Material Selection Guide for Rubber Covered Rollers

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Introduction

Why cover metal cores with rubber anyway?

Rubber, as a broad class of materials, has an impressive range of important properties, unmatched by other kinds of substances. It can be strong and chemically resistant, hard or soft, springy or damping, slick or grabby, and used for many differing applications. Over time many different types of rubber have been developed with varying chemistry to cover this wide range of requirements. In formulating a rubber compound for a specific application there are a number of compromises that must be made. Most times this is due to economics or a particular service condition that must be met. Optimizing for one property often degrades one or more other properties. To achieve overall acceptable performance, it almost always requires the balancing of several properties.

Where and why are rubber covered rollers used? Very small selections of generic uses with their corresponding important properties are given below.

Use	Properties
Transfer / Carrying Rollers	
Guiding / Centering	Abrasion
Idling	Coefficient of Friction
Feeding	Non-marking
Accumulating	
Drive / Laminating Rollers	
Nip	Abrasion
Pinch	Compression Set
Pull	Heat Build Up
	Toughness
	Release Properties
Application / Dispensing Rollers	
Coating	Chemical Resistance
Inking	Surface Finish
Metering	
Squeegee Rollers	
Squeegee	Chemical Resistance
Wringer	Abrasion
Wiper	
Energy Absorbing Rollers	
Impression	Toughness
Backup	Cut and Abrasion Resistance
Anvil / Scoring	Heat Build Up
Conducting / Insulating	

Physical Properties

- **Strength**
- **Hardness**
- **Abrasion Resistance**
- **Fluid Resistance**
- **Resilience**
- **Coefficient of Friction**
- **Release Properties**
- **Insulative / Conductive Properties**

Strength

Strength can be measured in a couple of ways. Most typically we talk about ultimate tensile strength which is the force (per unit area) required to break a material, usually reported in psi. A "dumbbell" shaped specimen is pulled until it breaks. The required breaking force is measured, and that force is divided by the cross-sectional area of the specimen to obtain the tensile value. When reporting tensile, we usually also report an ultimate elongation at break, in percent. Modulus is the force required to stretch material a certain percent elongation. This is typically reported at 100 and 300 % elongation usually in psi.

Tensile Strength **is the force (per unit area) required to break a material, usually in psi.**
Elongation **is the amount the material can be stretched before breaking, measured in percent (of its original length).**
Modulus **is the force required to stretch a material to a specified elongation, usually reported as 100 and/or 300% Modulus values, in psi.**
Tear Strength **is the force (per unit thickness) required to cause a tear to form, usually in ppi.**

Tensile values can range upwards of 4,000 psi (Natural Rubber, Urethane), but are usually less because of compromises to meet other requirements such as cost, hardness, etc. Useful roller compounds with tensile values of 1000 to 1250 psi can easily be found. Most very soft durometer compounds will have even lower tensile, as low as 500 psi.

Hardness

Probably the most common physical property that we need to determine in order to make a proper roller is hardness. Hardness is a measure of how easily or with what difficulty a material can be deformed. It is rubber's ability to deform and recover that allows materials to be handled or conveyed without damage and rollers to function without destroying themselves. By varying the hardness one can adjust the amount of "cushion" or "squeeze" exerted by the roller on the material. The hardness of the cover (along with pressure) also determines nip width. Softer materials and/or higher pressures will form a wider nip than harder ones at low pressure will. Softer materials will generate more heat from constant deformation than will harder materials.

***Hardness* is a measure of how easily or difficultly a material can be deformed.**

There are three different scales that are commonly used to measure hardness in the roller market, Shore A (most common), Shore D (used in harder materials), and P & J. An approximate comparison is shown below:

Scale	V. Hard --------->		Medium	---------> Soft
Shore A	100	75	50	25 0
Shore D	75	25		
P & J Plastometer	1	50	120	300

A *Durometer* or *Plastometer* is an instrument used to measure hardness in rubber.

The application generally determines what hardness should be used.

Durometer		Typical Market(s)
Very soft	less than 20 A	- Graphic Arts & Specialty Applications
Soft	20 to 40 A	- Graphic Arts
Medium	40 to 60 A	- Industrial
Hard	60 to 90 A	- Industrial & Paper
Very hard	greater than 90 A	- Paper & Specialty Applications

The RMA specifies a typical tolerance of +/- 5 Shore A when measuring rubber. Some suppliers hold tighter tolerances of +/- 3 Shore A. To do so requires that both the supplier and the customer have correlated their results and measuring techniques and that the durometer is calibrated on a regular basis. When measuring hardness, there is a fair amount of inherent variation due to instrument and operator differences.

Abrasion Resistance

Abrasion can be thought of as tearing on a microscopic scale. Typically, volume loss due to abrasion or an abrasion index can be measured using one of the following instruments.

Tabor Abraser (ASTM D3389)	A rotary platform with weighted rotating grinding wheels that produce a scuffing action. Results are most often reported as volume loss.
Pico (ASTM D2228)	Tungsten carbide knives are lowered onto rotating specimen. The result is reported as an index (compared to a standard).
NBS (ASTM D1630)	A rotating drum with sandpaper with a sample rotating underneath it. More often used in footwear industry.

Fluid Resistance

The number of materials that rollers can come in contact with is almost infinite. Many of these substances, especially fluids, will have to some degree a detrimental effect on the rubber covering. The temperature and concentration of the fluid are major influences on the roller's performance. Oils and solvents are the usual culprits. The effect is hardening (with shrinkage), softening (with swell), or in extreme cases, even dissolving. Swelling is caused by the fluid being absorbed into the polymer matrix causing an increase in volume, softening, and a loss in physical properties. Hardening is caused by the fluid leaching plasticizer out of the rubber, with the resultant material being harder and brittle. Maintaining dimensional and hardness stability is vital for a roller to perform properly. This makes fluid resistance one of the more important properties.

Resilience

When vulcanized rubber is deformed, its elastic nature causes it to want to return to its original shape. Resilience is a measure of how well the material recovers from deformation. How quickly and completely the recovery occurs is very dependent on the state of cure, the polymer type, degree of deformation, and to some extent, filler and plasticizer loading.

***Resilience* is a measure of how well the rubber compound recovers from deformation.**

One simple method to measure this is by percent rebound. Rubber compounds exist with very high rebounds (Natural Rubber). These are typically used where low heat-build-up is a priority. Others have very low rebound (Butyl) and they are used when dampening is more important. By proper polymer selection and compounding, a wide range of rebounds can be formulated.

Even a very resilient compound, when it is deformed, is not "efficient" enough to completely recover to 100% of its original form. **Most** of the energy that it took to make the deformation is given back to "push" the deforming object away, but some percentage is retained in the rubber and is released inside the rubber in the form of heat energy. Low resilience compounds can show dramatic increases in temperature because of the heat generated from constant flexing. This is especially important as speeds and the size of the deformation increase. If the roller can give up this heat to its environment as either radiant or conducted heat, the operating temperature does not increase. If the heat is generated faster than it is removed from the roller then the temperature will increase. Higher temperatures are a bad thing. Most materials, including rubber, expand as they are heated. The increase in diameter leads to higher operating pressures and constantly increasing temperature. This can in extreme cases continue until blowout occurs.

One instrument for measuring rebound is the *Bashore Resiliometer*.

Coefficient of Friction

The coefficient of friction can be very important in feed and drive situations. This is basically the amount of grab or slip that the surface of the roller has. Hardness can have a definite influence. Harder compounds are generally slicker than softer ones. Filler and plasticizer type and loading will also have an effect. Surface finish is very important as well.

Release Properties

The release properties of a roller generally refer to how well materials such as molten plastic, hot melt adhesive, varnish or ink transfer from the roll, or as to how well a particular substrate releases from the roll. This is obviously important when coating or laminating.

Insulative / Conductive Properties

Rubber is usually considered to be a good insulator of both electricity and heat, but it can be specially formulated to conduct electricity reasonably well or to conduct heat fairly well. Electrical properties are broken down into three groups, insulating, antistatic (somewhat conductive), and conductive.

What environment is the roller expected to see?

- Environmental conditions
  - Chemicals (Solvents, Water, Acids, Bases, Ozone, etc...)
  - Temperature (High, Low, Ambient)
  - Weather
  - Abrasion
- Running Conditions
  - Nip Pressure
  - Speed

Any customer supplied specifications?

Polymer types	ASTM Designation
General Purpose	
Natural Rubber	NR
Polyisoprene	IR
Styrene Butadiene Rubber	SBR
Polybutadiene Rubber	BR
Ethylene Propylene Rubber	EPDM
Butyl	IIR
Oil Resistant	
Butadiene Acrylonitrile (Nitrile)	NBR
Nitrile / PVC blend	NBR / PVC
Polychloroprene (Neoprene)	CR
Chlorosulfonated Polyethylene (Hypalon®)	CSM
Urethane (Millable)	AU, EU
Epichlorhydrin	CO, ECO
Specialty	
Silicone	SI
Polysulfide	T
Fluoroelastomer	FMK
Polyacrylate	ACM

Butadiene Acrylonitrile NBR

Common names: NBR, Nitrile, Buna-N

Key Properties: Fuel and oil resistant w/ good balance of other important properties.

Hardness Range: 20 to 100 Shore A
Service Temperature: -70F to 300F

Generally Resistant to: Aliphatic and aromatic hydrocarbons, mineral and vegetable oils, animal fats and oils, non-polar solvents.

Conditions to Avoid: Halogenated or oxygenated solvents, outdoor exposure, and ozone.

Good	Bad
Abrasion	Ozone resistance
Resistance to set	
Dynamic properties	
Low water absorption	

Specialty Types

NBR / PVC

A mechanical blend of NBR with PVC that, compared to regular NBR yields considerable improvement in abrasion resistance, vastly improved ozone / weather resistance, and improved resistance to aliphatic hydrocarbons.

XNBR

Carboxylated nitrile, an NBR modified with carboxylic acid during manufacture of the raw polymer. The improvement makes it superior to standard NBR in abrasion and chemical resistance, but makes it somewhat more difficult to process.

HNBR

Hydrogenated nitrile is also a modified NBR. This is one of the more expensive polymers commonly used in rollers. It was designed to compete with polyurethane and easily surpasses regular NBR. It possesses excellent mechanical and dynamic properties, has excellent oil & fuel resistance, and its properties change very little at elevated temperatures. Its improved abrasion results in a very long lasting, durable roller. This helps to offset higher costs due to less equipment downtime.

Ethylene Propylene Diene Rubber EPDM

Common name: EPDM

Key Properties: Extremely resistant to ozone attack, weather, and water.

Hardness Range: 20 to 100 Shore A
Service Temperature: -75 to 400F

Generally Resistant to: Alcohols, esters, acids, alkalis, ketones, hydraulic fluid, and antifreeze.

Conditions to Avoid: Oil, grease, and hydrocarbon solvents.

EPDM's chemical backbone is completely saturated leaving no sites for reaction or attack. This is why it is so resistant to oxidative attack from ozone, UV light, heat, and weather.

Good	Bad
Mechanical properties	Fatigue resistance
Abrasion resistance	
Heat resistance	
Ozone resistance	

Polychloroprene CR

Common trade names:	Neoprene
Key Properties:	Fuel and oil resistant w/ good balance of other important properties.
Hardness Range:	20 to 100 Shore A
Service Temperature:	-80F to 275F
Generally Resistant to:	Oil, alkalis, acids, water, salts, sunlight, ozone, and weather.
Conditions to Avoid:	Aliphatic and aromatic hydrocarbons.

Once a workhorse for the industry, it has been eclipsed by other polymers, Hypalon for example, but still offers good balance of properties. It has excellent physical properties, tensile, toughness, abrasion resistance, flex properties, cut resistance, low compression set, and flame resistance.

Chlorosulfonated Polyethylene CPE

Common names:	Hypalon®
Key Properties:	Fuel and oil resistant w/ good balance of other important properties.
Hardness Range:	30 to 100 Shore A
Service Temperature:	-65F to 300F
Generally Resistant to:	Oils, aliphatic and aromatic hydrocarbons, sunlight, ozone, weather, alkalis, dilute mineral acids, inorganic salts.
Conditions to Avoid:	Halogenated or oxygenated solvents.

Hypalon is a multipurpose elastomer with well-balanced properties. It has excellent physical properties, toughness, abrasion resistance, flex properties, and flame resistance. It also has a saturated backbone, which gives it excellent weathering, and ozone resistance.

Styrene Butadiene Rubber SBR

Common names: SBR

Key Properties: Low cost w/ good abrasion.

Hardness Range: 30 to 100 Shore A
Service Temperature: -75F to 250F

Generally Resistant to: Water, alkalis, dilute mineral acids, inorganic salts, alcohols.

Conditions to Avoid: Oils, aliphatic and aromatic hydrocarbons, sunlight, ozone, weather halogenated or oxygenated solvents.

Good	Bad
Abrasion resistance	Weathering
Heat resistance	

Natural Rubber NR

Common names: Natural Rubber

Key Properties: Strength and abrasion resistant with low cost.

Hardness Range: 20 to 100 Shore A
Service Temperature: -75F to 200F

Generally Resistant to: Alkalis, acids, water, inorganic salts.

Conditions to Avoid: Oils, aliphatic, aromatic, halogenated or oxygenated solvents.

Good	Bad
Abrasion resistance	Weathering
Resilience	
Strength	

Millable Polyurethane AU / EU

Common names:	Polyurethane, Urethane
Key Properties:	Excellent abrasion resistance, ozone and weather resistance, outstanding resilience, and good heat aging.
Hardness Range:	30 to 100 Shore A
Service Temperature:	-65F to 250F
Generally Resistant to:	Oils, aliphatic, aromatic, or halogenated solvents, ozone, weather.
Conditions to Avoid:	Alkalis, acids, water.

Good

Abrasion
Low compression set
Outstanding dynamic properties
High mechanical strength

There are two basic chemistries used in millable polyurethane, polyether and polyester. The polyester type has better solvent, fuel and oil resistance, but has poor resistance to water attack. The polyether type has better water resistance, but is similar to NBR in its solvent, fuel and oil resistance. Because of the difference in water resistance, polyether types are more suited to curing in a steam autoclave. If attempting to cure the polyester type in steam it must be thoroughly sealed in Mylar to block out the moisture.

Silicone SI

Common names: Silicone

Key Properties: Temperature range, release properties, resilience, weather resistance

Hardness Range: 30 to 100 Shore A
Service Temperature: -175F to 600F

Generally Resistant to: Alkalis, acids, water, inorganic salts.

Conditions to Avoid: Oils, aliphatic, aromatic, halogenated or oxygenated solvents, concentrated sulfuric acid.

Good

Tensile at elevated temperatures
Elongation
Tear
Compression set
Resilience
Weathering, ozone resistance

Fluoroelastomer FKM

Common names: FKM, Viton®

Key Properties: Very hot or cold temperatures, extremely corrosive environments.

Hardness Range: 50 to 95 Shore A
Service Temperature: -70F to 650F

Generally Resistant to: Aliphatic and aromatic hydrocarbons, fuels, oils, weather, sunlight fungus, and mold.

Conditions to Avoid: Halogenated or Oxygenated Solvents.

Specializes in:

- Very hot up to 400+F (500F intermittent).
- Cold down to -10F (dynamic), very cold down to near absolute zero for static seal applications.
- Very corrosive environments, wider range of fluid resistance than any non-fluorinated elastomer.
- Exceptional compression set resistance, especially at elevated temperatures.
- Exceptional weather resistance.
- Flame resistant.

Avoid:

- Ketones (MEK), esters (ethyl acetate), and very polar solvents swell Viton.
- Strong bases (conc. sodium hydroxide) and amines harden Viton.

Very Expensive, commonly used where nothing else will work, hence the cost is justified.

Polysulfide T

Common names: Polysulfide, Thiokol

Key Properties: Specialty chemical and solvent resistance.
Used only where nothing else will work.

Hardness Range: 20 to 100 Shore A
Service Temperature: -50F to 250F

Generally Resistant to: Oils, aliphatic, aromatic, or oxygenated solvents, ozone, weather.

Conditions to Avoid: Alkalis, acids.

Polybutadiene PBD

Common names: Polybutadiene

Key Properties: Strength, low temperature, and abrasion resistant, often blended w/ NR or SBR.

Hardness Range: 45 to 95 Shore A
Service Temperature: -150F to 200F

Generally Resistant to: Alkalis, acids, water, inorganic salts.

Conditions to Avoid: Oils, aliphatic, aromatic, halogenated or oxygenated solvents.

Polybutadiene is often used in blends to improve low temperature properties, cut resistance or resilience of other polymers.

Epichlorohydrin CO / ECO

Common names: Hydrin®

Key Properties: Used only sparingly in rollers.
High temperature oil resistance.

Hardness Range: 20 to 100 Shore A
Service Temperature: -15F to 325F

Generally Resistant to: Oils, aliphatic, aromatic, or halogenated solvents, ozone.

Conditions to Avoid: Alkalis, acids.

Butyl IIR, Cl-IIR, Br-IIR

Common names: Butyl, Chlorobutyl, Bromobutyl

Key Properties: Used only sparingly in rollers.
Very heat stable, very low permeability, very low resilience.
Low permeability makes it difficult to build rollers without air pockets.

Hardness Range: 30 to 100 Shore A
Service Temperature: -75F to 300F

Generally Resistant to: Alkalis, acids, water, inorganic salts, ozone, weather

Conditions to Avoid: Oils, aliphatic, aromatic, halogenated or oxygenated solvents.

Polyacrylate ACM

Common names: Acrylic

Key Properties: Used only sparingly in rollers.
High temperature oil resistance.

Hardness Range: 30 to 100 Shore A
Service Temperature: -75F to 300F
Generally Resistant to: Oils, aliphatic and halogenated solvents.
Conditions to Avoid: Alkalis, acids, water, inorganic salts, oxygenated solvents.