RUBBER PROCESSING TECHNOLOGY

1. Rubber Processing and Shaping
2. Manufacture of Tire and other Rubber Products
3. Design Consideration

Introduction
• Similar to the processing of plastics
• But the rubber industry is quite different from the plastics industry
• Dominated by one product: tires
• Technological breakthrough
  – Vulcanization (cross-linking) to transform weak natural rubber into a stronger material (1839).
  – The introduction of synthetic rubbers such as Styrene-butadiene rubber (SBR), Butadiene Rubber (BR) and Ethylene-Propylene-diene rubber (EPDM) (around WWII)

Rubber Processing and Shaping
• Two basic steps
  – Production - Agricultural crop or Petroleum
  – Shaping of rubber into finished goods
    • Compounding – Addition of Reinforcement (R) and Nonreinforcement (NR)
    • Mixing – Two stages of mixing, masterbatch (non-vulcanizing agents) and second stage (vulcanizing agents), using two-roll mill and internal mixer
    • Shaping – Extrusion, calendering, coating, molding and casting
    • Vulcanization – A curing (cross-linking) process developed by Goodyear

Production of Natural Rubber
• Latex (a colloidal dispersion (30%) of solid particles (polymer polyisoprene) in water) from Rubber trees (Hevea brasiliensis) on plantations in southeast Asia and other part
  – Diluted to 50% with additional water and coagulated by adding formic or acetic acids in large tanks.
  – Coagulum (soft solid slabs) is then squeezed through a series of rollers to loose water.
  – Drying
    • Ribbed smoked sheet in dark brown color - dried over wooden frames in smokehouses for several days, which are folded into large bales.
    • Air-dried sheet - A better grade of rubber, dried in hot air rather than smokehouses.
    • Pale crepe rubber in light tan - A even better grade involves two coagulation steps and warm air drying.

Production of Synthetic Rubber
• Most synthetic rubbers are produced from petroleum by the same polymerization techniques.
• Unlike shaping polymers in the form of pellets or liquid resins, synthetic rubbers start in the form of large bales.

Compounding
• The specific rubber is designed by vulcanization, (adding sulfur) or fillers.
• Fillers to enhance the rubber's mechanical properties (reinforcing fillers) or to reduce cost (non-reinforcing fillers)
• Carbon black, a colloidal form of carbon, obtained by thermally decomposing hydrocarbons (soot)
  – to increase tensile strength and resistance to abrasion and tearing
  – To protect from ultraviolet radiation
  – Appear black in color
Compounding

- China clays - hydrous aluminum silicates \((\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4)\) for other colors but less reinforcing than carbon black.
- Calcium carbonate (non-reinforcing) and Silica
- Other polymers (styrene, PVC, and phenolics)
- Recycled rubber (usually 10% or less)
- Antioxidants (anti-aging by oxidation); fatigue- and ozone-protective chemicals; coloring pigments; plasticizers and softening oils; blowing agents in the production of foamed rubber; and mold release compounds

Mixing

- To achieve uniform dispersion of ingredients
- Mechanical working increases its temperature up to 150°C (300°F)
- A two-stage to avoid “nightmare”
  - Carbon black & non-vulcanizing additives (masterbatch)
  - Vulcanizing agents after cooling
- Filament reinforcement to reduce extensibility while retaining the other properties
  - Examples: tires, conveyor belts
  - Filaments (cellulose, nylon, and polyester) and Fiber-glass and steel (e.g., steel-belted radial tires)
  - Continuous fiber materials must be added during shaping; not mixed like the other additives

Shaping and Related Processes

- Four basic categories of shaping processes:
  1. Extrusion
  2. Calendering
  3. Coating
  4. Molding and casting

Extrusion

- Screw extruders are generally used
- The L/D ratio of the extruder barrel is less than for thermoplastics, typically in the range 10 to 15, to reduce the risk of premature cross-linking
- Die swell occurs in rubber extrudates due to its highly plastic condition and the “memory” property
- It is done before vulcanization.

Calendering

- Stock is passed through a series of gaps of decreasing size made by a stand of rotating rolls where final roll gap determines sheet thickness:

Roller Die Process

Combination of extrusion and calendering for better quality product.
Coating or Impregnating Fabrics with Rubber

- Used in producing automobile tires, conveyor belts, inflatable rafts, and waterproof cloth tents and rain coats

Vulcanization

- Now various other chemicals are combined with sulfur to accelerate and strengthen the 15-20 minute treatment.
- A variety of non-sulfur vulcanizing treatments have also been developed.

Manufacture of Tire and Others

- Tire (¾ of rubber product), Footwear, Seals, Shock-absorbing parts, Conveyor belts, Hose, Foamed rubber products, Sports equipment
- Tire: Three basic constructions
  - Diagonal ply
  - Belted Bias
  - Radial ply

Molding

- Products include shoe soles and heals, gaskets and seals, suction cups, bottle stops, tires and foamed rubber parts.
- (1) compression molding (tire manufacture), (2) transfer molding, and (3) injection molding
- Curing (vulcanizing) is accomplished in the mold in all three processes
  - Vulcanization -Cross-linking of elastomer molecules to make stiffer and stronger while retaining extensibility.
  - First Goodyear invented vulcanization by sulfur at 140°C for about 5 hours in 1839.

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Tires

- Functions of vehicle tires:
  - Support the weight of the vehicle, passengers, and cargo
  - Transmit the motor torque
  - Absorb road vibrations and shock
- Automobiles, trucks, buses, farm tractors, earth moving equipment, military vehicles, bicycles, motorcycles, and aircraft
- A tire is an assembly of many parts about 50 to as many as 175 components
  - The internal structure, known as the carcass, consists of multiple layers of rubber coated cords, called plies
  - The cords are strands of nylon, polyester, fiber glass, or steel, which provide inextensibility to reinforce the rubber in the carcass

Tire Production Sequence

- Three steps:
  1. Preforming of components
  2. Building the carcass and adding rubber strips to form the sidewalls and treads
  3. Molding and curing the components into one integral piece
- Variations in processing depending on construction, tire size, and type of vehicle
Preforming of Components
• The carcass consists of a number of components produced by continuous processes and then pre-cut to size and shape for subsequent assembly

Building carcass

A machine known as a building drum with a cylindrical arbor that rotates.

Molding and Curing
Tire molding: (1) uncured tire is placed over expandable diaphragm; (2) mold is closed and diaphragm is expanded to force uncured rubber against mold cavity, impressing tread pattern into rubber; mold & diaphragm are heated to cure rubber

Other Rubber Products - Rubber Belts, Hose, Footwear
• Rubber belts
  – Widely used in conveyors and mechanical power transmission systems
  – Rubber belt must have little or no extensibility
    • Reinforced with polyester or nylon fibers
  – Fabrics of these polymers are usually coated by calendering, assembled together, and subsequently vulcanized by continuous or batch heating processes

Hose and Footwear
• Plain hose is extruded tubing
• Reinforced tube:
  – Inner tube - extruded of a rubber compounded for particular liquid that will flow through it
  – Reinforcement layer - applied to the inner tube as a fabric, or by spiraling, knitting, braiding
  – Outer layer – compounded for environmental conditions and applied by extrusion

Processing of Thermoplastic Elastomers (TPE)
• Processed like thermoplastics, but used like elastomer
• Shaping processes: injection molding and extrusion. More economical and faster than the traditional processes
• Molded products: shoe soles, athletic footwear, and automotive components such as fender extensions and corner panels
• Extruded items: insulation coating for electrical wire, tubing for medical applications, conveyor belts, sheet and film stock

Product Design Considerations
• Rubber parts can be produced by compression molding in quantities of 1000 or less
  – The mold cost is relatively low
• Injection molding requires higher production quantities due to more expensive mold
• Draft is usually unnecessary due to its flexibility to deform for removal from the mold
• Shallow undercuts, although undesirable, are possible