

# Speciality Plastics, Foams (Urethane, Flexible, Rigid) Pet & Preform Processing Technology Handbook

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Plastic technology is one of the fields where people can show their ability and performance both theoretically and practically. The Indian plastic and polymer industry has taken great strides. In the last few decades, the industry has grown to the status of a leading sector in the country with a sizable base. The material is gaining notable importance in different spheres of activity and the per capita consumption is increasing at a fast pace. Continuous advancements and developments in polymer technology, processing machineries, expertise and cost effective manufacturing is fast replacing the typical materials in different segments with plastics. Some examples of the specialty plastics are polytetra fluoroethylene (PTFE) , thermoplastic polyurethanes (TPU), polysulphones (PSO), polyester sulphone (PES), polyarylates, polyamide imide (PAI), etc. Polyurethane is polymer composed of a chain of organic units joined by carbamate (urethane) links. Polyurethane polymers are formed by combining two bi or higher functional monomers. Urethane foam is an artificial material with several different uses. The manufacturing process can produce foams of varying densities and flexibilities. This means it can serve functions as diverse as bedding, packaging and footwear. It is important to note that urethane foam is most commonly used to refer to a material made from polyurethane. Furniture, bedding, automotive interiors, energy management, footwear and insulation utilize flexible foam technology due to its wide range of density, cushioning ability and versatility of use. Appliance (refrigeration, water heaters), construction panels, roofing boardstock, and spray applied insulation utilize rigid polyurethane foam due its superior insulating and mechanical properties to reduce energy consumption and enhance structural integrity of the finished product. The versatility of the technology and processability makes rigid polyurethane foam uniquely suited for other applications, like architectural molding, energy absorbing materials in automobiles, entry doors, and even picnic coolers. Polymer Energy system is an award winning, innovative, proprietary process to convert waste plastics into renewable energy. Polymers are the most rapidly growing sector of the materials industry.

Some fundamentals of the book are properties and applications of speciality plastics, thermoplastic polyurethanes, formation of urethane foams, flexible foams, variables in the preparation of prepolymers, procedures for the preparation of prepolymers, catalyzed prepolymer preparation, application of flexible foams, applications of rigid foams, one-stage injection stretch blow moulding, pet material and applications, injection and co-injection preform technologies, pet film and sheet, plastics as safe & hygienic medium for packaging food & food products

The book covers processes and other required information for the manufacturing of different specialty plastics, Foams, PET and Pre form PET etc. This is very useful book for new entrepreneurs, technocrats, existing units, institutional libraries etc.

## 1. PROPERTIES AND APPLICATIONS OF SPECIALITY PLASTICS

Polytetra Fluoroethylene (PTFE)

Thermoplastic Polyurethanes (TPU)

Polysulphones (PSO)

Polyether Sulphone (PES)

Polyphenylene Sulphide (PPS)

Polyphenylene Ether (PPE)

Polyether Etherketone (PEEK)

Polyarylates

Polyamide Imide (PAI)

Polyether Imide (PEI)

Liquid Crystal Polymers (LCP)

## 2. FORMATION OF URETHANE FOAMS

Introduction

The Chemistry of Foam Formation and cure

1. Reaction of Isocyanates

2. Function of the isocyanate in Foaming

3. Role of Catalysts in Foam systems

A. The Tertiary Amine Catalysts

B. The Tin Catalysts

C. Mixed Catalysts Systems

The Final Cure of Urethane Foams

Colloid Chemistry of Foam Formation

1. Bubble Nucleation

2. Bubble Stability

3. Urethane Foam Systems

Viscoelastic Changes in Foaming

1. Effect on Cell Structure, Voids, and Foam Collapse

2. Relations between Cell Structure and Properties

3. Structure Factors Affecting Stress Relaxation and Creep in Flexible Foams

## 3. FLEXIBLE FOAMS

Introduction

Raw Materials Used in Flexible Foams

1. Isocyanates

2. Polyols Blowing

3. Agents Catalysts

4. Surfactants

5. Miscellaneous Additives

Foam Systems

1. General Methods of Preparation

2. Prepolymers

A. Variables in the preparation of prepolymers

1. Raw Materials Control

2. Effect of Isocyanate-Hydroxyl Ratio

3. Effect of Polyol Variation

4. Effect of Reaction Time and Temperature

5. Effect of water

6. Effect of catalysts
7. Effect of Agitation
8. Effect of Reactor size
- B. Procedures for the preparation of prepolymers
  1. Batch Procedures
  2. Preparation of Prewolymer with Biuret Branching
  3. Preparation of Prepolymer with Allophanate Branching
  4. Preparation of Prepolymer with Urethane Branching
  5. Preparation of Polyester Prepolymer
  6. Preparation of Castor Oil-Based Prepolymers
  7. Batch Plant Process for Polyether Prepolymers
  8. Catalyzed Prepolymer Preparation
  9. Stabilization of Prepolymers
- C. Foaming of prepolymers
  1. Free Isocyanate Content
  2. Water
  3. Surface Active Agents
  4. Catalysts
  5. Other Additives
- Plasticizers
- Pigments and Fillers
- Flame Retardants
3. Semi-Prepolymers
4. One-shot Foams
  1. Chemical variations
- Effect of water
- Effect of Catalysts
- Effect of Emulsifiers and Additives
  2. Mechanical Variations
  3. Physical Variations
  4. Formulation Variations
- B. Variables in the preparation of one-shot Polyether Foams
  1. Effect of Polyols
  2. Effect of Diisocyanate
  3. Effect of Blowing Agents
  4. Effect of Catalysts
  5. Effect of Silicones
  6. Effect of Filters and Additives
  7. Formulation Variations
- Methods of Foam Application
  1. Foaming Equipment
  2. Manufacture of Slab Stock
- A. Foam Production
- B. Sectioning of Slab Stock
- C. Counter Shaping
- D. Post-Forming
  3. Molding of Flexible Foam
  4. Frothing of Flexible Foams
  5. Foaming of Urethane Elastomers
  6. Spraying of Flexible Foams
- Properties of Flexible Foams
  1. General Properties
  2. Specific Properties

- A. Aging of Flexible Foam
- B. Sound Absorption
- C. Low and High Temperature Properties
- D. Solvent and Chemical Resistance
- E. Oxidation and Ultraviolet Resistance
- F. Flammability of flexible Urethane Foams
- G. Fatigue Properties

#### Application of Flexible Foams

- 1. Furniture
- 2. Bedding
- 3. Transportation
  - A. Automotive
  - B. Aircraft
  - C. Public Seating
- 4. Packaging
- 5. Clothing, Textile and Miscellaneous Foam Laminates
- 6. Carpet Underlay
- 7. Sporting goods
- 8. Toys and Novelties
- 9. Sponges and Miscellaneous Household Items
- 10. Filtering Materials
- 11. Construction, Insulation and Miscellaneous Uses
- 12. Military and Missile Uses
- 13. Horticultural
- 14. Footwear
- 15. Medical

#### Miscellaneous Flexible Foam Systems

### 4. RIGID FOAMS

#### Introduction

- 1. Raw Material used in Rigid Foams
  - 1. Isocyanates
  - 2. Polyols
  - 3. Blowing Agents
  - 4. Catalysts
  - 5. Surfactants
  - 6. Flame Retardants
  - 7. Miscellaneous Additives

#### Foam System

- 1. Polymer Preparation
  - A. Semi-Prepolymer
  - B. Complete Prepolymer
  - C. One-shot Systems
- 2. Foam Preparation
  - A. Effect of Isocyanate Variations
  - B. Effect of Polyol Variations
  - C. Effect of Blowing Agents
  - D. Effect of Catalysts
  - E. Effect of Surfactants
  - F. Effect of Fillers
  - G. Flame Retardants

#### Methods of Foam Production

- 1. Batch Preparation

## 2. Continuous of Intermittent Pouring

### A. Nonfroth Systems

Metering Equipment

Mixing of Components

### B. Frothing System

## 3. Spraying

## 4. Production of Finished Foam

### A. Continuous Slab Production

### B. Molding Operations

### C. Foming-in-Place

Foam Properties

#### 1. Genral Properties

#### 2. Specific Properties

##### A. Coefficient of Expansion

##### B. Service Temperature

##### C. Closed Cell Content

##### D. Thermal Insulation

##### E. Adhesion to Various Substrates

##### F. Water Absorption

##### G. Water Vapor Permeability

##### H. Humid Aging

##### I. Solvent Resistance

##### J. Electrical Properties

##### K. Sound Insulation

##### L. Fungus Resistance

Applications of Rigid Foams

#### 1. Refrigeration Insulation

#### 2. Refrigerated Trucks and Trailers

#### 3. Insulation of Pipes and Tanks

#### 4. Structural Uses

#### 5. Uses in the Aircraft Industry

#### 6. Military Uses

#### 7. Void Filling and Insulation of Ships

#### 8. Uses in Packaging

#### 9. Uses in the Electric Industry

#### 10. Aerospace Applications

#### 11. Miscellaneous Uses

Miscellaneous Foaming Systems

## 5. ONE-STAGE INJECTION STRETCH BLOW MOULDING

Introduction

One-Stage Machines

#### 1. One-Stage Machine Construction

Process Stations on one-Stage Machine

#### 1. Injection mould and hot runner

##### A. Process conditions affecting perform quality

#### 2. Conditioning Station

#### 3. Blowing Station

Integrated Two-Stage machines

Dying System

#### 1. Requirements for a reliable drying system

#### 2. Drying process monitoring

Preform Design

#### 1. Neck finish

2. Preform weight
3. Cycle time and preform wall thickness
4. Stretch ratios
5. Injection mould design and manufacture
6. Preform design for varying container sizes
7. Preform weight adjustment
8. Difference between one- and two-stage preform designs

#### Container Design

#### Hot-Fill Pet Bottles

#### Quality Control Procedures

#### Preform Examination

1. Appearance and shape
2. Preform weight
3. Neck dimensions
4. Preform eccentricity
5. Polarised light inspection
6. Intrinsic Viscosity (IV)
7. Acetaldehyde (AA)

#### Container Examination

1. Shape and appearance
2. Dimensions
3. Capacity
4. Container wall thickness and material distribution
5. Top load strength
6. Impact resistance (drop) test
7. Leakage of liquid (seal integrity)
8. Vacuum strength
9. Acetaldehyde (AA)
10. Oxygen permeation
11. Moisture Vapour transmission rate
12. Product filling temperature
13. Container weight

#### Bottles for Carbonated Beverages

1. Burst pressure
2. Thermal stability
3. Carbon retention

#### Additional Tests for Hot-Fill containers

#### Additional Tests for Returnable/refillable Pet Bottles

## 6. INJECTION BLOW MOULDING

#### Introduction

#### Basic Principles

#### History

#### Commercial Processes

1. Rotary table machines : Jomar, Uniloy and similar

#### Tooling

#### Procrea

#### Material

#### Applications

#### Machine and Process Capabilities

## 7. PET MATERIAL AND APPLICATIONS

Introduction

Polymerisation and Manufacturing Processes

1. Manufacturing plants

Structures, Morphology and Orientation

1. Structure

2. Morphology

3. Orientation

4. Creep

Properties

1. Molecular weight and intrinsic viscosity

2. End group

3. Thermal properties

2. End group

3. Thermal properties

Rheology and Melt Viscosity

1. Melt viscosity

2. Melt Flow

3. Moulding Shrinkage

Moisture Uptake and Polymer Drying

1. Moisture level

2. Polymer drying

Degradation Reactions

1. Thermal and thermal oxidative degradation

2. Environmental Degradation

Reheat Characteristics

Gas Barrier properties

Amorphous Polyesters

1. Homopolymers

2. Low copolymers

3. Medium copolymers

4. High copolymers

Crystalline polymers

Polymer Blends

Applications

Trends

Globals

## 8. INJECTION AND CO-INJECTION PREFORM TECHNOLOGIES

Multilayer Characteristics

Applications

1. Performance-Driven Applications

2. Economics - or Legislative-Drive Applications

3. Combination Applications

Closure vs Bottle Permeation

Container Performance

1. Barrier properties

2. Oxygen barrier

3. Carbon dioxide barrier

4. Scavenger property

Wall structure

Preform and Bottle Design

1. Permeation through finish, sidewall and base

2. Controlled fill

Headspace Oxygen Absorption  
Oxygen Desorption From Pet  
Beer Containers  
Small Juice Containers  
Small CSD containers  
Core layer volumes  
Comparison of Co-Injection technologies  
Co-Injection Moulding Equipment

## 9. PET FILM AND SHEET

Introduction

The Film Process

1. Polymer preparation and handling
2. Extrusion and Casting
  - a. Extrusion
  - b. Casting
3. Drawing
  - a. The forward draw preheat (FWDPH)
  - b. The forward draw (FWD)
  - c. The sideways draw preheat (SWDPH)
  - d. The sideways draw (SWD)
4. Heat Setting
5. Slitting and Winding
  - a. In line slitting and knurling
  - b. Winding conditions
6. Reclaim and recovery

Polymer, Process and Properties (3ps)

1. Polymer
2. Process
3. Properties

Surface and Bulk Properties

1. Film properties
2. Coating
3. Co-extrusion
4. Fillers
5. Shrinkage
6. Combination of effects

PET Sheet

1. Extrusion of PET sheet
2. Thermoforming of CPET sheet
4. Material
5. New developments

Conclusion-Film

## 10 PLASTICS AS SAFE & HYGIENIC MEDIUM FOR PACKAGING FOOD & FOOD PRODUCTS

Glimses of Modern India

Views & changing practices

Scarcity among plenty

Consumer market

Food packaging a need

Food Safety The Ultimata

Risk assessment & food packaging regulations



Compatibility studies  
Migration modelling  
Package Design  
Packaging Development Process  
Plastics as a Choice  
Plastic Use for Packaging in India  
Lowest cost packaging  
Plastic-Packaging Solution for Food Products  
Growing user of plastic in Packaging  
Plastics and their present usages  
Indian Polymer Demand in KTPA  
Plastics reduce post harvest wastage  
Wastage of food product in India  
Plastic crates for post harvest packing  
Polypropylene boxes for horticulture packaging  
Plastics in bulk packaging  
Bulk Packaging Jute V/s PWS  
Suitability of PP/PE Bags for Food Grains & Sugar Storage  
Specialized Food Packaging  
Case study  
Plastics & Food shelf Life  
Plastics packaging for sterilized/irradiated food products  
National Standards on Packaging code for fresh & Processed Food  
Indian Food Laws and Packaging specification  
Edible Oil packaging Act  
Packaging, Plastics & Environment  
IS packaging or plastics the Real Culprit  
ECO- Protection programmes  
Future: What plastics have to offer

## 11. TWO STAGE INJECTION STRETCH BLOW MOULDING

Introduction

1. The principles of the Two-stage process
  - a. Preform moulding
  - b. Container stretch blow moulding
  - c. Preform and container design
2. Technological Basics of Pet as a Stretch Blow moulding material
3. Production concepts and target market

Preform Injection Moulding

1. Injection machine concepts
  - a. Plasticizing

Clamping

2. Mould Design
  - a. Hot runner system
  - b. Gates and cavities

Productivity Parameters

- a. Cycle time
- b. Preform design and key related parameters
- c. Preform quality and key related parameters

Stretch Blow Moulding

1. Principles of the two stage stretch blow moulding process
  - a. Preform reheating
  - b. Stretch blow moulding

Technologies for thermally stable containers  
Thermal relaxation and pre-shrinkage  
Hot-fill  
Heat-set  
Super heat-set  
2. Machinery concepts  
Mould technology  
Preform and Container Design  
Container design  
Preform design

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Our Detailed Project report aims at providing all the critical data required by any entrepreneur vying to venture into Project. While expanding a current business or while venturing into new business, entrepreneurs are often faced with the dilemma of zeroing in on a suitable product/line.

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