SAE Collegiate Design Series
Tires 101

Steve Lyman

Formula SAE Lead Design Judge

DaimlerChrysler Corporation

My Day Job

My Hobby

What is a Tire?

* A High Performance Composite Structure

* Provides a Diverse Range of Performance Qualities
  - Carry Load
  - Transmit Drive/Braking torque
  - Produce Cornering Force
  - Provide Steering response
  - Cushion Road Inputs
  - Dimensional Stability
  - Consume Minimum Power
  - Low Noise / Vibration
  - Tolerate Poor Maintenance
  - Durable and Safe Performance
  - Long Wear Life

* Complex Material Makeup
  - 8 to 10 Different Rubber Compounds
  - 2 to 3 Types of Steel
  - 3 to 4 types of Fabric

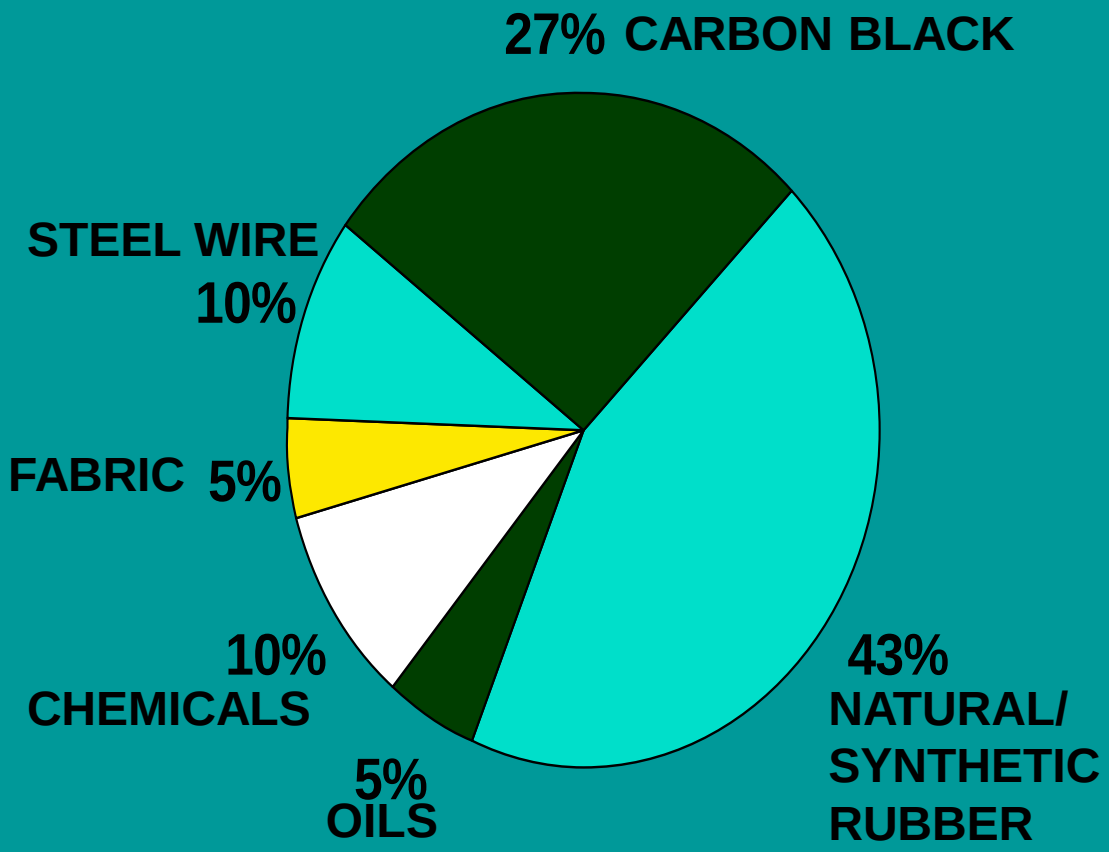
Tire Section Transparency and Door Prize Contest

Goodyear

Tire Performance Component Relation

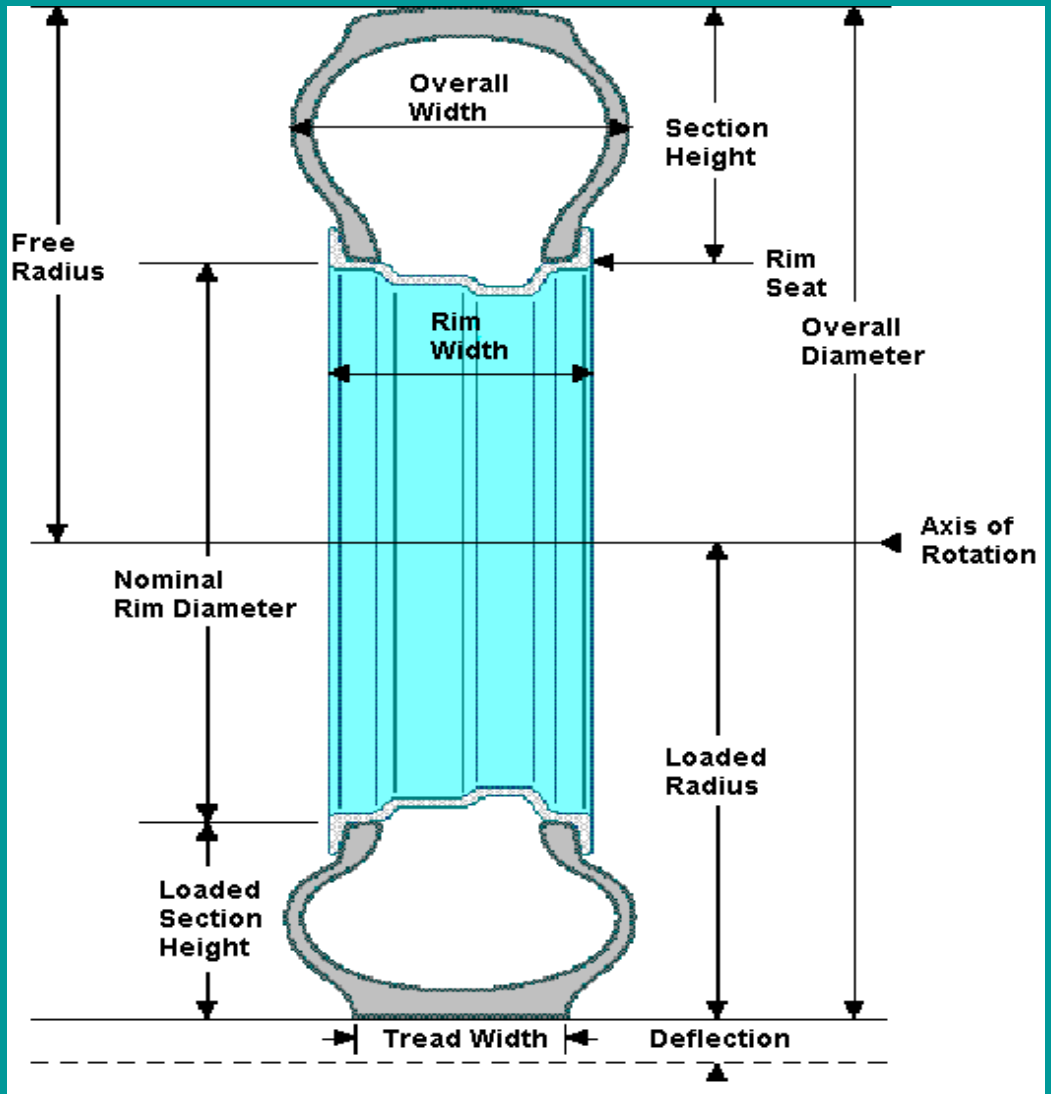
	LINER	PLY CARCASS	APEX	BELT SYSTEM	OVERLAY	TREAD	MOLD
TREADWEAR				X		X	X
NOISE	X	X	X		X	X	X
HANDLING		X	X	X	X	X	X
TRACTION						X	X
DURABILITY	X	X	X	X	X	X	X
ROLL RESIST	X		X	X		X	X
RIDE COMFORT		X	X	X	X	X	
HIGH SPEED		X	X	X	X	X	X
AIR RETENTION	X						
MASS	X	X	X	X	X	X	X

Materials of a Passenger Car Tire



Terminology

- Tire cross section illustrates terms used in discussing tires.



Terminology

Aspect Ratio: Section height ÷ Section width x 100

Deflection: Free radius minus loaded radius

Free Radius: Radius of the tire/wheel assembly that is not deflected under the load

Loaded Radius: Distance from axis of rotation to supporting surface at a given load and stated inflation pressure

Loaded Section Height: The loaded radius minus half of the nominal rim diameter. Distance from rim seat to outer tread surface of a loaded tire.

Nominal Rim Diameter: Diameter of rim seat supporting the tire bead. (Examples: 13″, 15″ and 16.5″)

Overall Diameter: The diameter of the inflated tire without any load.

Overall Width: Maximum width in cross-section of unloaded tire including protruding side ribs and decorations.

Revolutions Per Mile: Measured number of revolutions for a tire traveling one mile. This can vary with load and inflation.

Rim Width: Linear distance between rim flanges in contact with the tire.

Rolling Circumference: The linear distance traveled by a tire in one revolution. This can vary with load and inflation. Rolling circumference can be calculated as:

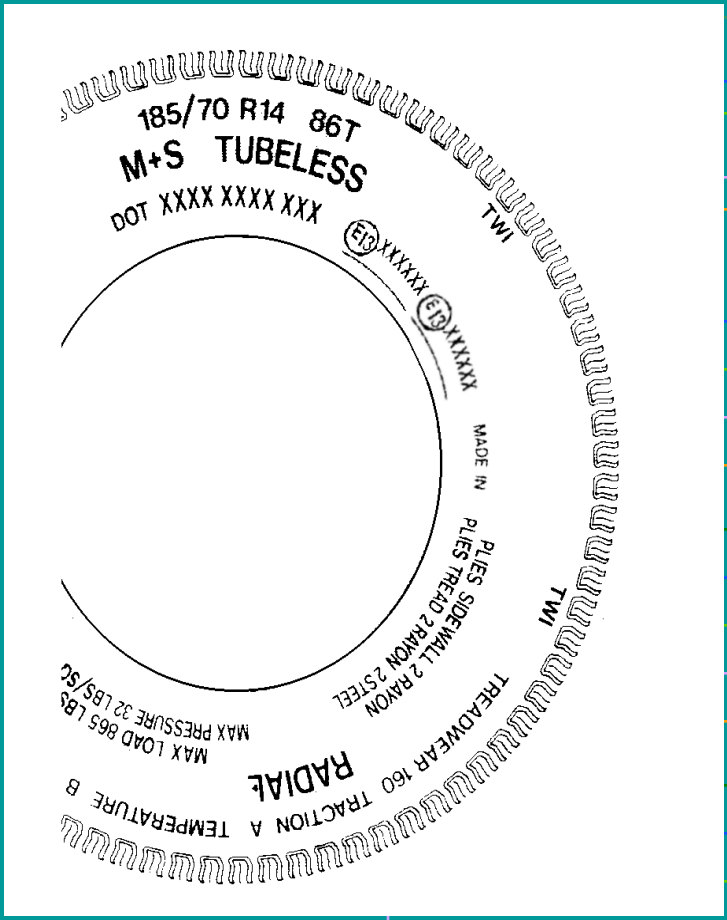
63,360 ÷ RPM = Rolling Circumference in inches

Section Height: Distance from rim seat to outer tread surface of unloaded tire.

Section Width: Linear distance between the outside sidewalls of an inflated tire without any load (exclusive of protruding side ribs and decorations).

Tread Width: The portion of the tread design which comes in contact with the road.

Illustration of Typical Tire Markings



1. Tire section width in mm.
2. Section height to section width relation in %.
3. Tire construction (R= Radial).
4. Rim diameter in inches.
5. Maximum load capacity (load index).
6. Speed symbol.
7. TUBELESS Tire.
8. ECE High Speed/Noise type approval mark and number.
9. Location of treadwear Indicator.
10. M&S (Mud & Snow) Winter capabilities.
11. Production date (week, year, : decade 1990-1999).
12. Department of Transportation compliance symbol.
13. D.O.T. manufacturer code.
14. Country of manufacture.
15. Trade name.
16. Tire construction details (D.O.T.).
17. Load and pressure marking (D.O.T.).
18. Tire type (radial).
19. Mark required by U.S.A. Consumer information regulations

How Are Tires Developed?

- Tire development is an iterative process.
- Tires affect many aspects of vehicle performance (comfort, fuel economy, braking, durability, etc.).
- Seek the best compromise of conflicting requirements (i.e. cost, rolling resistance, handling, ride, steering, noise, wet traction, wear, etc.).
- Tire development is art and science, even with the best modeling and analysis tools.

Tire Development Process
DC Street & Racing Technology

- Set Functional Objectives for Vehicle
- Match Performance Goals of Tire to Vehicle
- Input Tire Architecture into Suspension Model
- Optimize Suspension Geometry and Chassis Tuning to Exploit Tire Mechanical Properties
- Build tires, typically 3-4 constructions
- Joint test between SRT and tire supplier
- Usually 2-3 iterations
- Select/release best compromise constructions to meet functional objectives

Typical Test Venues-SRT

- 4 post shaker- DC Vehicle Dynamics Lab
- DC Proving Grounds
  - Skid Pad
  - Handling Road
  - Ride Roads
  - High Speed Oval
- Michigan Upper Peninsula (winter)
- Racetracks- OH, IL, TX, IN, MI,AZ, SC,VA
- Oscoda Wurtsmith Airport- Michigan
- Local public roads- ride/steering

Tire Slip Angle Tranparency

Tire Coefficient of Friction Transparencies

Tire Friction or Traction Circle Transparency

Understeer/Oversteer Tire Slip AngleTranparencies

- Neutral steer
- Oversteer
- Understeer
- There’s more to it than “loose” and “tight”

Care and Feeding of Tires

- Record track,ambient,tread (I-C-O) temps for each test and beginning and end of test
- Keep track of number of heat cycles on each tire, measure change in rubber hardness with durometer gage (Shore A)
- Record tire pressures at beginning and end of test
- Note alignment settings and corner weights with driver
- Record tread wear observations
- Record lap times, g’s, speeds, driver comments for each construction

Advice for Productive Testing

- Don’t make more than one change at a time-at least in related areas
- Don’t evaluate chassis performance on cold or worn out tires
- Don’t evaluate chassis performance until you have established good throttle response
- Don’t make miniscule changes until you are close to optimum performance- 1 click on dampers, for example
- Don’t be afraid to try big changes—you can always go back to the previous iteration
- Don’t trust subjective judgments or lap times. Take corner and straight segment times to find out where you are gaining and losing time
- Don’t make or accept excuses—”we’re a second, but we have our weak motor in the car or if we had new tires or if the sun wasn’t in the driver’s eyes….”
- Don’t work with a physically or mentally exhausted driver
- Testing is expensive. Be prepared, have a test plan in advance