

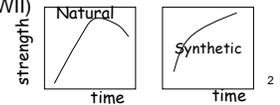
## RUBBER PROCESSING TECHNOLOGY

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

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### Introduction

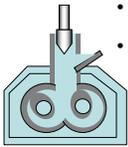
- Similar to the processing of plastics
- But the rubber industry is quite different from the plastics industry
- Dominated by one product: *tires*
- Technological breakthrough
  - Vulcanization (cross-linking) to transform weak natural rubber into a stronger material (1839).
  - The introduction of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



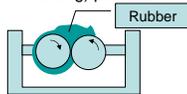
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### Rubber Processing and Shaping

- 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, calendaring, coating, molding and casting
    - Vulcanization – A curing (cross-linking) process developed by Goodyear



Internal mixer



Two-roll mill

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### 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.

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### 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.

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### 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

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## 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

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## Mixing

- To achieve uniform dispersion of ingredients
- Mechanical working increases its temperature up to  $150^\circ\text{C}$  ( $300^\circ\text{F}$ )
- 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

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## Shaping and Related Processes

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

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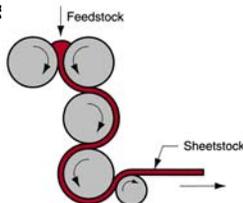
## Extrusion

- 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.

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## Calendering

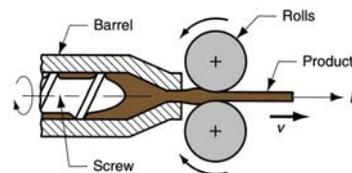
- Stock is passed through a series of gaps of decreasing size made by a stand of rotating rolls where final roll gap determines sheet thickness:



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## Roller Die Process

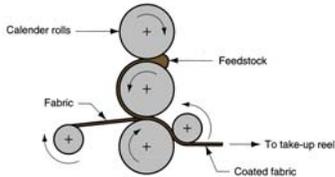
- Combination of extrusion and calendering for better quality product.



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### Coating or Impregnating Fabrics with Rubber

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



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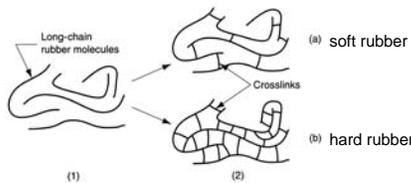
### Molding

- Products include shoe soles and heels, 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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### 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.



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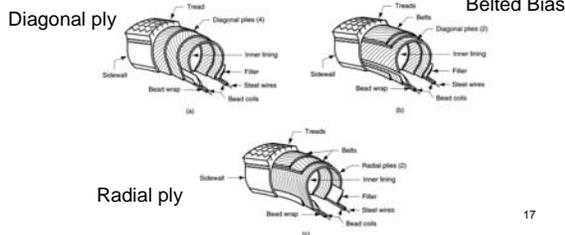
### Tires

- 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

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### 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



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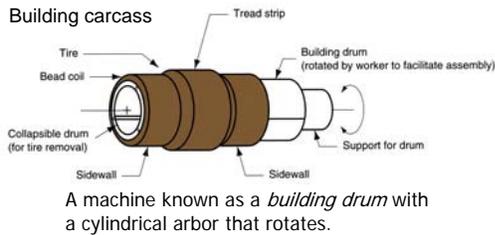
### Tire Production Sequence

- 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

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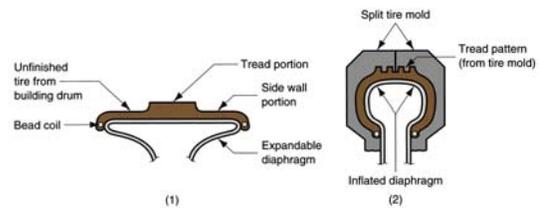
## Preforming of Components

- The carcass consists of a number of components produced by continuous processes and then pre-cut to size and shape for subsequent assembly



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## 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

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## 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 calendaring, assembled together, and subsequently vulcanized by continuous or batch heating processes

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## 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
- Soles, heels, rubber overshoes, and certain upper parts
- Molded parts by injection molding, compression molding, and special molding techniques developed by the shoe industry
- Both solid and foamed
- For low volume production, manual methods are used

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## 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

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## 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

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