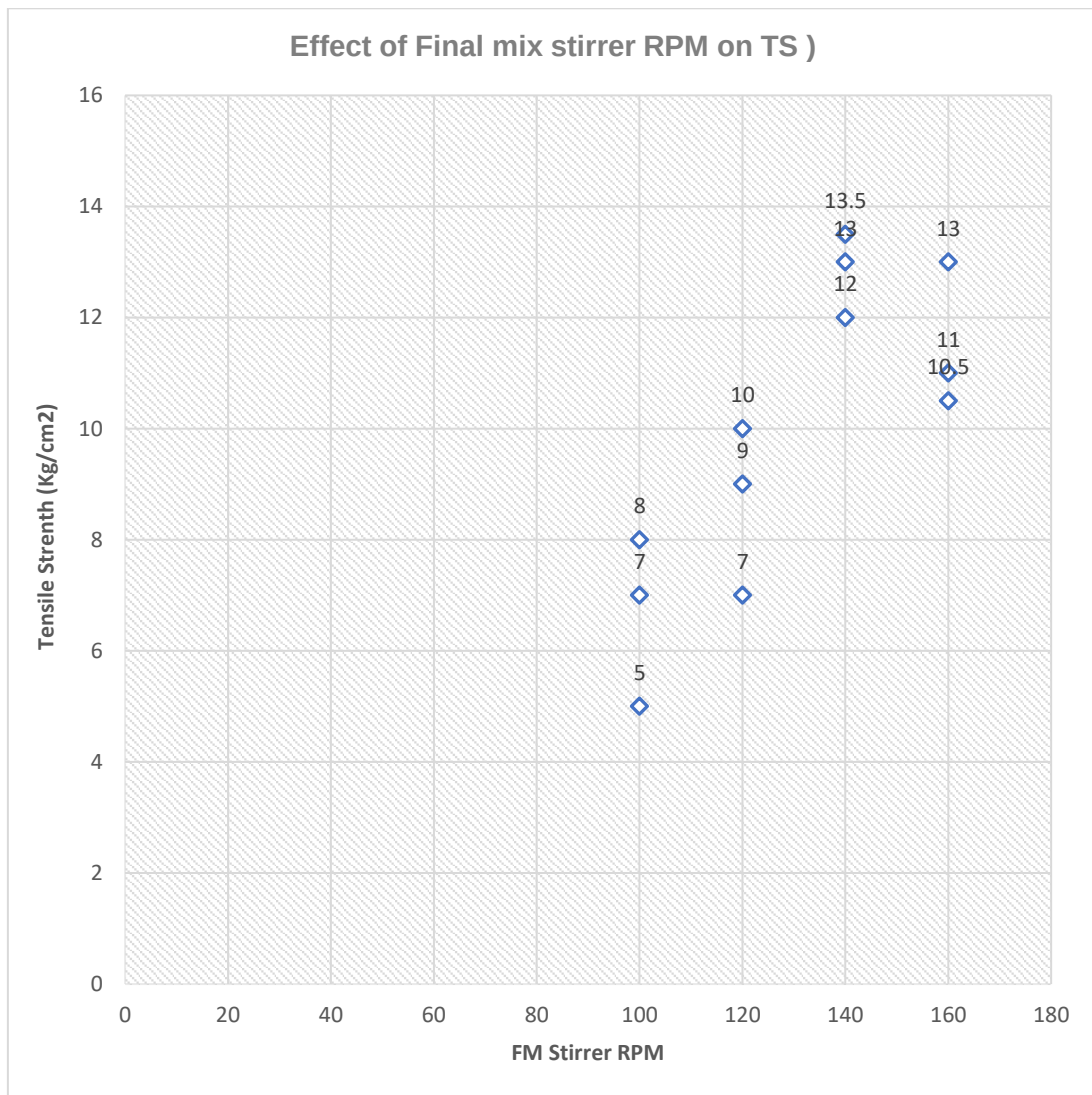


Figure 4.2 : Premix stirrer RPM Vs Tensile Strength(Kg/cm2) Graph

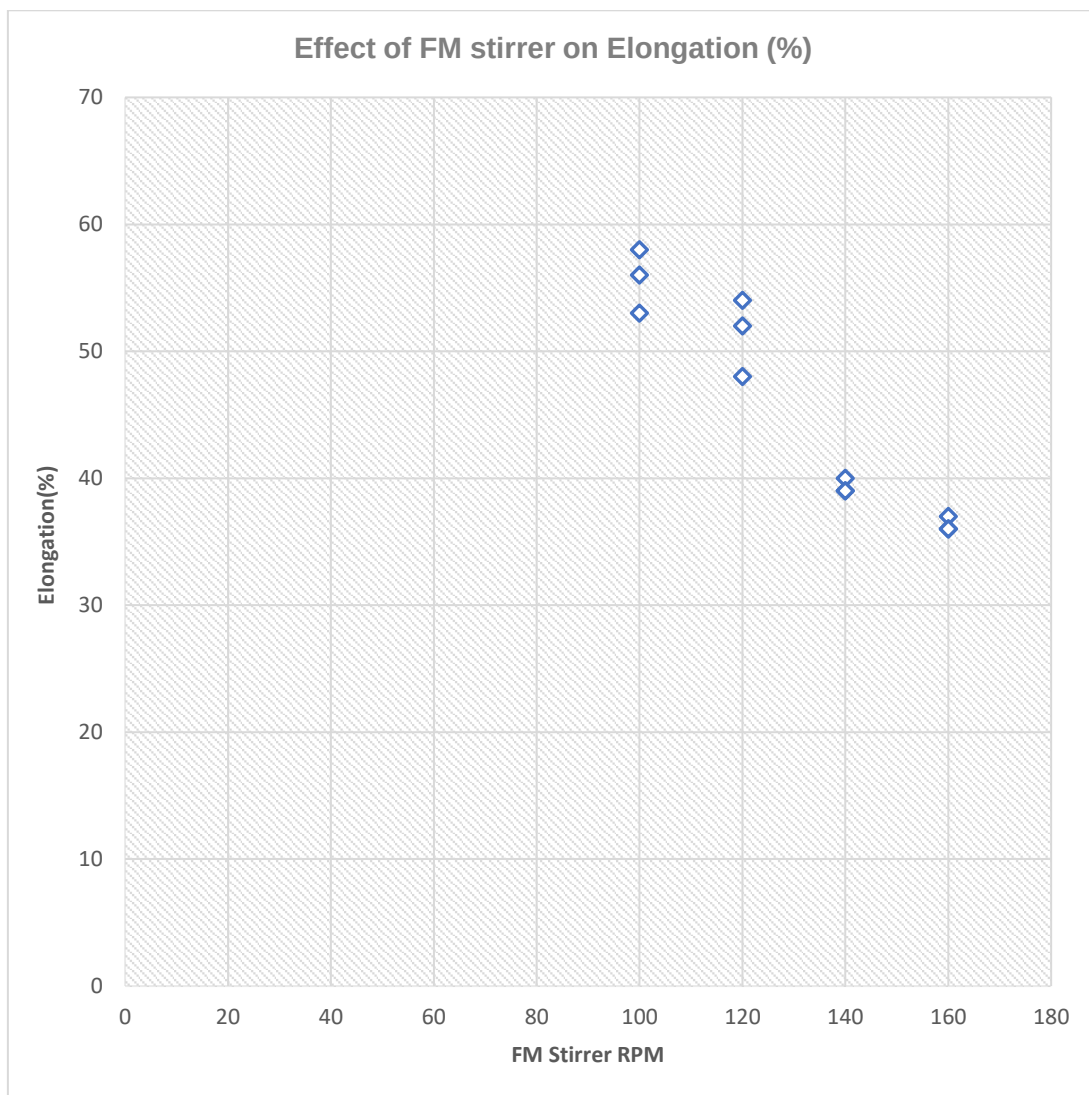


Figure 4.3 : Final mix stirrer RPM Vs Elongation (%)Graph

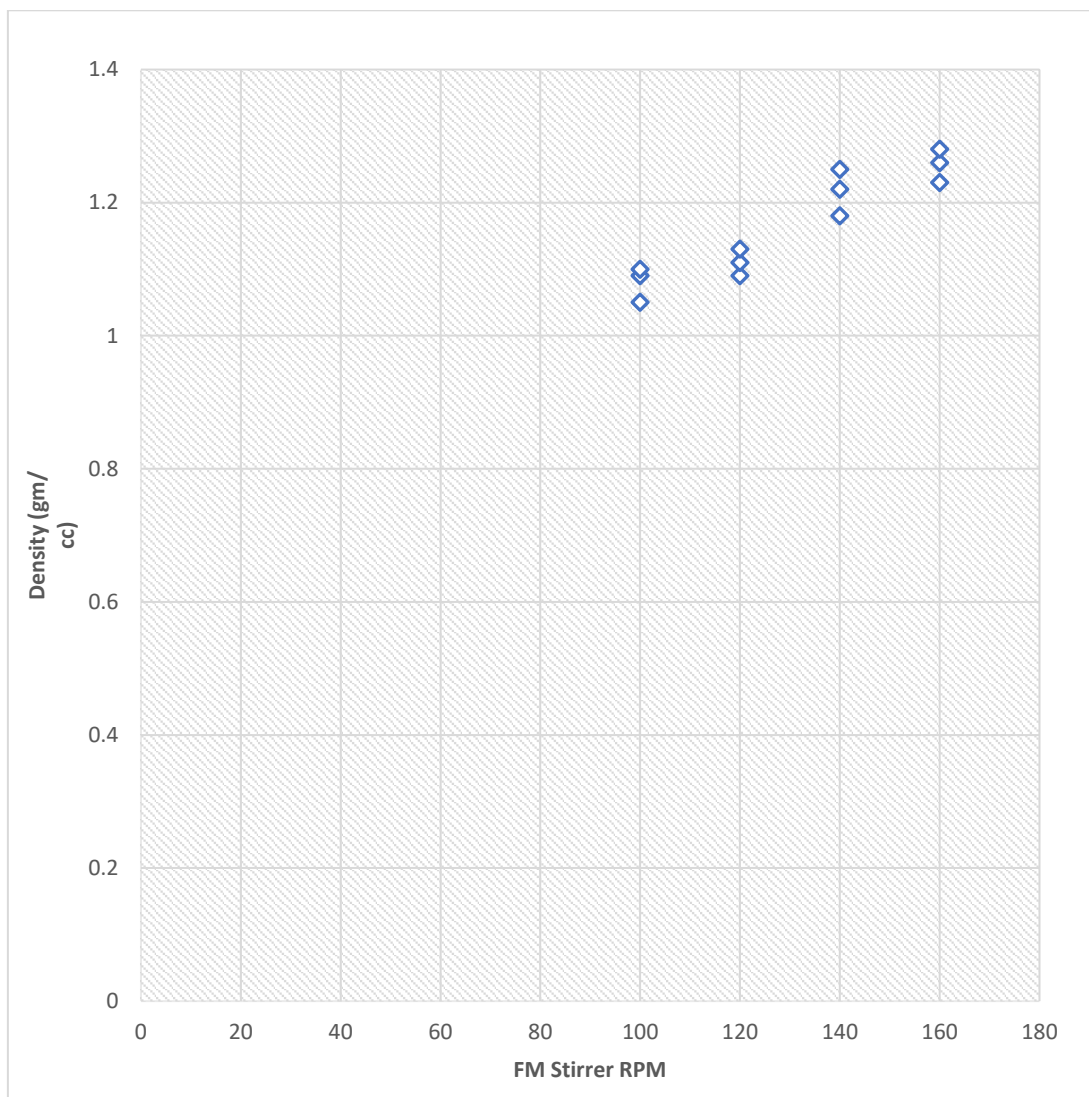


Figure 4.4 : Final mix stirrer RPM Vs Density Graph

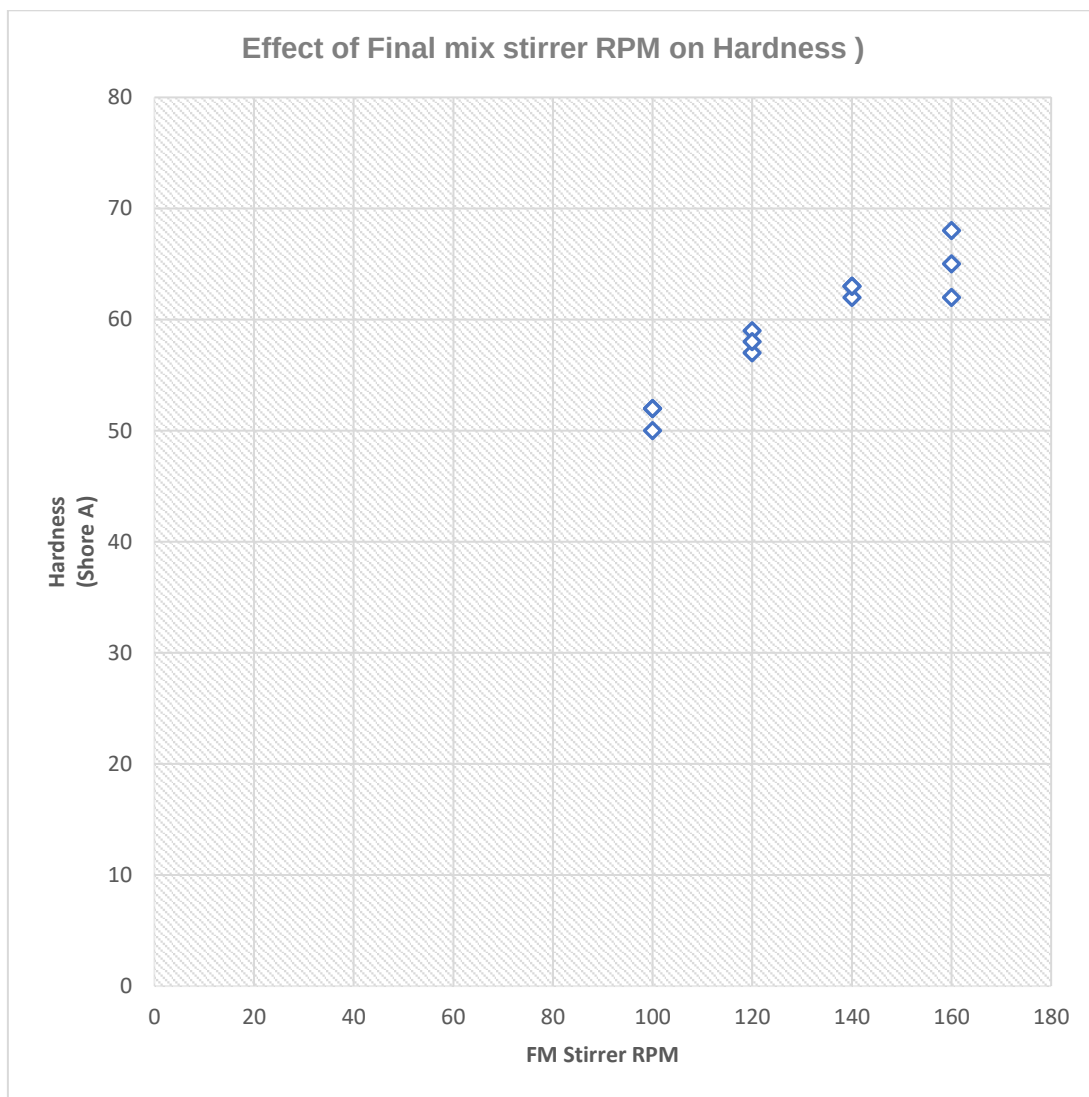


Figure 4.5 : Final mix stirrer RPM Vs Hardness Graph

Table 4.3 Final Mix Experimental Matrix-2

EXPERIMENT NO.	FM SPEED	MIXING TIME	TEMPERATURE	POT LIFE
TRIAL-F1	100	3	30	10
TRIAL-F2	100	6	35	12
TRIAL-F3	100	9	40	8
TRIAL-F4	120	3	52	15
TRIAL-F5	120	6	60	13
TRIAL-F6	120	9	65	15
TRIAL-F7	140	3	68	38
TRIAL-F8	140	6	62	42
TRIAL-F9	140	9	63	39
TRIAL-F10	160	3	65	20
TRIAL-F11	160	6	65	18

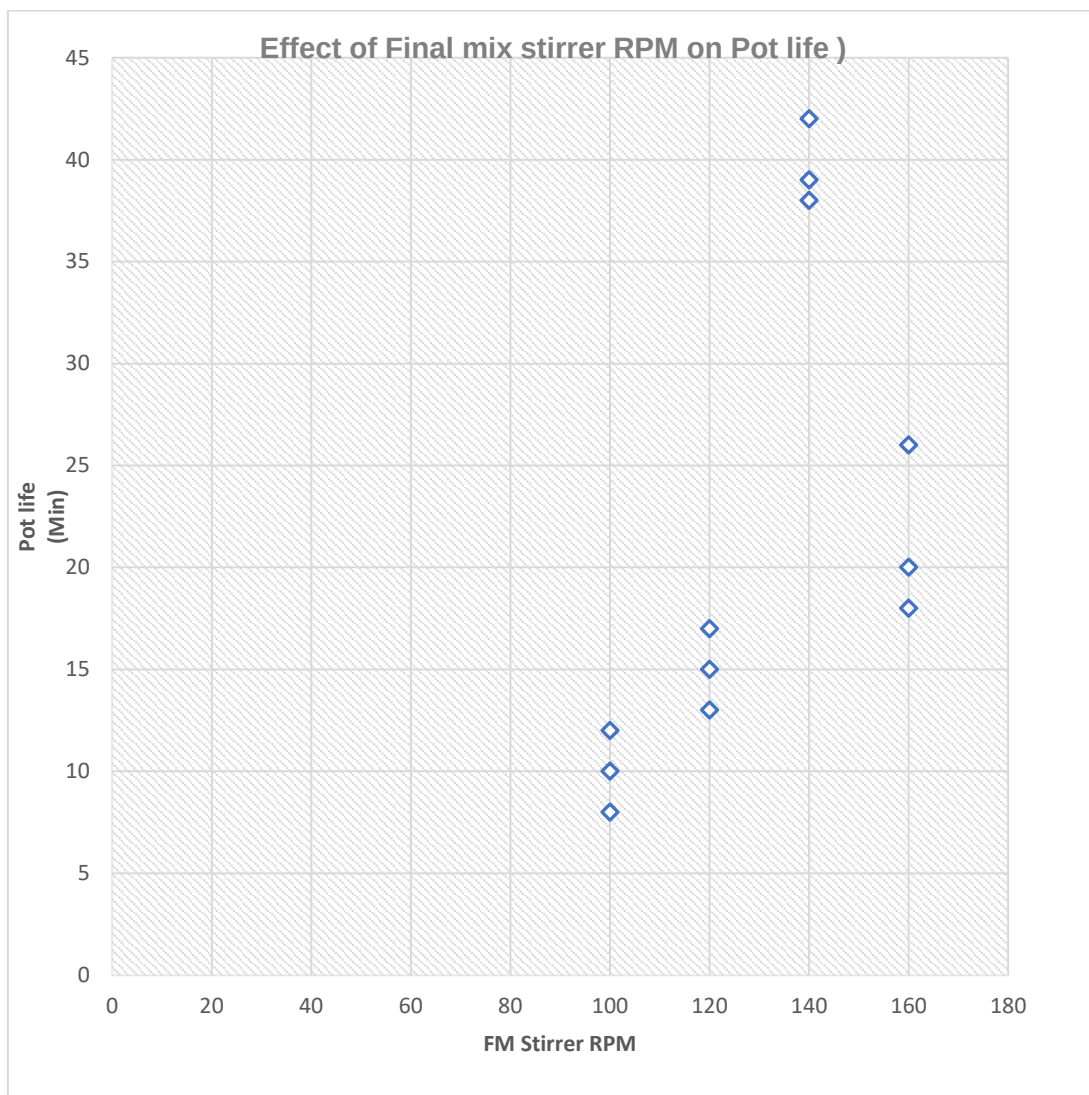


Figure 4.6 : Final mix stirrer RPM Vs Pot life Graph

CHAPTER-5

CONCLUSION

Understand the peculiarity of the material. Knowing the behaviour of IR-1 and effect of varies factors on the reaction by the constructive experimental methods. Identify the process difficulties. Selection of stirrer required for the resin mixing is the major role in this experiment. Different stirrer has been chosen for better mixing of IR-1. After a set of trails pitched blade turbine is selected and it is modified to customised design for process. Based on homogeneity by testing solid content at 3 locations of the drum i.e., top middle and bottom, after 3 consecutive trails RPM and mixing time are fixed. RPM VS solid content Graph is plotted final mix is complicated than the premix, due to the exothermic reaction involved. After addition of curator and accelerator reaction takes place and heat liberating. Based on mechanical properties of the product and pot life of IR-1 RPM and time for mixing is set. Graphs are plotted between RPM VS mechanical properties and pot life of IR-1

REFERENCES

1. Aamer, Farag, Waseim Azzam, Ahmed Farouk, Ahmed Nasr, and Ashraf Nazir. "Utilization of blade anchor for improving the uplift capacity of pile in sand: Model Study." *Ocean Engineering* 278 (2023): 114435.
2. Allport, Dennis C., David S. Gilbert, and S. M. Outterside, eds. *MDI and TDI: safety, health and the environment: a source book and practical guide*. John Wiley & Sons, 2003.
3. Al-Munajjed, Amir A., Joachim Hammer, Edgar Mayr, Michael Nerlich, and Andreas Lenich. "Biomechanical characterisation of osteosyntheses for proximal femur fractures: helical blade versus screw." *Studies in health technology and informatics* 133 (2008): 1-10.
4. Ates, Murat, Selin Karadag, Aysegul Akdogan Eker, and Bulent Eker. "Polyurethane foam materials and their industrial applications." *Polymer International* 71, no. 10 (2022): 1157-1163.
5. Bakker, A., K. J. Myers, R. W. Ward, and C. K. Lee. "The Laminar and Turbulent-Flow Pattern of a Pitched Blade Turbine." *Chemical engineering research & design* 74, no. 4 (1996): 485-491.
6. Coyle, C. K., H. E. Hirschland, B. J. Michel, and J. Y. Oldshue. "Mixing in viscous liquids." *AIChE Journal* 16, no. 6 (1970): 903-906.
7. Dotson, K. W., S. Koshigoe, and K. K. Pace. "Vortex shedding in a large solid rocket motor without inhibitors at the segment interfaces." *Journal of propulsion and power* 13, no. 2 (1997): 197-206.
8. Driss, Z., G. Bouzgarrou, W. Chtourou, H. Kchaou, and M. S. Abid. "Computational studies of the pitched blade turbines design effect on the stirred tank flow characteristics." *European Journal of Mechanics-B/Fluids* 29, no. 3 (2010): 236-245.
9. Green, Don W., and Robert H. Perry. *Perry's chemical engineers' handbook*. McGraw-Hill Education, 2008.
10. Kamla, Youcef, Houari Ameer, Abdelkader Karas, and Mohammed Ilies Arab. "Performance of new designed anchor impellers in stirred tanks." *Chemical Papers* 74, no. 3 (2020): 779-785.
11. Kopstein, Melvyn. "Potential uses of petrochemical products can result in significant benzene exposures: MSDSs must list benzene as an ingredient." *Journal of occupational and environmental hygiene* 3, no. 1 (2006): 1-8.

12. Kresta, Suzanne M., and Philip E. Wood. "The flow field produced by a pitched blade turbine: characterization of the turbulence and estimation of the dissipation rate." *Chemical engineering science* 48, no. 10 (1993): 1761-1774.
13. Kresta, Suzanne M., Arthur W. Etchells III, David S. Dickey, and Victor A. Atiemo-Obeng, eds. *Advances in industrial mixing: a companion to the handbook of industrial mixing*. John Wiley & Sons, 2015.
14. Leshchinsky, Ben, John Sessions, and Jeff Wimer. "Analytical design for mobile anchor systems." *International Journal of Forest Engineering* 26, no. 1 (2015): 10-23.
15. McCabe, Warren L., Julian C. Smith, and Peter Harriott. *Unit operations of chemical engineering*. McGraw-hill, 1993.
16. Miles, Derek Cyril, and John Herbert Briston. *Polymer technology*. London: Temple Press Books, 1965.
17. Mutlu, Hatice, and Michael AR Meier. "Castor oil as a renewable resource for the chemical industry." *European Journal of Lipid Science and Technology* 112, no. 1 (2010): 10-30.
18. Nagappa, R., M. R. Kurup, and A. E. Muthunayagam. "ISRO's solid rocket motors." *Acta Astronautica* 19, no. 8 (1989): 681-697.
19. Norton, Tomás, and Da-Wen Sun. "Computational fluid dynamics (CFD)—an effective and efficient design and analysis tool for the food industry: a review." *Trends in Food Science & Technology* 17, no. 11 (2006): 600-620.
20. Paul, Edward L., Victor A. Atiemo-Obeng, and Suzanne M. Kresta. *Handbook of industrial mixing*. Wiley-Blackwell, 2004.
21. Scheurich, Frank, Timothy Fletcher, and Richard Brown. "The influence of blade curvature and helical blade twist on the performance of a vertical-axis wind turbine." In *48th AIAA aerospace sciences meeting including the new horizons forum and aerospace exposition*, p. 1579. 2010.
22. Stelmach, Jacek, Czesław Kuncewicz, Szymon Szufa, Tomas Jirout, and Frantisek Rieger. "The influence of hydrodynamic changes in a system with a pitched blade turbine on mixing power." *Processes* 9, no. 1 (2020): 68.

23. Strauss, Eric, Joshua Frank, Jason Lee, Frederick J. Kummer, and Nirmal Tejawani. "Helical blade versus sliding hip screw for treatment of unstable intertrochanteric hip fractures: a biomechanical evaluation." *Injury* 37, no. 10 (2006): 984-989.
24. Yusof, Nurul Farhana Mohd, Edmund Ung Eng Soon, Iman Fitri Ismail, and Akmal Nizam Mohammed. "Mixing Performance of Anchor and Helical Stirrer Blades for Viscous Fluid Applications." *CFD Letters* 13, no. 1 (2021): 58-71.

PROJECT REPORT.docx

by Sheik Hameed

Submission date: 27-Oct-2023 01:29PM (UTC-0400)

Submission ID: 2205953681

File name: PROJECT_REPORT.docx (366.1K)

Word count: 7278

Character count: 39558

1. INTRODUCTION

Mixing is the process of combining two or more initial separated chemicals or substances to form uniform distribution of all chemicals or substances by which new product is created for desired properties for particular application. Mixing is an important operation in many chemical and allied process industries. Mixing plays a vital and important role in industries like petroleum, polymers, cosmetics chemicals, waste water treatment, pharmaceuticals, paper and pulp industries, etc.

Based on the application variety of mixing equipment's are available. The Selection mixing equipment is very much important as it is directly associated with final product quality. Impellers are the heart of mixing equipment and properties of solids/fluids which is to be mixed is also main consideration for the selection of impellers for given mixing equipment. Different designs of impellers are used for different applications. Some of the important aspect need to be considered while mixing of new chemicals/sustenance's i.e., 1) type of mixing equipment 2) Type of raw materials 3) weighment 4) safety during mixing operation

The type of mixing equipment used depends overall on the quantity of raw materials to be handled and type of operation. This mixer consists of vessels/containers/drums, impellers for solid/liquid motion, baffles for avoiding vortex, inlet/outlet pipes and vents for samples collection.

Raw materials with suitable size are also a requirement for given mixer. Some of the chemicals/sustenance's having high viscosity and solid substances to be mixed with this type fluids so this decision is crucial as it determines the properties and characteristics of the final mixture/product.

Accurate weighment of all the ingredients/chemicals is essential to ensure that the desired proportions are maintained. This can be achieved by using standards and using calibrated weigh balances and other measuring equipment's etc.

Strictly following the safety norms by wearing appropriate personal protective equipment (PPE), like gloves, vapour masks, dust masks and safety goggles. Safety is an utmost importance when working with chemicals. Personnel working in this area

proper ventilation should be maintained at chemical storage area of chemicals to reduce quantum of the health risk.

For all new process/ chemical/ mixture different types of impellers are being used. Mainly ¹⁰ two types of flow patterns that can be developed mixing impellers those are axial or radial. Radial flow impeller discharges the fluid to the vessel wall in horizontal or radial direction. If suitable baffle is placed there is a strong top to bottom axial movement also can be achieved in case of axial flow top to bottom movement of materials can be observed. Basically, mixing is the process of combining two or more chemical substances to produce a uniform or homogeneous and well-mixed mixture or to initiate a chemical reaction. Mixing may be with chemical reaction or without chemical reaction. The efficiency of mixing or mixing equipment in without chemical reaction is known through the homogeneity. In case of chemical reaction involves monitoring the concentration of reactions and products over a time can provide the progress of the mixing. Efficient mixing is important in every mixing process in order to get pure product with desired properties and less unwanted by products.

The ultimate goal of any mixing process is to get a homogenous distribution of the all the ingredients/components. In some cases, process should be done in controlled temperature to achieve required operations such as Heating or cooling or to control reaction rates in case of chemical reaction so then the mixing technique can vary depending on the chemicals or components to be mixed.

It is essential to monitor the chemical reaction if mixing involves a reaction. This can be done by temperature monitoring, periodic sampling and analysis to verify the reaction rates so reaction progress with time.

Standard operating procedure: it is to be prepared and must be followed during the entire process so that the final product meets the desired properties and specific values.

Raw materials specifications: all raw materials specifications should be strictly followed and if any deviation then that batch may be rejected

Residual management: Proper housekeeping and equipment cleaning and disposal of residue or byproducts is to be discarded safely without environment hazards

Industrial mixing processes having a wide scope. From lab, pilot plant, small scale process to large scale industry. Every process had its own procedures and precautions based of their nature and the process requirement.

1.1) Key Aspects of Mixing

Efficient Mixing: It refers to the proper utilisation of impellers/stirrers for specific chemicals. It can be controlled by changing the varies parameters like stirrer RPM, mixing time, blade configuration, Different applications require different mixing intensities.

Mode of operation: mixing processes can be performed in batch or continuous modes depends on the demand and requirement or convenient. Batch mixing refers to components charged in to the vessel after batch time, a well-mixed material will take out as a product, while in continuous process involves a continuous feeding and product delivering takes place

Viscosity and Rheology: The viscosity and rheological properties of a materials had an impact on the selection of mixing equipment and the mixing process itself. Highly viscous or non-Newtonian fluids may require customised mixing designs.

Environmental impact: Safety is utmost in chemical engineering. Proper handling of hazardous & toxic chemicals, explosion prevention techniques, and environmental impact assessment are primer aspects of chemical mixing.

Residual management system: in many chemical mixing process biproducts, residual disposal techniques create safe work environment Chemical engineers often employ optimization techniques and control strategies to ensure that mixing processes meet desired specifications and objectives efficiently.

System of reliability & Quality Control: Regular quality control helps to maintain the quality of the mixing and ensure that they meet the expected standards and specifications.

Mixing is a multifaceted field that requires a deep knowledge of fluid behaviour through properties, rate of reaction, chemistry of the raw materials, and laws principles. It plays a vital role in various chemical processes, from basic laboratory level to production level, and contributes significantly to product quality, process efficiency, and safety. Mixing is an important operation in various chemical industries, and it can be divided into various types based on criteria, including the nature of the materials being mixed, the purpose of mixing, and the equipment used. Here are some common categories of mixing:

Mixing for Homogenization: The objective of this type of mixing is to get a homogenised mixture throughout the vessel. It is commonly used to create turbulence which makes all components distributed evenly.

Blending: Blending is the process of combining chemicals/components to obtain required exact composition or consistency. It is used to mix different powders, granules, or liquids to create a particular composition.

Reaction/Mixing: In this type of process, chemical reactions take place due to reactants being in contact with each other, either by batch reactions, continuous reactions, and polymerization.

Slurry Mixing: Slurry mixing involves distributing the solid particles in a liquid medium to create a homogeneous mixture. This is common in many chemical industries like bentonite sulphur manufacturing and inhibition resin mixing etc.

Agitators: Agitators are equipment that are used to maintain the mixture's composition uniform throughout the vessel by making shear to a fluid or material, which causes the fluid to homogenize. Mixers differ from agitators by the action while mixers are used to mix two or more components and agitators for maintaining homogeneity.

Gas-Liquid Mixing: it involves the Gas dispersion through the (e.g., air or oxygen) into a liquid medium. It is often used in processes like fermentation, aeration, and wastewater treatment.

1.11) Based on Equipment:

Agitation Mixing: Agitation mixing involves the use of mechanical agitation, typically through impellers or stirrers, to promote mixing. It is widely used in both laboratory and industrial settings.

Shear Mixing: High-shear mixing uses for material with high viscous and containing solids and fines in it, so intense mixing is required for this kind of materials. It is commonly used suspensions, pastes, and slurries.

Powder Mixing: it is a dry mixing, predominately uses in pharmaceutical industries. Tumble blenders, ribbon blenders, screw blender comes in this category.

Planetary Mixing: Planetary mixers are high precision mixer which is having a combination of both rotating and revolving motions to achieve thorough mixing of materials. These are used in propellant slurry mixing.

1.12) Based on Material State:

Liquid-Liquid Mixing: In this type of mixing, two or more liquids are mixed together to get a product having expected properties within given specifications.

Solid-Liquid Mixing: Solid materials are mixed with liquids to create saturated solution, suspensions, or dispersions.

Solid-Solid blending: Solid materials, often in powder or granular form, are blended together to create homogeneous mixtures or compositions. In mixed fertilizer plant this type of blending takes

These categories are not mutually exclusive, and mixing processes can often involve a combination of these types based on the specific requirements of a given application or industry. The choice of mixing method and equipment depends on the

characteristics of the materials being mixed, the desired end product, and the scale of the operation.

The mixing efficiency can be depended on various factors, both intrinsic and extrinsic. Understanding these factors is important for achieving the desired outcomes in terms of product quality, reaction efficiency, and process safety. Here are some of the factors that can affect a mixing process:

1.13) Nature of the Materials:

Chemical Compatibility: The compatibility of the chemicals being used is critical. Some chemicals may react with each other, leading to unwanted side reactions or safety hazards.

Physical Properties: Properties like viscosity, density, solubility, and particle size of the materials can impact the mixing process. Highly viscous fluids, for example, paints and emulsifiers may require more energy for effective mixing.

Reactivity: Reactive materials may require special precautions to prevent uncontrolled reactions like run off reactions during mixing. Temperature and pressure conditions must be carefully controlled.

1.14) Mixing Equipment:

Type of Mixer: The choice of mixing equipment and auxiliary equipment **such** as impellers, agitators, or blenders, depends on the specific requirements of the mixing process, based on the process requirement s and nature of chemicals being used. Different types of mixers provide varying levels of agitation and shear.

stirrer Speed: The speed at which the stirrer /impeller operates affects the intensity of mixing. Higher speeds produce more turbulence and can help faster mixing but may also increase energy consumption and heat generation.

Design of impeller: The design of agitators, including the size, shape and no. of blades or impellers, influence mixing efficiency. Proper design is key factor for achieving desired product.

Size and shape of Mixing Vessel: The size and shape of the vessel is an important parameter for better mixing. Insufficient vessel size and improper vessel shape resulting in improper mixing, while excessively large vessels may result in longer mixing times and increased energy consumption.

1.15) Operating Conditions:

Temperature: Temperature control is essential for processes involving temperature-sensitive materials or those requiring specific temperature conditions for reactions to occur.

Pressure: In some cases, mixing processes may require pressurized vessels to maintain reactants in a specific phase or to enhance solubility.

Mixing Time: The duration of mixing can affect the degree of homogeneity and reaction completeness. Overmixing can lead to degradation or other unwanted effects.

Understanding and managing these factors is crucial for optimizing chemical mixing processes and achieving the desired outcomes in terms of product quality, process efficiency, and safety.

When dealing with viscous slurries in mixing applications, it's important to select the appropriate impeller design to achieve efficient mixing and proper fluid dynamics. The choice of impeller depends on factors such as the viscosity of the slurry, the desired mixing intensity, and the specific process requirements. Here are some types of impellers commonly used for mixing viscous slurries:

INTRODUCTION TO ROCKETS

Rocket is a vehicle which is used to insert the satellite in their precise orbit

rocket engine or motor is basically works on the principle of newtons third law. Rocket engine/motor produces high thrust and temperatures by the fuel and oxidiser combustion, flue gases travel through nozzle which is having convergent–divergent section.



BASIC PRINCIPLE OF PROPULSION

propulsion² is the action or process of propelling. It is a method of propels or pushing an object in a forward direction. The word “propulsion” derived from the Latin word propellere, where pro means forward or backward and pellere means push. In addition, we know that the verb “propel” means to drive or cause to move an object in a specified direction.

Generally liquid propellants are called as rocket engines and solid motors called as motors

TYPES OF ROCKETS: rocket is a vehicle that inserts the satellite in precise orbit.

Based on the payload launch vehicles are divided in to following types

GSLV-MK3:

geosynchronous satellite launch vehicle 3.

payload 10 tons to LEO and 4 tons to GTO

GSLV-MK2:

geosynchronous satellite launch vehicle-2

Payload 2.5 tons

PSLV:

polar satellite launch vehicle:

Payload 2-3 tons

SSLV

small satellite launch vehicle

Pay load 500 Kg to 500 km lower earth orbit

APPLICATION OF SATELITES

- Earth observation
- Communication
- Weather forecasting
- navigation

INHIBITION RESIN (IR-1)

In solid rocket motor especially in solid stage a controlled and pre-determined burning of propellant is required to meet the specified machine requirement. It plays a vital role for attain pressure vs time graph

Inhibition is a non-combustible polymeric material having a very low thermal conductivity and high specific heat due to these properties it is avoiding unwanted surface area burning and prevent the propagation of flue gases and guides the travel of flue gases through the nozzle to create sufficient pressure in this case it is called as thrust. So, inhibition material pouring on the surface of propellant decreasing gradually by erosion. other hand due the compression factor inhibition used in the joint of segments of the all rockets like PSLV, GSLV and GSLV MK-3 etc.

A polyurethane is typical resin produced by reacting hydroxyl groups of castor oil reacts with the isocyanates in TDI, here silica fabrics plays a typical by acting as a reinforcements/filler material. This monomer combines together to form a polymer. Additional polymerisation takes place in this reaction.

the term "inhibition" may not be commonly used in rocketry, the control and regulation of various rocket systems are fundamental to their safe and efficient operation. These mechanisms ensure that the rocket can achieve its mission requirements by placing satellites in to the orbit to exploring the varies planets, communication spying, weather, geological surveys etc. concept of rocket inhibition is to controlling the rocket operations.

flight Control: Rockets generally produces thrust through propulsion. Inhibition mechanisms controls the unwanted surface area burning to developed required thrust.

inhibition for radial flow: In the context of fluid dynamics and flow control, "inhibition" for radial flow is not a standard term or concept. However, if you are referring to controlling or inhibiting the radial flow of fluids in a specific system or application, you

may need to employ various techniques or mechanisms to achieve this control. Here are a few methods and considerations for controlling radial flow:

Flow Restriction: To inhibit or control radial flow, you can use flow restriction devices such as valves, orifices, or nozzles. These components can be placed strategically within a fluid system to limit the flow rate and control the distribution of fluid in the radial direction.

In summary, controlling or inhibiting radial flow involves the use of various engineering techniques and components to manage the distribution of fluids or particles in a radial direction within a system. The specific method chosen will depend on the nature of the fluid system and the desired outcome, such as minimizing radial dispersion, optimizing mixing, or achieving other specific objectives.

Polyurethane resin, often simply referred to as polyurethane, is a versatile and widely used polymer material. It is created through a chemical reaction between polyols and isocyanates. Here are

Specific heat is a fundamental property that plays a central role in understanding how heat energy is transferred and stored in materials and substances. It is used extensively in fields like thermodynamics, heat transfer, and materials science. In the context of rockets and propulsion systems, "inhibition" usually refers to the process of preventing or controlling the ignition and combustion of propellants or explosives when they are not supposed to ignite. Inhibition mechanisms are crucial for ensuring the safe handling, storage, and transport of rocket propellants and explosive materials. Here are some key aspects related to inhibition in rockets:

Safety: In rocketry, safety is of paramount importance. Rockets and their components may contain highly reactive or explosive materials. Proper inhibition mechanisms are essential to prevent accidental ignition and ensure safe handling.

Inhibited Propellants: Many rocket propellants, such as solid propellants, can be inhibited to prevent unintended ignition. Inhibition typically involves the addition of

chemical compounds or coatings to the propellant that inhibit combustion or lower its reactivity.

Insensitive Munitions: In the defence industry, the concept of "Insensitive Munitions" (IM) is critical. IM is a set of safety standards and technologies designed to reduce the likelihood of accidental detonation of ammunition and explosives. This includes inhibition methods.

In summary, inhibition in rockets and propulsion systems is a critical safety measure that involves the use of chemical agents or mechanisms to prevent unintended ignition and combustion of propellants or explosives. It plays a vital role in ensuring the safe handling, storage, transport, and deployment of rockets in both military and civilian applications. In the context of rocket motors and solid rocket engines, the terms "radial burning" and "axial burning" refer to the patterns of combustion or burning of the propellant within the rocket motor. These terms describe how the propellant burns with respect to its geometry and orientation within the motor casing.

Radial Burning: In radial burning, the propellant burns outward from the port toward the outer surface of the motor casing. The burning occurs in a radial or outward direction, perpendicular to the axis of the rocket motor. Radial burning is often associated with grains of solid propellant that have a star-shaped or radial configuration. These grains have channels or perforations that allow the combustion gases to flow outward from the centre. This burning pattern can result in a relatively large burning surface area and a high thrust-to-weight ratio, making it suitable for certain rocket applications.

Axial Burning: In axial burning, the propellant burns along the length or axis of the rocket motor. This is also called as end burning the burning occurs parallel to the axis, from one end of the motor to the other. Axial burning is common in rocket motors with cylindrical or tubular propellant grains that do not have channels or perforations that promote radial burning. This burning pattern may result in a lower thrust-to-weight ratio compared to radial burning, but it provides more stable and predictable thrust characteristics. The choice between radial and axial burning depends on the specific requirements of the rocket design and the desired thrust profile. Engineers and

designers consider factors such as thrust control, burn rate, stability, and the desired trajectory when selecting the appropriate burning pattern for a particular rocket motor.

Additionally, some advanced rocket motor designs incorporate a combination of radial and axial burning by using propellant grains with specific geometries or additives that control the burn rate along different directions. This allows for more precise control of the rocket's thrust profile and trajectory.

Ultimately, the selection of radial or axial burning is a crucial aspect of rocket motor design, impacting the performance and behaviour of the rocket during flight.

The "M-curve" in the context of solid rocket motors refers to the Mass vs. Time curve, which describes the variation in the rocket motor's total mass as it burns over time during a rocket's flight. The M-curve is a critical parameter in the design and analysis of solid rocket motors. Here's how it works:

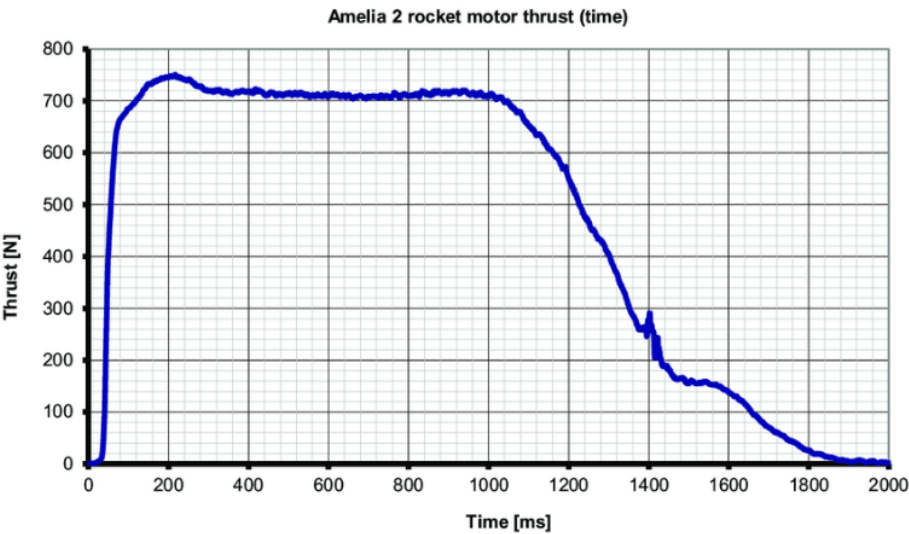
Initial Mass (M_i): At the beginning of a rocket motor's operation, its total mass is represented by M_i . This includes the mass of the rocket motor casing, propellant, igniter, and any other components.

Burnout Mass (M_f): As the rocket motor burns, the propellant inside is consumed, and its mass decreases. The point at which the propellant is completely burned, and the rocket motor ceases to produce thrust, is called burnout. The mass of the rocket motor at burnout is represented by M_f .

In summary, the M-curve in solid rocket motors provides a graphical representation of how the rocket motor's total mass changes over time as the propellant is consumed. It is a critical parameter used in the design, analysis, and optimization of solid rocket motors for a wide range of applications. Inhibition is a critical safety measure in rocketry, especially when dealing with energetic materials like propellants and explosives. It involves the use of specific mechanisms or agents to prevent or control the ignition, combustion,

In conclusion, inhibition in rocketry is crucial for ensuring the safe handling, transport, storage, and operation of rockets and their energetic materials. It helps prevent

accidental ignition or detonation, reduces the risk of accidents, and contributes to overall safety in both civilian and military rocket applications.



PROBLEM STATEMENT

Manual mixing in industrial processes can be fraught with several potential problems, which can lead to inefficiencies, safety hazards, and product quality issues. Some common problems associated with manual mixing in industry include:

Inconsistent Mixing: Human operators may have difficulty consistently achieving the desired mixing quality, resulting in variations in product quality and performance.

Operator Fatigue: Continuous manual mixing can lead to operator fatigue, which can impair their ability to maintain consistent mixing quality over time.

Safety Risks: Mixing certain substances manually can expose operators to hazardous chemicals, extreme temperatures, or physical strains. This can lead to workplace accidents or health risks.

Limited Scale and Capacity: Manual mixing processes are generally limited in terms of scale and capacity. It may not be feasible to manually mix large quantities or scale up production easily.

Time-Consuming: Manual mixing can be time-consuming, which may result in slower production rates and reduced overall efficiency.

Waste and Material Loss: Inaccurate or inconsistent mixing can lead to material waste and increased production costs.

Quality Control Challenges: Manual processes can make it difficult to monitor and control mixing parameters, making it challenging to maintain consistent product quality.

Lack of Data Collection: Manual mixing may not provide the data needed for process analysis, optimization, or quality assurance.

Non-Reproducible Recipes: Operators may struggle to reproduce specific mixing recipes accurately, leading to variations in product characteristics.

Human Error: Manual processes are susceptible to human error, which can result in costly mistakes or safety incidents.

Limited Flexibility: Manual mixing processes may lack the flexibility to adapt quickly to changing production demands or recipe adjustments.

Regulatory Compliance: Some industries, such as pharmaceuticals and food processing, have strict regulatory requirements. Manual mixing can pose challenges in meeting these requirements consistently.

To address these problems, many industries are increasingly turning to automation for their mixing processes. Automated mixing systems offer advantages such as precision, repeatability, scalability, and the ability to operate in hazardous conditions without human intervention. They also allow for data collection and process monitoring, which can aid in quality control and compliance.

However, the decision to switch from manual to automated mixing depends on factors such as the specific industry, process requirements, budget, and safety considerations. In some cases, a hybrid approach may be suitable, where automation is used for critical or large-scale mixing tasks, while manual mixing remains for smaller or less complex operations.

AIM & SCOPE

1. Basic understanding of typical inhibition resin
2. Selection of stirrer for Pre-mix and Final mix system to achieve homogeneity of the pre-mix to achieve cure reaction between binder and curator in final mix
3. To minimize the toxic chemicals exposure to working environment like Toluene Di-Isocyanate, Benzene, Tri-Chloro Ethelene etc.
4. To achieve optimized pot life for inhibition resin
5. To carry out experimental study on stirrer configuration for premix and final mix
7. Stirrer RPM selection for premix and final mix
8. Mixing Time for Pre-mixing & Final Mixing
- 9) To carry out typical inhibition resin mixing (pre-mix and final mix) by using mixing equipment
- 10) Utilization of advanced technologies in the mixing process
- 11) Increases the production rate of inhibition resin mixing Decrease manpower of mixing operation

Inhibition Resin is a non- combustible inert polymeric composite material used in solid rocket motors to achieve controlled burning of propellant and meet desired mission requirements. this inhibition resin is polyurethane based and formed mainly from reaction between Hydroxyl terminated polyol as a binder and isocyanate as a curing agent and to increase the curing reaction rate accelerator is added. To increasing polymer strength solid filler is added. The resin thus prepared is applied manually on the end surfaces of solid rocket motor. In present scenario due to increase in the size of solid rocket motors and frequency of launching, production of inhibition resin at high throughput is required, so in this project detailed study is carried out for design of mixing equipment for inhibition resin mixing. as mixing play an important and vital role

in chemical reaction of heterogenous system. design of mixing equipment is considered without affecting final properties of inhibition resin. The scope of work is an implementing automation process i.e. mixing equipment foe premix and final mix inhibition resin which is applied on the solid rocket motors to avoid motor burning in axial direction and allows in radial direction In current scenario,

1. MATERIALS AND METHODOLOGY:

Inhibition mixing is divided in to 2 parts premix, final mix

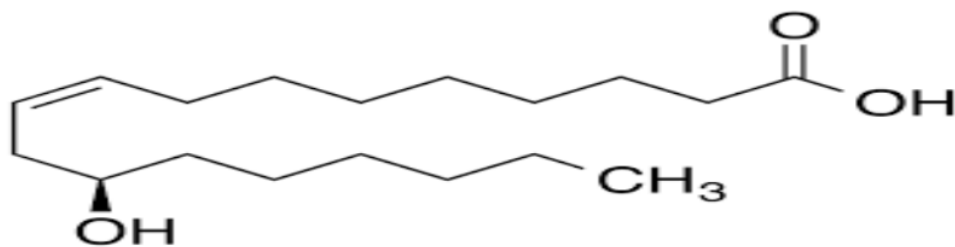
PRE-MIX: it contains the following chemical

- 1) castor oil,
- 2) typical silica fabrics,
- 3) PBNA
- 4) Fe₂O₃

Raw materials for pre-mix

s.no	chemical	composition	Purpose
1	Castor oil	65	Binder
2)	Typical silica fabrics	30	Fillers/Reinforcement
3)	PBNA	4	Anti-oxidant
4)	nano filler	1	Filler

Castor oil is a naturally occurred oil extracted from the pressing the seeds of castor oil plant. It is mainly produced in Africa south America Brazil, China and India. It is a colourless liquid with a different taste and Odor



Castor oil is the main reactant in this polyurethane reaction

Properties of castor oil

State	liquid
Colour	colourless or pale-yellow colour
Odour	oily odour
Density	0.961 g/cc
Viscosity	580 CP
Boiling point	313 °C
Fash point	229.4 °C
Hydroxyl value	160-168
Auto ignition temperature	448.9 °C
Thermal conductivity	4.727 (W/m°C)
Specific heat	0.089

Amorphous silica fabrics: a typical silica fabric is used as the filler. These are in the form of fibres and the matrix binds the fabrics, it plays a vital role in the product quality and curing time. Due to the fibrous nature of the particle and density differences solids settles down in a specific time period, so before final mixing, premix drum should be mixed thoroughly until the solid particles distributes uniformly throughout in the storage drum.

It is high heat resistant material. Some important thermal properties of a filler as given below

Physical state	solid fibres
Melting point	3000
Specific gravity	2.60
Thermal conductivity	0.08 W/m K
Specific heat	816 J/Kg °C

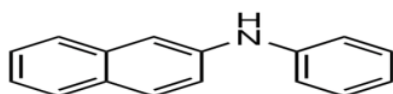
PBNA:

⁶ *N*-phenyl-β-naphthylamine (PBNA) acts as a antioxidant and prevents the degradation of the materials by ⁶inhibits the activity of oxidants, such as NO_x, to prevent the degradation of energetic materials.

Synonyms: N-(2-Naphthyl) aniline

Formula: C₁₆H₁₃N

Molecular weight: 219 g/mol



Fe₂O₃: (iron oxide)

it is a nano filter. It shows both acid and base behaviour.

molecular weight 159 g/mol

Density 5.24 g/cc



FINAL MIX: it contains

1)premix

2)TDI

3)FeAA

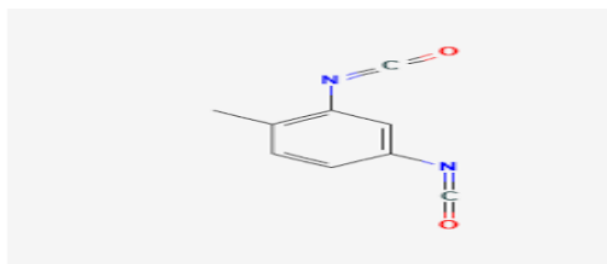
Raw materials for pre-mix

s.no	chemical	Wight in grams	Purpose
1	IR-1 PREMIX	100	resin
2)	TDI	24	curator
3)	FeAA	10	accelerator

IR-1 Premix: it does contain the chemicals as discussed; homogeneity and moisture content are two critical factors which affect the quality of product. to follow.

TDI: Toluene diisocyanate

It is a curing agent for the main reaction. NCO groups available in TDI will reacts with the hydroxyl groups of castor oil and to form polyurethane reaction in the presence of FeAA catalyst.



Reactivity and Handling: TDI is highly reactive and can react with moisture in the air and scale formations takes place. (white colour flakes) Therefore, it must be sealed properly after usage and at most care should be taken for storing. Proper ventilation and exhaust system is essential while handling TDI. Proper PPE is must for the manpower handling and using TDI.

Short term exposure limit is 0.002 PPM

PPE (personal protective equipment):

1) vapour mask

2) goggles

3) PVC gloves

4) safety shoe

Physical state	powder
density	5.24 g/ml
Molecular formula	$C_{15}H_{21}FeO_6$
Molecular Weight	353.17

FeAA solution: to increase the reaction rate an accelerator added along with reactants. The role of accelerator to increase the rate of reaction to achieve the uniform distribution of solids in order to get curing and hardness. FeAA is in solid form and reactants are in liquid/slurry form. For well mixing FeAA, it dissolves in a toluene solvent (5% w/w)

Toluene

Physical State	Liquid, colourless
Odour	sweetish Odor
Vapor Pressure	28.4 mm Hg
Solubility	insoluble
Specific Gravity/Density	0.86
Molecular Formula	C ₆ H ₅ CH ₃
Molecular Weight	92.14

Hazard statements:

4
Highly flammable liquid and vapour

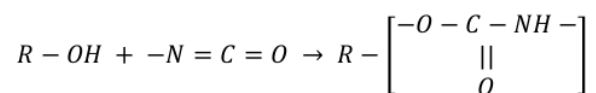
Inflammable

Carcinogenic

Causes skin irritation

May cause drowsiness or dizziness

Reaction



1
A polyurethane is typically produced by reacting an isocyanate with a hydroxyl groups. Since a polyurethane contains two types of monomers, which polymerize one after the other, they are classed as alternating copolymers. Both the isocyanates and polyols used to make a polyurethane contain two or more functional groups per molecule.

Mechanical Properties of IR-1

Density (g/cc)	1.0±1
Tensile strength (Ksc) Min.	5.5 Min.
Elongation (%)	30 min.
Hardness shore A	30 Min.

Thermo-chemical properties of IR-1

Thermal conductivity (W/m·K)	2×10^{-6}
Coefficient of expansion (J/Kg °C)	
Specific heat capacity (J/Kg °C)	1110
Erosion rate (sec)	0.02

Thermal conductivity: Thermal conductivity (k) is defined as ⁵the rate at which heat energy (Q) ¹³is conducted through a unit cross-sectional area (A) of a material over a unit temperature gradient (ΔT) perpendicular to that area. The formula is given by:

⁹
 $q = -k \, dt/dx$

k is the thermal conductivity (W/m·K)

q ¹⁶is the heat transferred per unit time (W)

dt/dx is the temperature gradient

Thermal conductivity is an important property of IR-1 since it is a non-combustible material it should have very low k value. During the rocket launch high temperatures occurs due to the combustion of fuel and oxidiser temperatures reaches upto 1500 °C Inhibition should be withstand that temperature to achieve controlled burning.

¹⁵
Coefficient of expansion: it is the change in length of a material when exposed to the temperature either heating or cooling.

¹¹
$$\Delta L/L = \alpha(\Delta T)$$

ΔL =change in length

ΔT = change in temperature

³
Specific heat capacity: amount heat required to raise the temperature of a body to 1 °C. it is measured in (J/Kg °C).

⁸
$$Q = mC \Delta T$$

Where,

Q= heat energy

M=mass

C=specific heat capacity

ΔT = change in temperature

Erosion rate: decreasing/ losing itself with time is known as erosion,

Pot life : another important parameter in processing of IR-1 resin is ¹²pot life .it is defined as the time taken to cease the flow of IR-1 after adding curator to the pre-mix. With in pot life, the operation should complete to achieve better result of the product pot life depends on so many factors like raw material properties (since castor oil is a natural product property especially no. of hydroxyl groups availability and other properties) and process conditions like temperature and pressure and mixing time and intensity of mixing.

normally pot life of IR-1 ranging from 15-20 minutes

Castor oil as resin, heat resistance powder as a solid filler, Toluene Di-isocyanate as Curator and an accelerator. All chemicals are obtained from our regular suppliers and chemical analysis is carried out as per ISRO standards. inhibition premix drum which contain 100-110 kg of inhibition resin, with stirrer motor for rotation of stirrer.

No of trails are carried out using different types of premix stirrer and final stirrer is fixed on the basis of optimization of time for mixing and RPM of stirrer

Initially, mixing of inhibition resin i.e., premix is done for 20-30 minutes at premix station to achieve homogeneity by uniform distribution of solid content throughout the container. process is continued in the containers based on number of containers required to meet the inhibition process.

In final mix station, after addition of curator, reaction between polyol and curator (TDI) starts and to increase reaction rate, accelerator is added and mixed.

SELECTION OF STIRRER

Selection of mixing equipment especially stirrer is an important task in the mixing process of both IR-1 Pre-mix and final mix. The slurry having 40% of fibrous solids and viscous liquids. Viscosity range of premix is around 6000 to 8000 CP.

Considering the viscosity of the material the bellow stirrers has been tried for mixing

Anchor or Paddle Impeller: Anchor impellers are used for high viscous fluids and slurries and non-Newtonian fluids. Laminar mixing takes place in this type of mixing due to high viscosity. They are designed with multiple flat blades or paddles attached to a central shaft. The paddles provide a sweeping the material and through the material from walls to the centre. This impeller is used for mixing of slurries, gels, and high-viscosity fluids.

Process difficulties:

Laminar mixing taking place

Low shear of material was observed

It requires accurate design of vessel is required to avoid wear and tear

Expensive

Helical Ribbon Impeller: Helical ribbon impellers have a helical ribbon-like design that promotes axial flow and prevents excessive shear, making them suitable for viscous materials. They are commonly used in mixing processes involving pastes, gels, and heavy slurries, such as in the production of ceramics, polymers, and adhesives.

Disadvantages: Less radial mixing and these impellers generally having less clearance between impeller and vessel, so accurate design required to avoid contact of impeller and vessel

Pitched Blade Turbine Impeller:

Pitched blade turbine impellers consists of blades with angle that create axial flow as well as radial flow patterns. They are suitable for viscous slurries with different types of viscosities.

The choice of impeller for mixing viscous slurries should be based on a careful evaluation of the material properties, desired mixing intensity, and process

A pitched blade turbine, also known as a pitched blade impeller, is a type of mixing impeller used in various industrial applications to promote fluid mixing and agitation. It consists of two or more flat blades that are pitched (angled) to the central axis of the impeller. The design of the blades allows for efficient mixing of fluids, making it a common choice in chemical processing, pharmaceuticals, wastewater treatment, and other industries. Here are some key features and characteristics of pitched blade turbines:

1. **Blade Pitch:** The blades of a pitched blade turbine are inclined or pitched at an angle relative to the axis of rotation. The angle of pitch can vary, and it influences the flow pattern and mixing efficiency. Common pitch angles range from 30 to 45 degrees.
2. **Blade Geometry:** Pitched blade impellers typically have a flat, rectangular or trapezoidal shape. The width and length of the blades can vary depending on the application and the desired level of agitation.
3. **Flow Patterns:** The pitched blades induce both axial and radial flow in the fluid being mixed. This combination of flow patterns helps ensure good mixing throughout the vessel, from top to bottom and from the center to the periphery.
4. **High Mixing Efficiency:** Pitched blade turbines are known for their high mixing efficiency, making them suitable for blending, suspension of solids, and promoting chemical reactions within the fluid.
5. **Viscosity Range:** They are effective in a wide range of fluid viscosities, from low-viscosity liquids to moderately viscous materials.
6. **Low Shear:** While pitched blade turbines are effective mixers, they typically generate lower shear forces compared to high-shear mixers or other high-shear impeller designs. This makes them suitable for shear-sensitive applications.

7. Vessel Size: Pitched blade impellers are used in vessels of various sizes, from small laboratory containers to large industrial tanks.
8. Materials of Construction: They are available in various materials of construction, including stainless steel, plastic, and other materials, to suit the compatibility requirements of the process.
9. Versatility: Pitched blade turbines are versatile and can be used for a wide range of mixing tasks, including blending, dispersing, solid suspension, and heat transfer.
10. Blade Variations: Some variations of pitched blade turbines include three-blade, four-blade, or six-blade designs. The choice of blade configuration depends on the specific mixing requirements.
11. Motor Power: The power required to drive a pitched blade impeller depends on factors like the blade size, the fluid viscosity, and the desired mixing intensity.

In summary, a pitched blade turbine is an effective and versatile mixing impeller used in various industries to achieve efficient fluid mixing and agitation. Its blade design and flow patterns allow for thorough mixing of fluids with different viscosities and for various applications. The choice of impeller design and operating conditions should be tailored to the specific requirements of each mixing process

Impeller type	observation	Remarks/ conclusion
Anchor	1)Laminar mixing is observed 2)Axial flow of material predominately, less radial flow 3)high power consumption	At the bottom of the vessel solids are settled as a sludge.
Helical ribbon	1)Axial movement was observed 2)due to less clearance between impeller and vessel high accurate design is required	Due to complicated design of blades cleaning is difficult
Pitched blade turbine	1)Both axial and radial movement taking place 2)turbulence mixing takes place 3)easy to clean	After set of trials, it is observed proper mixing of materials and through lab analysis

RESULT AND DISCUSSION:

As premix is a mixture of two different density materials i.e. hydroxyl polyol and solid content, solid content is bound to settle down over a period of time. For evaluation of mixing index, solid content is selected as performance parameter. At initial stage, during 60% of total mixing time, bottom blade is only functional and disturb the solid content settlement and provide radial mixing. Remaining time both top and bottom blades are operational where top blade provides axial dispersion and spread material uniformly. After mixing inhibition resin premix for about specified period time the samples are collected from three different zones i.e., top, middle and bottom of drum and analyze for solid content. (%) and trials matrix is shown in table 1 and results are plotted on graph

process difficulties with IR-1 pre-mix while conducting experiment

settling of solid particle: due to the density differences solid particles sedimentation takes place. These solids fine particles bind together to form a cluster. Due to this agitating the bottom of the drum is too difficult in order to get homogeneity of the entire drum

effect of moisture: moisture reduces the purity of the premix due to these bubbles and voids formation takes place which effect the density and Tensile bond strength properties

Moisture due to the two reasons

- 1) Ageing of the premix
- 2) Exposure of the premix to the atmosphere
- 3) Drying of raw materials

Solid Particles size: particular size of solid particles is required for premix. Deviation in size leads to off spec of parameter.

Experiment No:	PM Stirrer RPM	Time of mixing (min)	Solid content (%)		
			Bottom	Middle	Top
TRIAL-P1	50	20	52	30	22
TRIAL-P2	50	30	55	32.5	26
TRIAL-P3	50	40	57	36	26
TRIAL-P4	60	20	56	25	31
TRIAL-P5	60	30	54	27	31
TRIAL-P6	60	40	51	29.5	34
TRIAL-P7	70	20	34.5	35.5	35
TRIAL-P8	70	30	35	35.6	35.1
TRIAL-P9	70	40	35.1	35.8	35.2
TRIAL-P10	80	20	36.3	35.3	35
TRIAL-P11	80	30	36.1	36	36.3
TRIAL-P12	80	40	37.1	35.3	35.5

Experimental study on Inhibition resin as FINAL MIX:

After achieving the inhibition resin premix homogeneity, the required quantity of material taken into container and remaining chemicals added one after other in required quantity then mixing carried out for specified time at specified final mix RPM and results are shown on graphs.

Procedure: 1 Kg of inhibition resin premix material is taken in the container this premix is mixed by selected stirrer for specified time at specified RPM to achieve complete curing after mixing, from final mix container sample were taken and slab were prepared of 150 by 150 mm and after 24 hrs i.e. complete curing of resin slabs were sent for analysis These slabs are cut into dumble shape pertaining to ASTM D-412 and test were carried out and results are noted Experiments conducted revealed that rpm of final mix stirrer RPM 140 gives pot life of 38-42 (ref fig:1) which is required for inhibition process. Further experiments are carried out at 140 RPM to study the effect of mixing time at different stages on pot life

process difficulties with IR-1 final-mix

exothermic reaction: controlling this polyurethane reaction is too difficult due to the heat producing. We know that the poly addition reaction between OH groups and NCO groups is an exothermic reaction. As the isocyanate is added with the catalyst, the temperature of the reaction begins to rise gradually. The rate of the reaction proportional to the temperature and volume of reactants. As the temperature rises, the rate of the reaction will also increase.

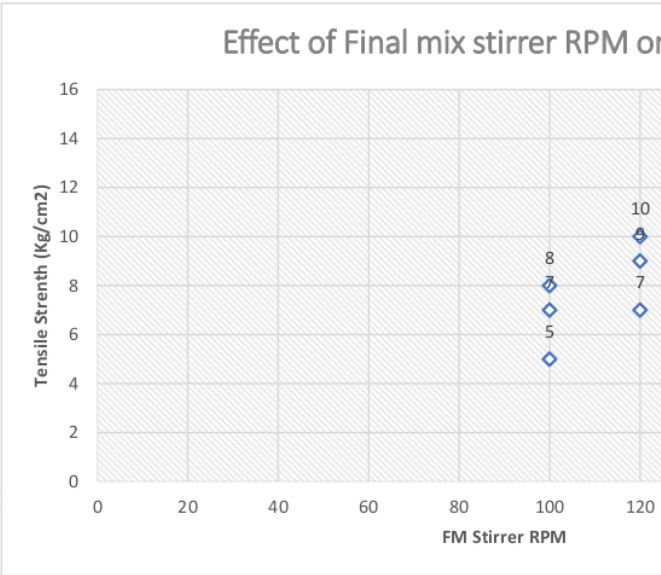
Pot life depends on each raw material properties, castor oil is naturally occurring so every batch need to do flow trails to find pot life of that IR-1 batch. Due to less pot life 1kg material selected for processing

Interlayer porosity: porosity is an undesired property.it is having the effect on almost all properties like density, TBS, elongation etc.,

Time of mixing (min)	properties			
	TS	ELONGATION	DENSITY	HARDNESS
	5	53	1.05	50
	7	56	1.09	52
	8	58	1.10	52
	7	52	1.09	57
	9	54	1.11	59
	10	48	1.13	58
	12	40	1.18	62
	13.5	39	1.22	63
	13	39	1.25	63
	13	37	1.23	62
	11	36	1.26	65

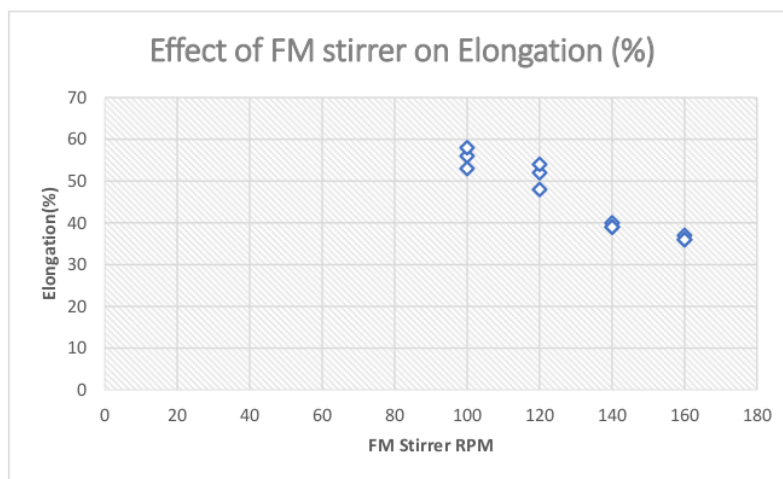
Table 2: Final mix Experimental matrix

FM Stirrer RPM	TS (Kg/cm ²)
100	5
100	7
100	8
120	7
120	9
120	10
140	12
140	13.5
140	13

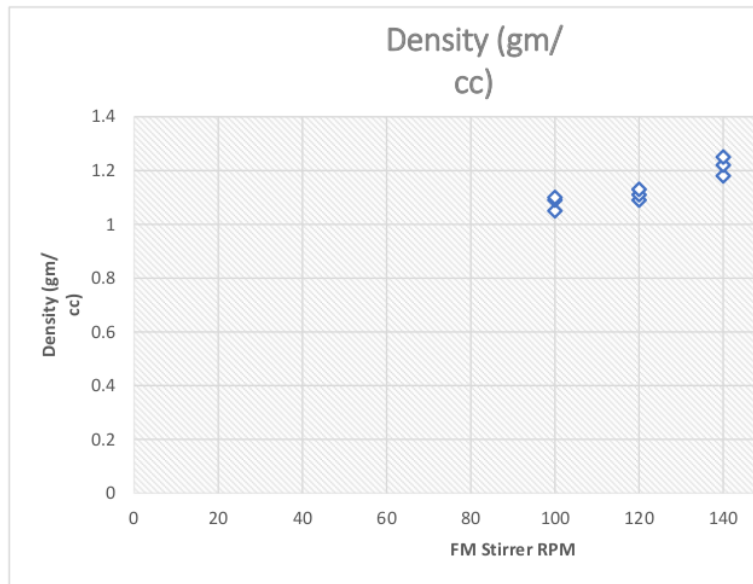


160	13
160	11
160	10.5

FM Stirrer RPM	Elongation (%)
100	53
100	56
100	58
120	52
120	54
120	48
140	40
140	39
140	39
160	37
160	36
160	36



FM Stirrer RPM	Density (gm/ cc)
100	1.05
100	1.09
100	1.1
120	1.09
120	1.11
120	1.13
140	1.18
140	1.22
140	1.25
160	1.23
160	1.26
160	1.28



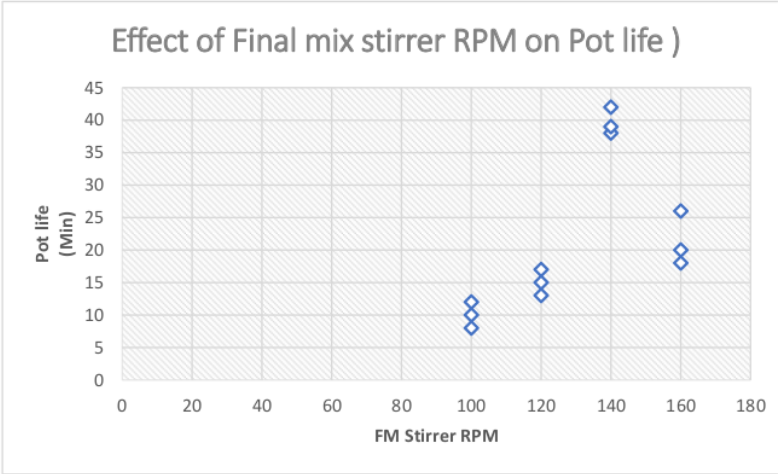
Effect of Final mix stirrer RPM on Hardness)

80

FM Stirrer RPM	Hardness (Shore A)
100	50
100	52
100	52
120	57
120	59
120	58
140	62
140	63
140	63
160	62
160	65
160	68

No:	FM Stirrer RPM	Time of mixing (min)	Temperature	Pot life
	100	3	30	10
	100	6	35	12
	100	9	40	8
	120	3	52	15
	120	6	60	13
	120	9	65	17
	140	3	68	38
	140	6	62	42
	140	9	63	39
	160	3	65	20
	160	6	65	18

FM Stirrer RPM	Pot life (Min)
100	10
100	12
100	8
120	15
120	13
120	17
140	38
140	42
140	39
160	20
160	18
160	26



CONCLUSION:

Understand the peculiarity of the material. Knowing the behaviour of IR-1 and effect of various factors on the reaction by the constructive experimental methods. Identify the process difficulties. Selection of stirrer required for the resin mixing is the major role in this experiment. Different stirrer has been chosen for better mixing of IR-1. After a set of trials pitched blade turbine is selected and it is modified to customised design for process. Based on homogeneity by testing solid content at 3 locations of the drum i.e., top middle and bottom, after 3 consecutive trials RPM and mixing time are fixed. RPM VS solid content Graph is plotted

final mix is complicated than the premix, due to the exothermic reaction involved. After addition of curators and accelerators reaction takes place and heat liberating. Based on mechanical properties of the product and pot life of IR-1 RPM and time for mixing is set. Graphs are plotted between RPM VS mechanical properties and pot life of IR-1

PROJECT REPORT.docx

ORIGINALITY REPORT

4%

SIMILARITY INDEX

3%

INTERNET SOURCES

1%

PUBLICATIONS

2%

STUDENT PAPERS

PRIMARY SOURCES

1

en.wikipedia.org

Internet Source

1%

2

ftp.idu.ac.id

Internet Source

1%

3

archive.org

Internet Source

<1%

4

Submitted to Aston University

Student Paper

<1%

5

ujcontent.uj.ac.za

Internet Source

<1%

6

Kitmin Chen, Alexander S. Edgar, Zheng-Hua Li, Oana C. Marina, Dali Yang. " Roles of HNO and Carboxylic Acids in the Thermal Stability of Nitroplasticizer ", ACS Omega, 2023

Publication

<1%

7

Submitted to SETA Training & Advisory Services

Student Paper

<1%

8

www.coursehero.com

Internet Source

<1%

9	robotics.jpl.nasa.gov Internet Source	<1 %
10	Submitted to Royal Melbourne Institute of Technology Student Paper	<1 %
11	Submitted to Waikato Institute of Technology Student Paper	<1 %
12	Liu, Hu, Hong Yan Zhu, Qian Qian Shang, and Guo Min Xiao. "Preparation of Water-Based Anti-Graffiti Polyurethane Coating", Advanced Materials Research, 2013. Publication	<1 %
13	trace.tennessee.edu Internet Source	<1 %
14	Burdock, . "Fenaroli's Handbook of Flavor Ingredients, Fifth Edition", Fenaroli s Handbook of Flavor Ingredients Fifth Edition, 2004. Publication	<1 %
15	es.scribd.com Internet Source	<1 %
16	vta.co-aol.com Internet Source	<1 %

Exclude quotes Off

Exclude bibliography Off

Exclude matches Off