

COURSE OUTLINE

Rubber Extrusion Technology

Not all topics are covered because of participant preferences and time constraints

I. MATERIALS

- A. Elastomer Properties
 - 1. Chemical Structure
 - 2. Molecular Weight/Distribution
 - 3. Morphology and Crystallinity
 - 4. Viscosity (Flow)
 - a. Shear Rate
 - b. Temperature
 - c. Slip
 - 5. Elasticity (Swell)
 - a. Shear Stress
 - b. Die L/D
 - 6. Scorch
- B. Laboratory Tests for Extrudability
 - 1. Mooney Viscometer
 - 2. Processability Testers
 - 3. Standard Dies (Garvey)
 - 4. State of Cure Tests
- C. Compound Ingredients
 - 1. Elastomers
 - 2. Fillers
 - 3. Plasticizers and Process Aids
 - 4. Cure Systems/Nitrosamines
- D. Processing and Compounding
 - 1. EPDM
 - 2. Polychloroprene (Neoprene)
 - 3. SBR/BR
 - 4. Nitrile Rubber
 - 5. Chlorosulfonated Polyethylene
 - 6. Silicone Rubber
 - 7. Fluoroelastomers

II. PUMPING EQUIPMENT

- A. Rubber Processes
 - 1. Unit Operations
 - 2. Equipment Configurations
 - 3. Hot / Cold Feed Characteristics
- B. Barrels
 - 1. Construction
 - 2. Materials
 - 3. Thermal Control
- C. Screws
 - 1. Construction
 - 2. Materials
 - 3. Feed Devices
- D. Machine Design Fundamentals
- E. Screw Adaptions
 - 1. Hot Feed
 - 2. Conventional Cold Feed
 - 3. Barrier
 - 4. Superposed Flights
 - 5. Thermoplastic Elastomer
 - 6. Silicone Rubber
- F. Barrel Adaptions
 - 1. Pin
 - 2. Multicut Transfermix
 - 3. Pin Transfermix
- G. Extruder Attachments
 - 1. Gear Pumps
 - 2. Shear Heads
- H. Gear Extruder
- I. Devolatilizing Extruder
 - 1. Construction
 - 2. Operation
- J. Mixing Extruders
 - 1. Specialized Extruders
 - 2. Continuous Mixers
 - 3. Twin Screw Extruders
- K. Ram Extruder
 - 1. Operation
 - 2. Heads and Dies

III. SHAPING EQUIPMENT

- A. Heads
 - 1. Inline Heads
 - 2. Crossheads
 - 3. Tire Heads
 - a. Cold Feed
 - b. Hot Feed
 - 4. Single Roller Head
 - 5. Double Roller Head
 - 6. Breaker Plates & Screen Changers
 - 7. Dynamic Head Technology
 - a. Curved Extrusion
 - b. Takeaways
 - c. Rapid Die Change
 - d. Dimensional Control
 - 8. Robotic Extrusion
- B. Dies
 - 1. Types and Design Criteria
 - 2. Flow Dynamics
 - a. Viscosity
 - b. Pressure-Flow Relations
 - c. Swell
 - 3. Drawdown
 - 4. Profile Dies
 - a. Product Design
 - b. Tool Design
 - i. Flow Distribution
 - ii. Hollow Profiles
 - iii. Downstream Distortion
 - iv. Design Methods
 - v. Orientation Dies
 - vi. Lumen Transitions
 - vii. Die Surface Treatment
 - c. Die Operation
 - d. Coextrusion Dies
 - e. Coating Dies
 - 5. Die Relief Strategies
 - 6. Spreadsheet Computations
 - a. Annulus & Flange
 - b. Keyhole Die
 - c. Tube with Side Feed
 - d. Die with Carrier
 - e. Coextrusion Dies with Swell
 - 7. Finite Element Simulations

IV. DOWNSTREAM EQUIPMENT

- A. Continuous Vulcanization
 - 1. Compounding
 - 2. Salt Bath
 - 3. Hot Air
 - 4. Microwave
 - 5. Pressure Tube
 - 6. Rotation Curing
- B. Batch Cure
 - 1. Autoclave
 - 2. Hose Vulcanization
- C. Post Vulcanization Equipment
 - 1. Cooling
 - 2. Cutting
 - 3. Windup
- D. Hose Manufacture
 - 1. Construction
 - 2. Materials
 - 3. Process
 - 4. Reinforcement

V. INSTRUMENTATION

- A. Instrumented Extrusion Lines
- B. Temperature Sensors
 - 1. Thermocouples
 - a. Fixed
 - b. Mobile
 - 2. Resistance Devices
 - 3. Thermistors
 - 4. Infrared Sensors
- C. Pressure Sensors
- D. Dimension Sensors
 - 1. Optical
 - a. Blocked Beam Laser
 - b. Linear Profile Laser
 - c. 360° Profile Laser
 - d. 360° Profile & Surface LED
 - e. Laser with EM Induction
 - f. Laser Velocity Measurement
 - 2. Ultrasonic Devices
 - 3. X-ray
 - 4. Millimeter Wave
 - 5. Coating Thickness
 - 6. Electromechanical Devices
 - 7. Length or Surface Change
- E. Weight Sensors

VI. OPERATIONS

- A. Extruder Dynamics
 - 1. Flow in Screw Pumps
 - 2. Output Rate Variables
 - 3. Operating Curves
 - 4. Heat Transfer
 - 5. Stock Temperature Variables
 - 6. Conveyor Operation
 - a. Variability
 - b. Contraction
 - 7. Curvature of Extrusions
- B. Productivity and Quality
 - 1. Optimum Conditions
 - a. Quality Measurement
 - b. Output Rate
 - c. Stock Temperature
 - d. Feed Conditioning
 - 2. Feed Strip Optimization
 - 3. Hot Feed Operation
 - a. Feed Mills
 - b. Line Performance
 - 4. Adjustments on Pin Barrels
 - a. Pin Removal
 - b. Mixing Capability Test
 - 5. Screw and Barrel Wear
 - a. Causes of Wear
 - b. Characteristics of Wear
 - c. When to Change
 - d. Measurement of Dimensions
 - e. Maintenance
 - 6. Starved Operation
 - 7. Die Drool

VII. PROCESS VARIATION & CONTROL

- A. Variation
 - 1. Sources of Variation
 - 2. Root Cause by Cross-correlation
- B. Control
 - 1. Feedback Control
 - 2. Size and Shape
 - 3. Size Control (Weight or Area)
 - a. Line Speed
 - b. Screw Speed
 - 4. Shape Control (Single Component)
 - a. Die Temperature
 - b. Stock Temperature
 - c. Adjustable Dies
 - 5. Shape Control (Multicomponent)
 - 6. Commercial Controls
 - a. Systems
 - b. Wireless

VIII. TROUBLESHOOTING

- A. Introduction
- B. Product Geometry
 - 1. Surface Defects
 - 2. Lumps
 - 3. Porosity
 - 4. Dimensional Variability
- C. Extruder Operation
 - 1. Safety
 - 2. Output Rate
 - 3. Temperature
 - 4. Vent Plugging and Surging
 - 5. Wear
 - 6. Die Drool
- D. Compound

IX. CURRENT TRENDS AND NEW TECHNOLOGIES

A. Trends

1. Gear Pumping
2. Laser Sensing
3. Die Technology
 - a. Face Relief
 - b. Mechanical Adjustments
- c. Mechanical Adjustments
4. Extruders Under Mixers
5. Cassette Windups
6. Integrated Line Control
7. Multifunctional Extruders
 - a. Mixing (Wall Flights & Side Feed)
 - b. Devolatilization Control
 - c. Mastication Control
8. Multifunctional Heads
 - a. Quick Change & Six compounds
 - b. Robotic Extrusion
9. Simulation
10. Company Wide Technical Symposia

B. New Technologies

1. Shape Control
2. Surface Patterning
3. Dynamic Head Technology
4. Troubleshooting with Online Data

X. REFERENCES

- A. Books
- B. Paper