How a Tire is Made

The tire manufacturing process might seem complicated – but we've made it easy to understand in this section.

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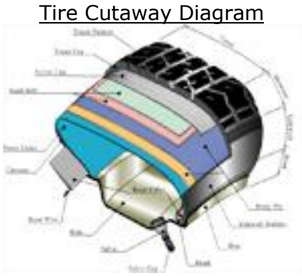
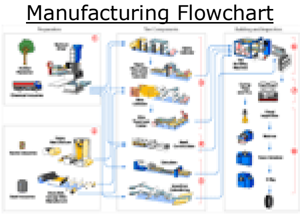
Tire Cutaway Diagram



Everyone knows what a tire is and what it's for, right? It's a black donut made of rubber, placed on a vehicle so the driver can transport himself and his cargo from point A to point B. The tire has to allow for easy steering, braking and cornering. It must provide for a comfortable, safe ride. It needs to be durable. And that's about the extent of what most of us know.

Actually, a tire is an advanced engineering product made of a lot more than rubber. Fiber, textile, and steel cord are just some of the components that go into the tire's innerliner, body plies, bead assembly, belts, sidewalls, and tread. As you can imagine, the manufacture of this complex product is, well, complex. It requires the latest technology, heavy equipment, precision instruments and—most importantly—qualified people.

Manufacturing Flowchart



Some of the activities that go on in the tire factory are the mixing of the rubber compound; preparation of the fabric cord, steel cord, and bead wire; "calendering" of the innerliner, steel belt and ply cord; extrusion, or shaping, of the tire's sidewall and tread; and the actual building, curing, and inspection of the tires. Read on for a more detailed explanation and refer to the manufacturing flowchart for a visual reference to each process.

Rubber Compound Mixing Operation

Refer to section 1 on the Manufacturing Flowchart.

- **Rubber compound formulation**
  The two major ingredients in a rubber compound are the rubber itself and the filler, combined in such a way as to achieve different objectives. Depending on the intended use of the tire, the objective may be to optimize performance, to maximize traction in both wet and dry conditions, or to achieve superior rolling resistance. The desired objective can be achieved through the careful selection of one or more types of rubber, along with the type and amount of filler to blend with the rubber.

  In general, there are four major rubbers used: natural rubber, styrene-butadiene rubber (SBR), polybutadiene rubber (BR), and butyl rubber (along with halogenated butyl rubber). The first three are primarily used as tread and sidewall compounds, while butyl rubber and halogenated butyl rubber are primarily used for the innerliner, or the inside portion that holds the compressed air inside the tire.

The most popular fillers are carbon black and silica, and there are several types of each. The selection depends on the performance requirements, as they are different for the tread, sidewall, and apex. Other ingredients also come into play to aid in the processing of the tire or to function as anti-oxidants, anti-ozonants, and anti-aging agents. In addition, the "cure package"—a combination of curatives and accelerators—is used to form the tire and give it its elasticity.

- **Rubber compound mixing**
  Once the compound is determined, the next challenge is how to mix it all together. The mixing operation is typically a batch operation, with each batch producing more than 200 kilograms of rubber compound in less than three to five minutes. The mixer is a sophisticated piece of heavy equipment with a mixing chamber that has rotors inside. Its main function is to break down the rubber bale, fillers, and chemicals and mix them with other ingredients.

  The sequence in which the ingredients are added is critical, as is the mixing temperature, which can rise as high as 160 - 170 degrees Celsius. If the temperature is too high, the compound can be damaged, so the mixing operation is typically accomplished in two stages. The curative package is normally added in the final stage of mixing, and the final mixing temperature cannot exceed 100-110 degrees Celsius or scorching may occur.

  Once the mixing is completed, the batch is dumped out of the mixer and sent through a series of machines to form it into a continuous sheet called a "slap." The slap is then transferred to other areas for bead wire assembly preparation, innerliner calendering, steel and/or fabric belt/ply cord calendering, tire sidewall extrusion, and tire tread extrusion.

Fabric/Steel Cord Preparation

Refer to section 2 on the Manufacturing Flowchart.
Because tires have to carry heavy loads, steel and fabric cords are used in the construction to reinforce the rubber compound and provide strength. Among those materials suitable for the tire application: cotton, rayon, polyester, steel, fiberglass, and aramid.

- **Fabric cord**

  Fabric cord quality is based on its strength, stretch, shrinkage, and elasticity. The yarn used is first twisted, and then two or more spools of yarn are twisted into a cord. Before shipping the cord to the tire factory, the manufacturer pre-treats the cord and applies an adhesive to promote good bonding with the rubber. The temperature, humidity, and tension control are critical before the fabric cords are calendered with rubber compound. For this reason, fabric cord is kept in a temperature-and-humidity-controlled room once it arrives at the factory.

- **Steel cord**

  Steel wire cord quality is based on tensile strength, elongation, and stiffness. It is manufactured from steel rod with high carbon content; and while the steel wires used have different configurations, all are brass-coated strands twisted together into cords. If the wire is used in a multi-ply tire rather than a belted tire, the fatigue performance will be important. If used in belted tires, then stiffness is of primary concern. Since the steel wire is brass coated, storage conditions are important to maintain the steel wire to rubber bonding properties. Therefore, the steel wires are also kept in a temperature and humidity controlled room once they arrive at the factory.

Belt and Ply Calendering

Refer to section 3 on the Manufacturing Flowchart.

To produce fabric or steel belts, the fabric or steel cord must go through a calendering process—an operation in which the rubber compound is pressed on and into cords. Because the bonding of fabric to rubber or steel to rubber is critical to performance, the calendering process is an important step.

The calender is a heavy-duty machine equipped with three or more chrome-plated steel rolls which revolve in opposite directions. The roller temperature is controlled via steam and water. In this process, the rubber compound is applied to the cords.

First, a pre-set number of fabric or steel cords under proper tension are continuously pressed through two steel rollers, and rubber compound is added to the opening area between the rollers. Then the rubber compound is pressed into, on top of and on the bottom of the fabric or steel cords. A continuous sheet of cord-rubber composite goes through several more rollers to ensure good penetration and bonding between the rubber and cords. Quality is measured by the thickness of the sheet, spacing between cords, the number of cords and the penetration of rubber into the composite sheet. The composite sheet is then cut into appropriate sizes, shapes, and angles depending on the desired contour of the tire.

Innerliner Calendering

The innerliner is just what it sounds like -- the inner-most layer of the tire. Its main functions are to retain the compressed air inside the tire and maintain tire pressure. Due to its low air permeability, butyl rubber—or halogenated butyl rubber compound—is the primary rubber compound used. Because this is a thin layer, it is also produced using the calender. The gauge control and no-defect surface finish are critical to retaining air pressure. Innerliner calendering is also a continuous operation. The proper length of innerliner sheet is pre-cut to be ready for the tire building process.

Bead Component Preparation

Refer to section 4 on the Manufacturing Flowchart.

The bead component of the tire is a non-extensible composite loop that anchors the body plies and locks the tire onto the wheel assembly so that it will not slip or rock the rim. The tire bead component includes the steel wire loop, apex or bead filler; the chafer, which protects the wire bead components; the chipper, which protects the lower sidewall; and the flipper, which helps hold the bead in place. The bead wire loop is made from a continuous steel wire covered by rubber and wound around with several continuous loops. The bead filler is made from a very hard rubber compound, which is extruded so as to form a wedge. The bead wire loop and bead filler are assembled on a sophisticated machine.

The precision of the bead circumference is critical. If too small, tire mounting can be a problem; but if too loose, the tire can come off the rim too easily under loading and cornering conditions. After the circumference is checked, the bead component is ready for the tire building operation.

Tire Tread and Sidewall Extrusion Operations

Tire components such as tread, sidewall, and apex are prepared by forcing uncured rubber compound through an extruder to shape the tire tread or sidewall profiles. Extrusion is one of the most important operations in the tire manufacturing process because it processes most of the rubber compounds produced from the mixing operation and then prepares various components for the ultimate tire building operation.

The extruder in a tire manufacturing process is a screw-type system, consisting primarily of an extruder barrel and extruder head. First, the rubber compound is fed into the extruder barrel where it goes through a heating, blending, and pressurizing process. Then, the rubber compound flows to the extruder head where it is shaped under pressure. The modern cold-feed extruder is computer-controlled for accuracy.

Tire Tread Extrusion

Refer to section 5 on the Manufacturing Flowchart.
Tire tread, or the portion of the tire that comes in contact with the road, consists of tread itself, tread shoulder, and tread base. Since there are at least three different rubber compounds used in forming this complex tread profile, the extruder system consists of three different extruders sharing an extruder head. Three rubber compounds are extruded simultaneously from different extruders and are then merged into a shared extruder head. The next move is to a die plate where the shape and dimensions

are formed, and then through a long cooling line—from 100 to 200 feet long—to further control and stabilize the dimensions. At the end of the line, the tread is cut according to a specific length and weight for the tire being built.

Tire Sidewall Extrusion

The tire sidewall is extruded in a way similar to the tire tread component; however, its structure and the compound used are quite different from tread. Sometimes the sidewall extrusion process can be more complicated, and four extruders may be needed; for example, when building a tire with white sidewalls or with white lettering on the sidewalls.

Tire Building

Refer to section 6 on the Manufacturing Flowchart.

Finally, the tire is ready to be built by a highly robotized machine which ensures quality and efficiency. All components—bead assemblies, calendered plies, belts and innerliner, tread and sidewall sections—are assembled and the building process begins.

A typical radial tire is built on a flat drum in a two-stage process. In the first stage, the innerliner is wrapped around a drum and the first body ply is wrapped on top, followed by the second body ply. The bead assemblies are then positioned, and a bladder on the drum is inflated and pushed in from both ends of the drum, forcing the body plies to turn up to cover the bead assemblies. The sidewall sections then are pressed onto both sides.

In the second stage of the tire building process, another machine is used to apply the belts, nylon cap, and tread on top of the first stage. At this point, the tire still needs curing because there is no tread pattern on it.

Tire Curing

Refer to section 7 on the Manufacturing Flowchart.
In this final step, curing occurs through a series of chemical reactions. In addition, the sidewalls and tread are molded. Tire curing is a high-temperature and high-pressure batch operation in which the uncured tire is placed into a mold at a specified temperature. After the mold is closed, the rubber compound flows in to mold the shape and form the tread details and sidewall. The mold cannot be opened until the curing reaction is completed.

Tire Inspection

Refer to section 8 on the Manufacturing Flowchart.

Tire inspection is the last step in the tire manufacturing process—an important step in ensuring quality in both performance and safety. The tire inspection includes:

- Trimming of the mold flash and micro-vents
- Visual inspection for appearance and to spot obvious defects
- X-ray examination to check internal structure and to spot defects
- Tire durability, uniformity, and weight balance inspection

After a tire passes these rigorous inspections, it’s time for the rubber to meet the road! Our tire is ready to be put into service.