Scrap Tires

Recycling

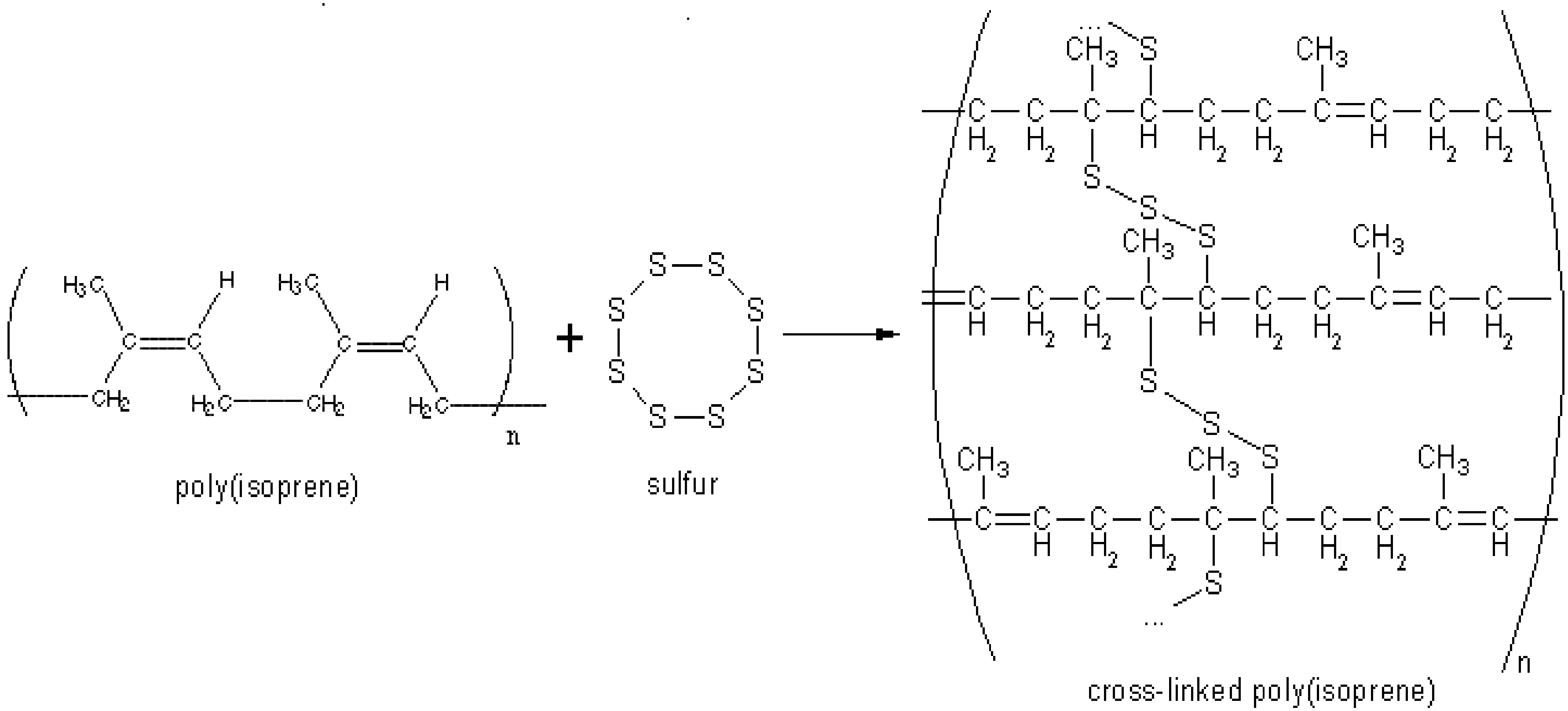
Introduction

- What materials go into the making of a tire?

- Rubber is the basic elastomer used in tire making
- Carbon Black, forms a high percentage of the rubber compound. This gives reinforcement and abrasion resistance.
- Silica, used together with carbon black in high performance tires, as a low heat build up reinforcement.
- Antioxidants prevent sidewall cracking, due to the action of sunlight.
- Textile fabric reinforces the carcass of the tire.

Introduction

- Sulfur cross-links the rubber molecules in the vulcanization process.



Disposal

- Scrap tires represents one of the most difficult recycling problems ever encountered.
- This is due to chemically cross-linked rubber molecules that neither melt nor dissolve.
- Also, scrap tires pile up in landfills, they can fill with water and provide a breeding ground for mosquitoes and rodents.
- There are approximately 2 billion scrap tires currently piled in U.S. landfills.
- The largest tire dump in the Northeast is located in Smithfield, R.I. It contains approximately 20-30 million scrap tires and is an EPA Superfund site.

Tire Derived Fuel

- Incineration of scrap tire rubber as a fuel source is currently the most widely used method of disposal.
- Tire derived fuel produces same amount of energy as oil and 25% more than coal.
- Ash residues from TDF contains lower heavy metal content than coal.
- However, combustion of tires leads to emission of volatile organic chemicals (VOCs) such as benzene, chloroform, 1,2-dichloroethane (DCE), and methylene chloride (MC).

How do we recycle scrap tires?

- Reclaimed rubber is ground into a fine powder and mixed with virgin unvulcanized rubber.
- The mixture is then vulcanized in order to restore its strength and elasticity.
- Subjecting this mixture to pressures of approximately 8.5 MPa pressure, and temperatures in the range of 200 degrees Celsius (400 degrees Fahrenheit), the powder sinters (heats & compacts below its m.p) together to form a solid rubber object.
- The resulting material typically retains 35-40% percent of the original strength and elasticity.

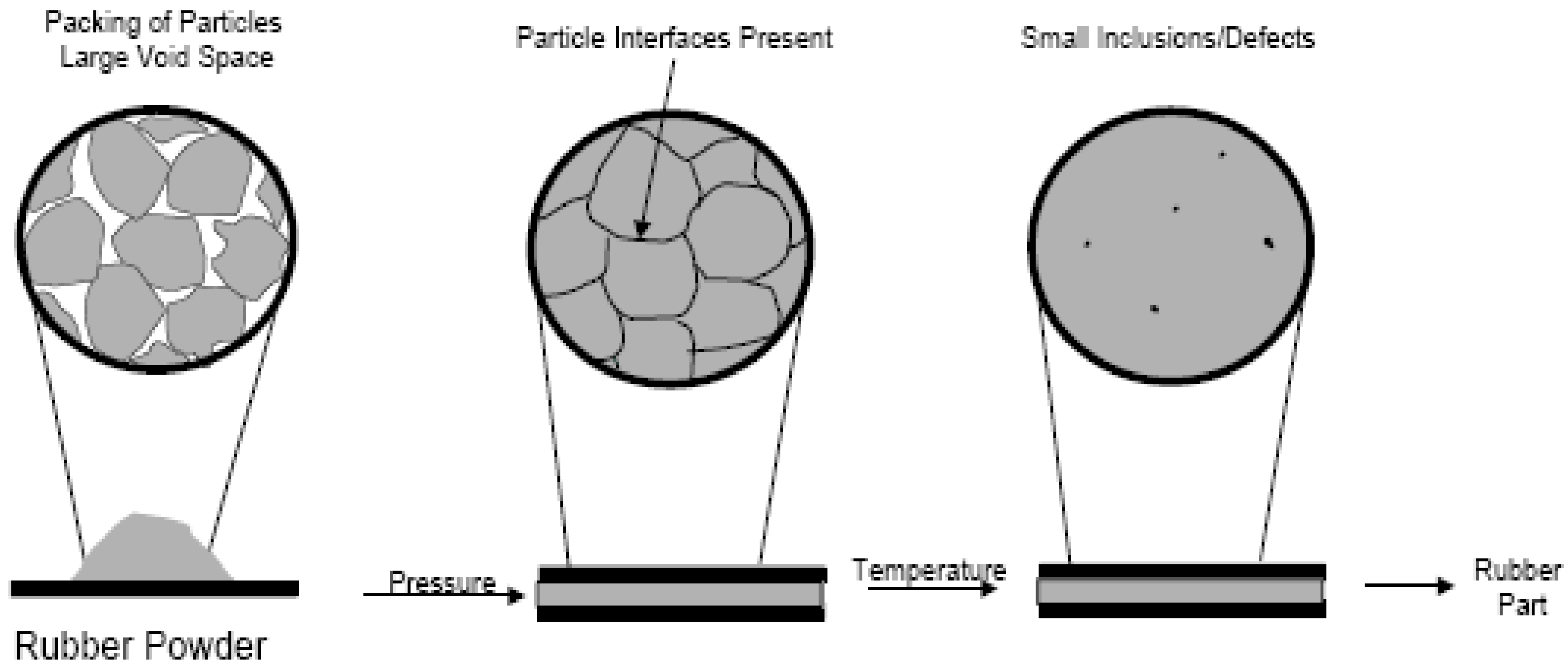


Figure 1, Schematic of a typical cycle for the technique of "High-Pressure High-Temperature Sintering"

Effect of Temperature

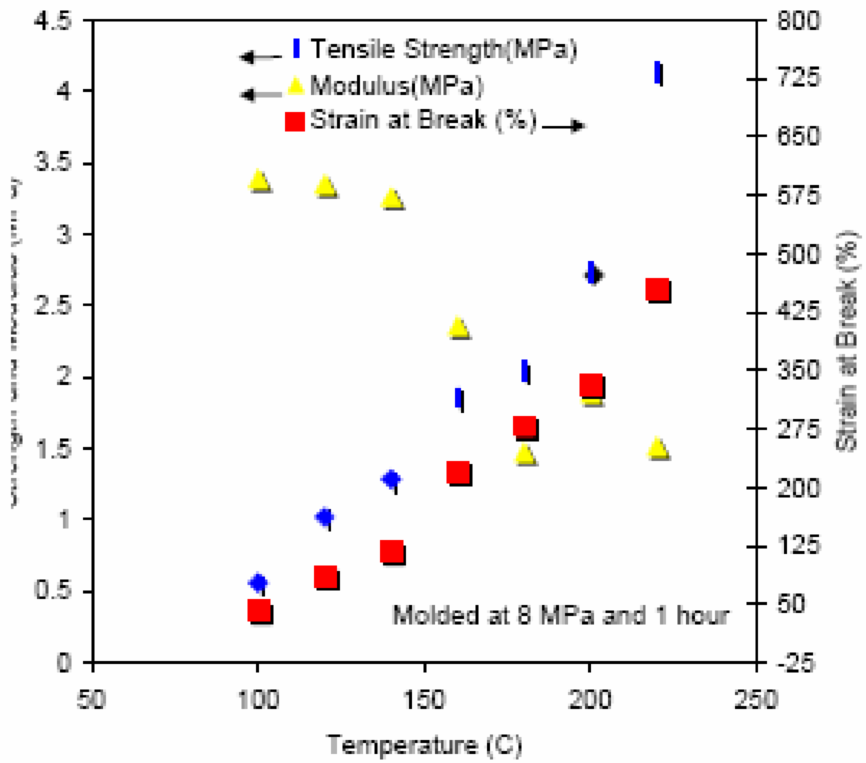
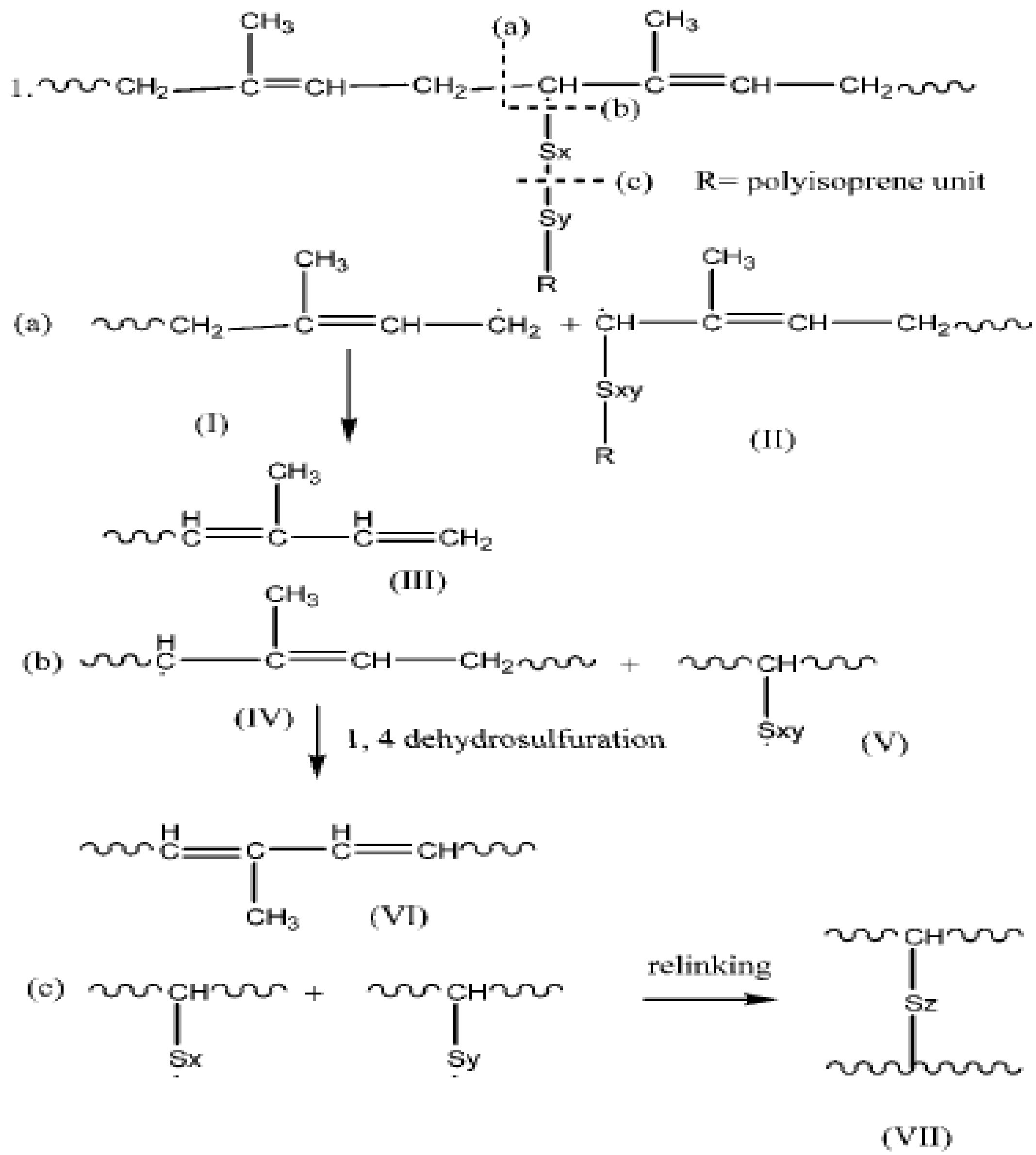


Figure 2, Effect of the Molding Temperature on the Mechanical Properties

- Below 80 degrees, this process does not work.
- Strain and strength increase with increasing temperature.
- Modulus shows more chemicals are ruptured than reformed at elevated temperatures.

Scheme 1. Breaking of Cross-Link on Heating[22]



Effect of Pressure

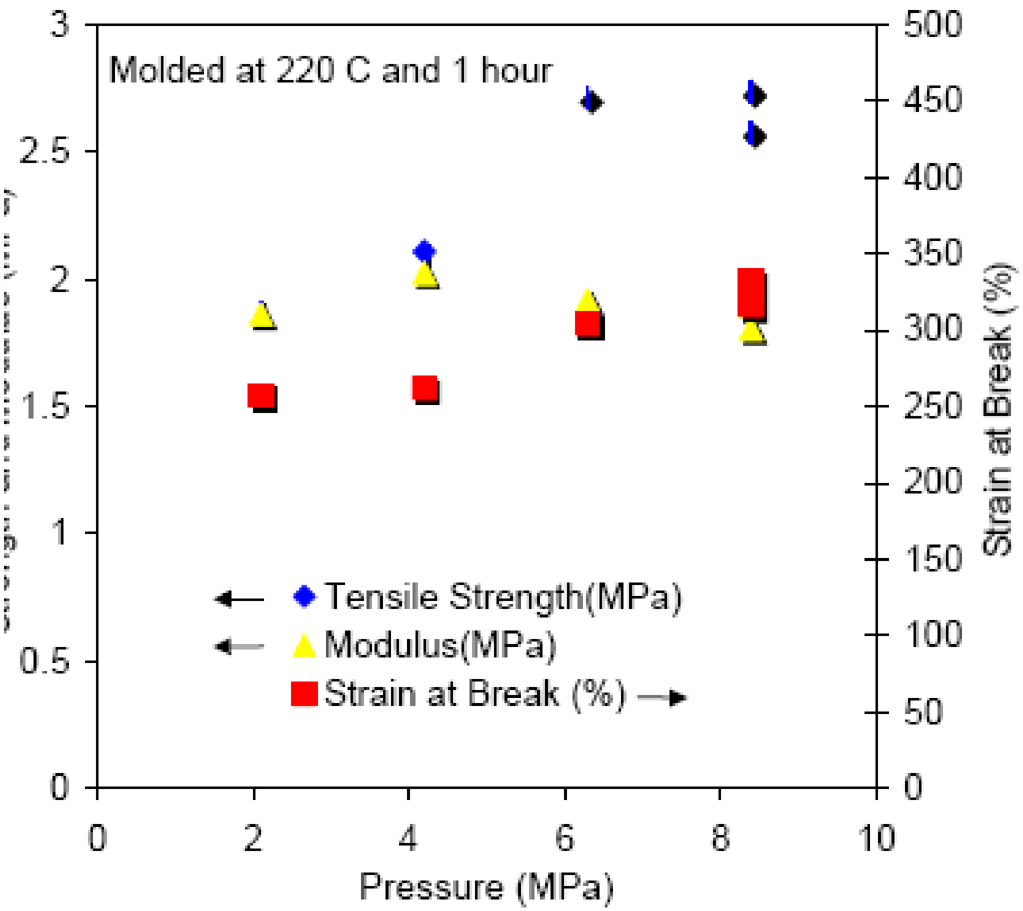


Figure 4, Effect of Molding Pressure on the Mechanical Properties

Effect of Particle size

Table 1 , Summary of Types of Rubber Powders Investigated

Name	Type Rubber	Mesh Size	Cross-link Type	Grinder
SBR-80	styrene-butadiene rubber	80	sulfur	Rouse Rubber Industries Inc
GF-80	Natural rubber/SBR	80	sulfur	Rouse Rubber Industries Inc
EPDM-80	ethylene proplyene diene rubber	80	sulfur	Rouse Rubber Industries Inc
FKM-150	flouroelastomer	150	amine/peroxide	Rouse Rubber Industries Inc
Si-140	silicone rubber	140		Rouse Rubber Industries Inc
Epoxy	expoxy	25	amine/peroxide	In House
Polybutadiene		25	peroxide	Spalding
PE	polyethylene	25	radiation cured	In House
Blends	50/50 FKM and GF			
Blends	33/33/33 FKM, GF, Silcone			

Effect of Particle Size

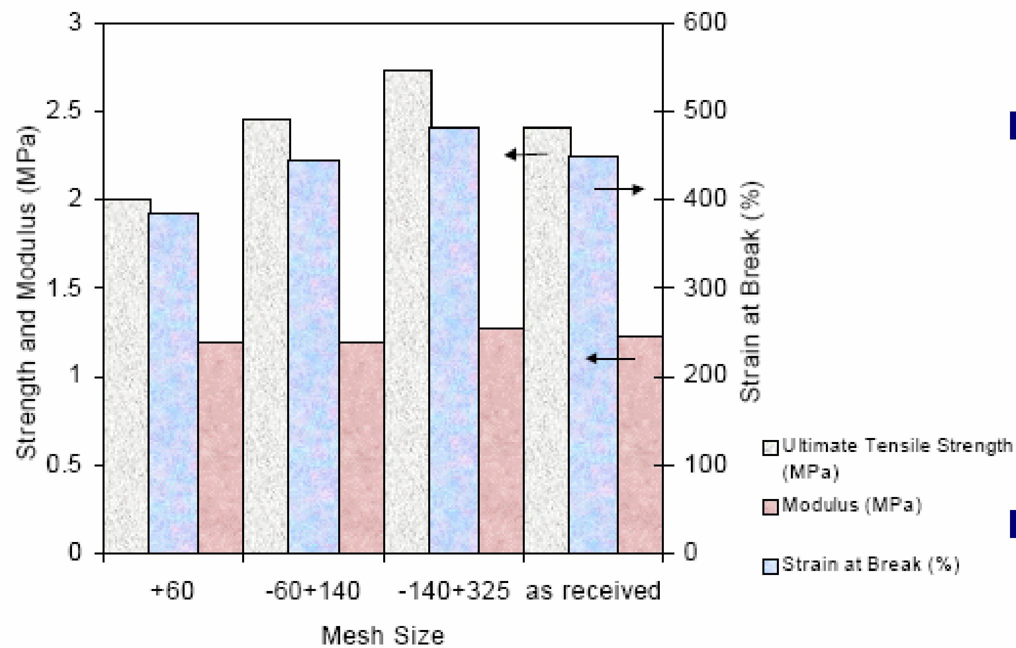


Figure 6, Effect of Particle Size on the Mechanical Properties

- As particle size decreases, there is an increase in both strength and strain at break.
- Modulus stays constant.

35 % recovery?

- Compounds such as benzoic acid, salicylic acid, phthalic acid, phthalic anhydride, phtalimide, maleic acid, and maleic anhydride were mixed with vulcanized natural rubber.
- Sintering followed
- Greater than 70% of the original properties of the vulcanized elastomer were recovered.

Cyclohexylbenzothiazole

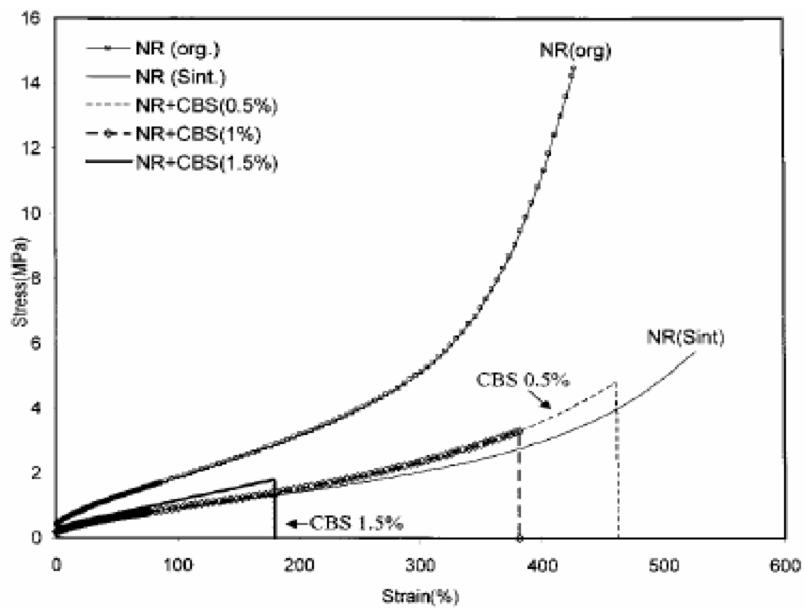


Figure 2. Stress–strain curve of sintered natural rubber powder with the addition of CBS.

- Promotes sulfur vulcanization
- Inferior mechanical properties

- Sulfur vulcanization is driven by alkaline media.
- Acids slow this process by reacting with rubber accelerators.

100% modulus with additives is the same as the sintered rubber, and both are lower than the starting rubber.

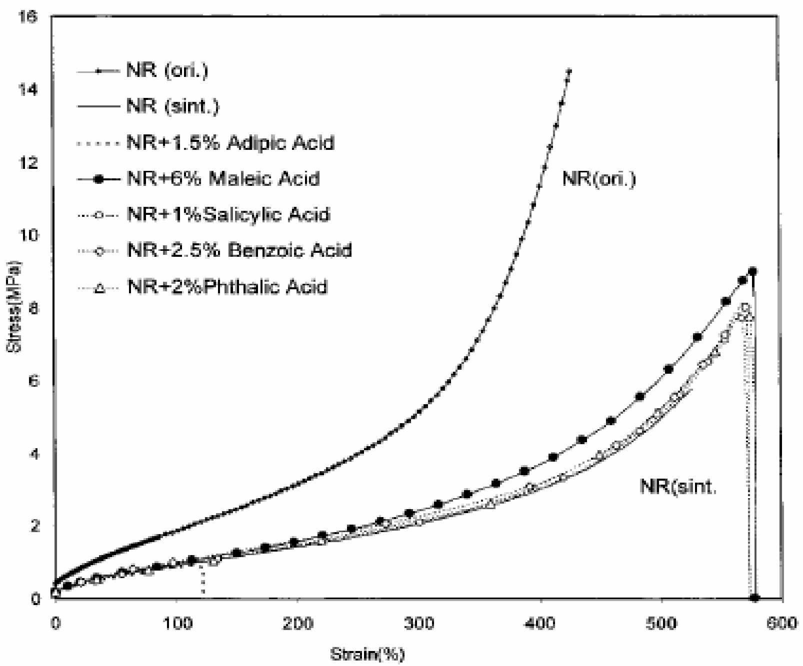


Figure 4. Stress−strain curve of sintered natural rubber powder with the addition of acids.

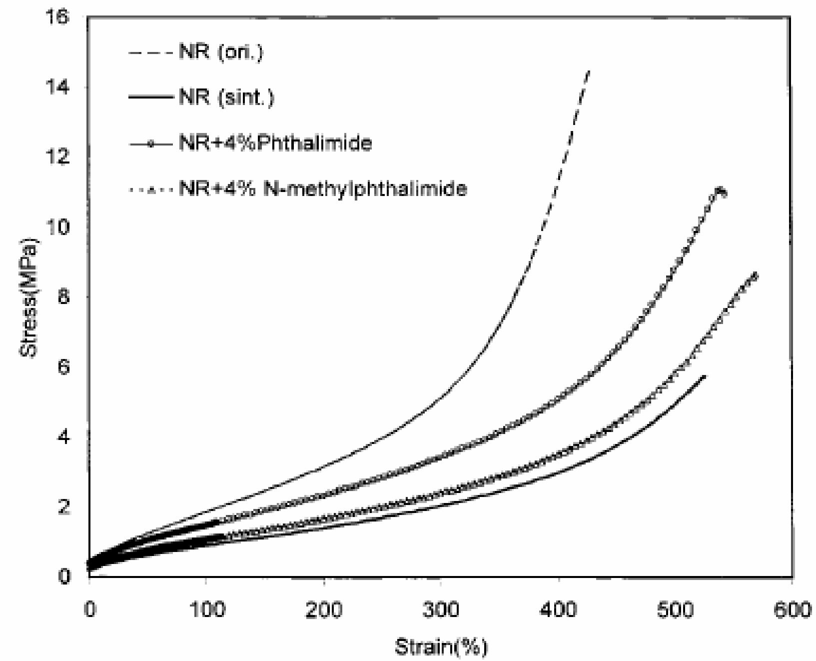
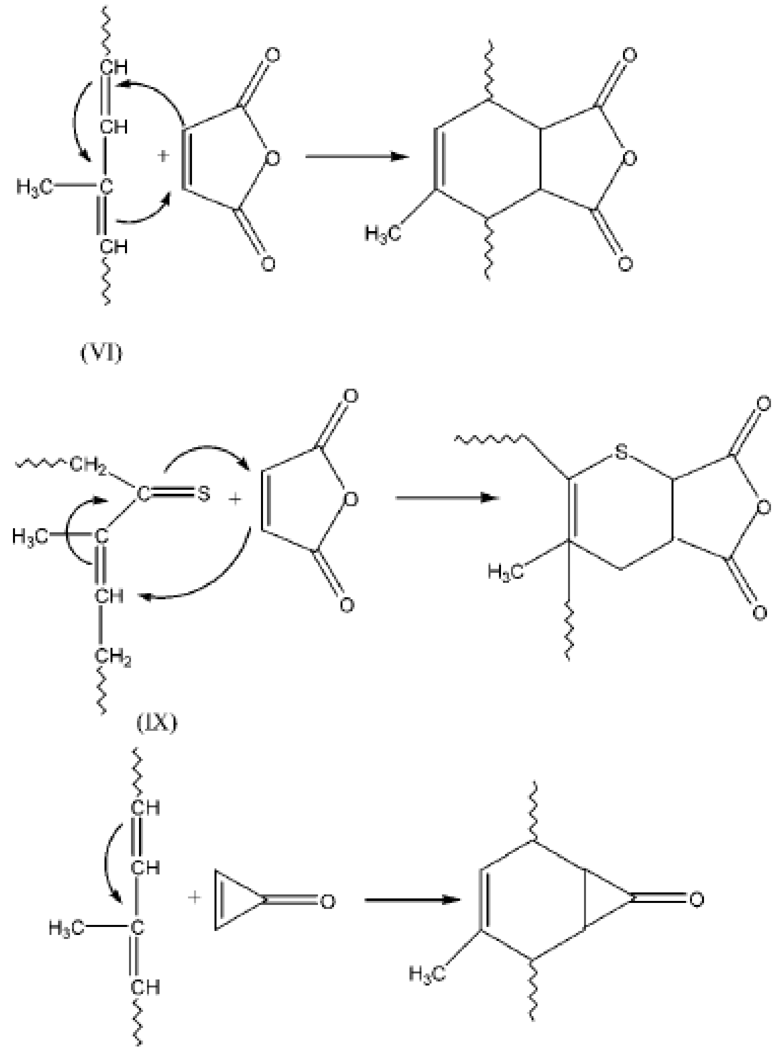
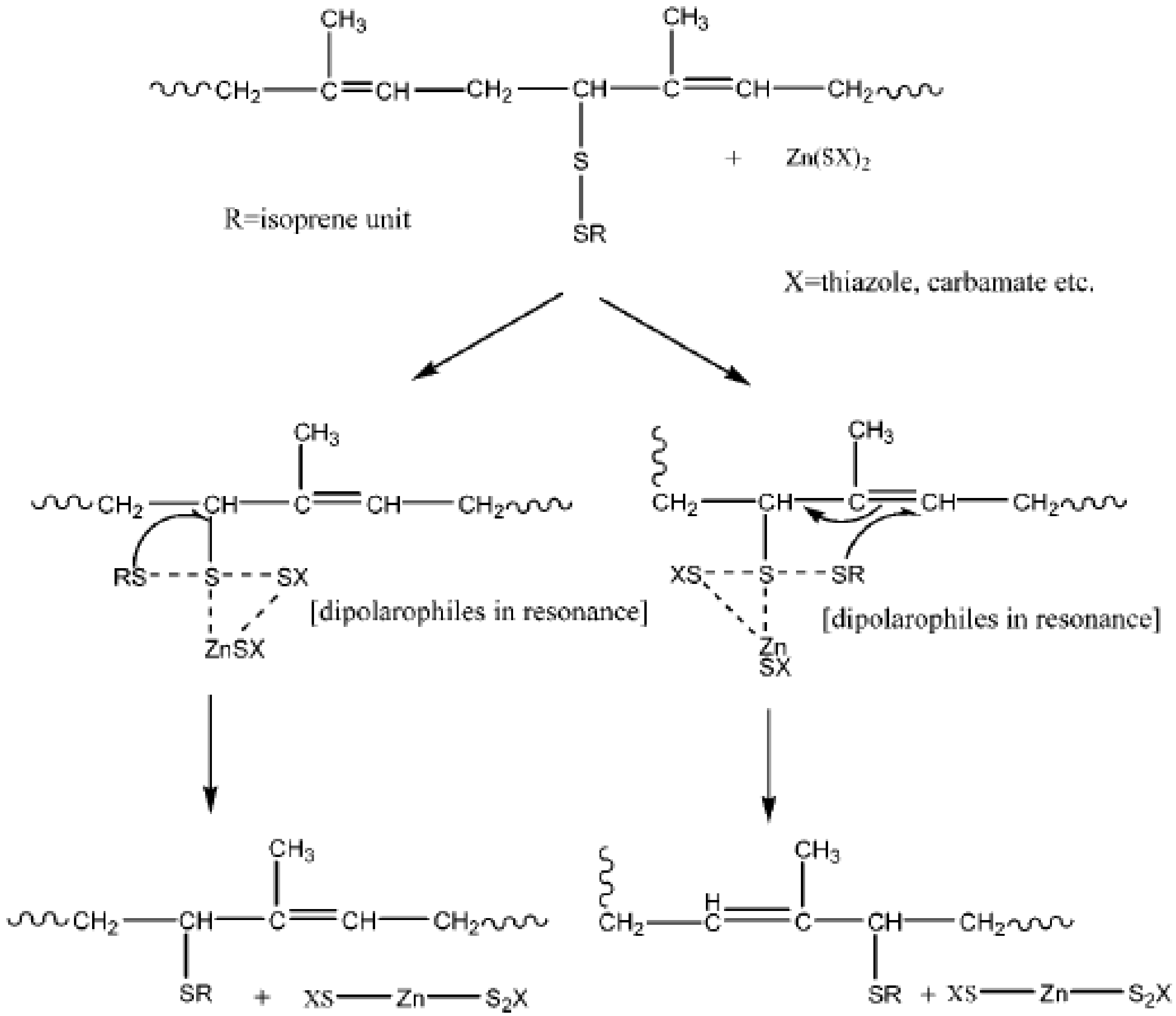


Figure 7. Stress−strain curve of sintered natural rubber powder with the addition of imides.

Scheme 2. Diels Alder Reaction and Thionyl Cycloaddition



Scheme 3. Reversion Reaction in the Presence of Zn(II) Complex



Asphalt

- Another method includes the combination of rubber and asphalt.
- Asphalt is a tar-like substance and is the basis for making roofing shingles and asphalt roads.
- Frozen asphalt is ground into a fine powder before blending it with the rubber powder derived from scrap tires and then the mixture is subjected to the sintering process.
- The resulting material is an asphalt alternative that withstands traditional asphalt’s tendency to melt or become sticky in hot weather and it remains very flexible even at very low temperatures.

Crumb Rubber

- Crumb rubber is produced by chopping up and grinding up waste tires to a desired size, cleaning the rubber and removing any metal particles
- Crumb rubber can be used as a filter media.
- Traditionally, sand or anthracite are used.
- Larger solids are removed at the top layer of the filter and the smaller solids at a lower level, greatly minimizing the clogging problem.
- Is much more cost effective because of substantially higher water filtration rates and lighter weight in comparison to sand or anthracite.

Tire chips as chemical absorbants

- Tire chips of can absorb harmful organic compounds from the environment.

- the researchers inserted tire chips just six to nine millimeters in diameter between layers of sand and peat root mix and gravel .

- The nitrate from fertilizers is trapped.
- Soil microbes will remove the nitrate from the rubber layer, which could remain intact for years

What about chemicals released from the tires?

- The amount released is minimal compared to the amount of chemical the tires can trap from fertilizers.
- Tire chips trap heat, promoting turf and root growth longer into autumn and earlier in spring.

Dam Building

- Sand dams are designed to prevent erosion and build up soil by trapping the silt carried by water in the wash.
- A tire dam is made of automobile tires filled with one-inch gravel, tied together with plastic ties and anchored into the wash bottom with rebar.
- But constructing this dam involved placing the individual tires, fastening them together and filling them with gravel, which turned out to be labor intensive and time consuming.
- The tire dam cost $6,500 whereas a similar concrete dam would cost about $70,000.
- This concept is also used in septic drain fields

Activated Carbon adsorbents

- Activated carbon is commonly produced from carbonaceous materials such as wood and coal.
- Tire-derived activated carbons have commercial value in the removal of toxic pollutants from fossil-fuel-fired power plants, storage of alternative fuels such as natural gas in vehicles, and the removal of volatile organic compounds from industrial gas streams.
- In addition, almost 70 percent of tire rubber is volatile material that can be recovered as oils and gases and used as an energy source for processing the tires

Table 2. Select Properties of Coal- and Tire-Derived Carbons

sample ID[a]	preoxidation conditions (°C, h)	charring conditions (°C, h)	activation conditions (°C, h)	N_2-BET (dry) (m^2/g)	micropore volume (cm^3/g)	CH_4 adsorption at 500 psig[b] (g/g)	bulk density (g/cm^3)	V_m/V_s (cm^3/cm^3)
C1	none	400, 1	850, 1.5	897	0.330	0.0525	0.33	54
C2	225, 4	400, 1	850, 2	1037	0.370	0.0643	0.44	73
C3	225, 4	400, 1	825, 3	1056	0.410	0.0610	0.44	76
C4	none	none	800, 0.5 (KOH)	1478	0.620	0.0903	0.27	68
C5	225, 1.5	400, 1	825, 3 (H_3PO_4)	945	0.384	NA[c]	0.44	67
C6	225, 1.5	400, 1	825, 3 ($ZnCl_2$)	826	0.322	NA	0.44	61
PA1	none	400, 1	825, 3.5	682	0.212	NA	0.58	57
PA2	none	400, 1	825, 3.5	725	0.226	NA	0.58	58
PA3	none	400, 1	825, 3.5	840	0.237	NA	0.58	60
PB1	none	400, 1	825, 3.5	857	0.253	NA	0.65	65
PB2	225, 1.5	400, 1	825, 3.5	1159	0.392	NA	0.65	83
TA1	none	600, 0.75	850, 3	888	0.254	0.0540	0.15	44
TA2	none	600, 0.75	900, 1	1031	0.278	0.0530	0.13	41
TB	none	600, 0.75	850, 2.5	420	0.131	NA	0.24	38
TC	none	none	850, 1.5 (KOH)	820	0.274	NA	0.33	53
BPL	unknown	unknown	unknown	1000	0.430	0.0606	0.46	72

Backfill for walls and bridge abutments

- Tire shreds are used
- The weight of the tire shreds reduces horizontal pressures and allows for construction of thinner, less expensive walls.
- Reduce problems with water and frost build up behind walls because tire shreds are free draining and provide good thermal insulation.

Conclusion

- Recycling of vulcanized natural rubber through “high - pressure high-temp sintering” is possible.
- Mechanical properties of sintered materials can be improved by incorporating small amounts of dienophiles or organic additives.
- Other applications of rubber include construction, water filtration, and source of carbon adsorbents.

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Thank You