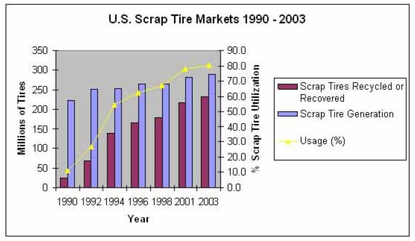
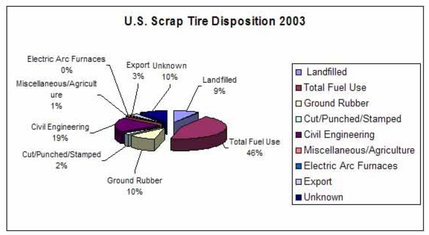
ILLINOIS INSTITUTE OF TECHNOLOGY

IPRO It takes a team INTERPROFESSIONAL PROJECTS PROGRAM

ENPRO 352
Tire Recycling for a Better Future





Crumb Rubber Market 2003

Application/Market	million lbs.	metric tons
Rubber Modified Asphalt	292	132,727
Molded Products	307	139,545
Athletic Surfaces	141	64,091
Tires/Automotive	112	50,909
Devulcanized and Surfac	36	16,364
Plastic/Rubber Blends	38	17,273
Construction and Miscella	70	31,818
Total	**996**	**452,727**

Burning of tire derived fuel (TDF) releases as much air pollution as burning coal. Only 1/4 of the energy invested in the production of the tires is recovered. There is no new economic interest in producing high volume, low performance products for civil engineering, such as road filler, railroad crossing ties, and speed bumps. In contrast, there is great market opportunity for fine mesh rubber products.

Current Recycling Technologies

Tires are collected and fed into shredders.

Steel, non-reclaimed rubber particles, fibers, etc. are removed before feeding rubber into granulators.

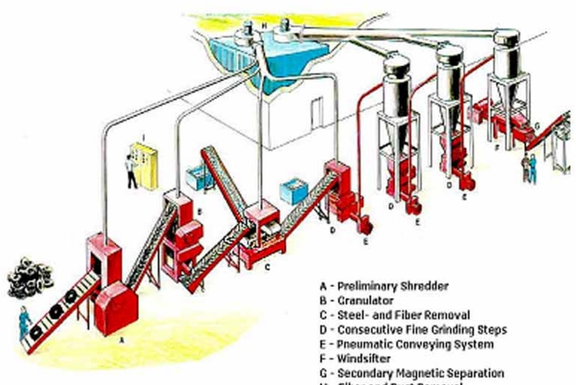
Leading Tire Recycling Methods

Parameter	Ambient	Cryogenic
Operating Temperature	ambient, max. 120° C	below - 80° C
Size Reduction Principle	cutting, tearing, shearing	braking cryogenically embrittled rubber pieces
Particle Morphology	spongy and rough, high specific surface	even and smooth, low specific surface
Particle Size Distribution	relatively narrow particle size distribution, only limited size reduction per grinding step	wide particle size distribution (ranging 10 mm to 0.2 mm) in just one processing step
Maintenance cost	higher	lower
Electricity Consumption	higher	lower
LN2 Consumption	N/A	0.5 – 1.0 kg LN2 per kg tire input

Ambient grinding systems use consecutive grinding steps to achive smaller particle sizes. They are limited to the production of large particles in the size of 10 - 40 mesh.

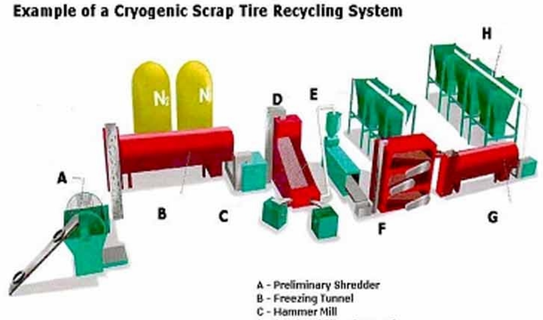
Cryogenic systems cool the rubber to a glassy state and hammer the material to produce small particles. High costs are associated with the use of liquid nitrogen to cool down the rubber.

Example of an Ambient Scrap Tire Recycling System



(courtesy of CIMP France)

Example of a Cryogenic Scrap Tire Recycling System



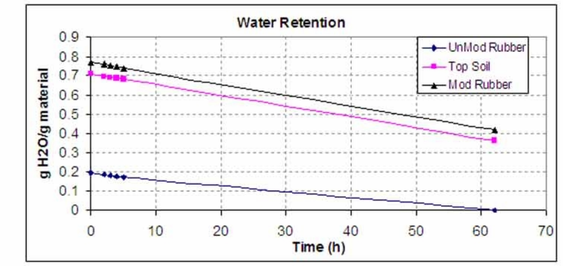
(Courtesy of RTI, Canada)

Where does SSSE fit into the current recycling process?

With this technology, ground rubber particles can be produced at much lower operating costs than the competing cryogenic process and can produce fine particle sizes not achievable with current non-cryogenic technology. SSSE is best licensed as an add on to ambient systems. In the absence of the ability to purchase upstream equpment, the customers for SSSE are companies who desire to produce mesh 70 or greater rubber particles.

Risks and Mitigation

Feedstock sensitivity - use “clean” 1/4” feed with no steel parts or fibers
Scale up - limited scale up of extruder due to max exerted forces, use multiple extruders
Demand - use in conjunction with PPIPN, optimal particle size for use with PPIPN tech
nology will reinforce a need for SSSE technology



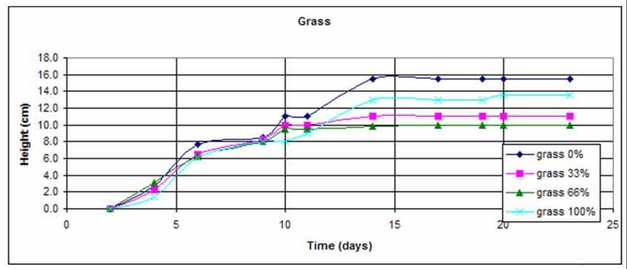
What happens when modified rubber is added to paint?

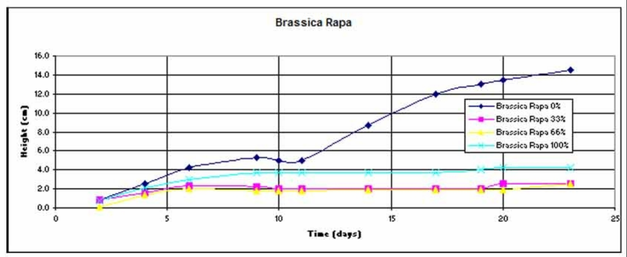
scrubability and stain resistance- similar to the regular paint, though particles rub off with just one coat of paint

Texture- particles give a very textured appearance similar to that of non-slip floor coatings, a second coat of paint does not harm the appearance

appearance- paint loses all gloss with one coat, a second coat restores gloss

Amount Retained	Ambient	Cryogenic	SSSE
30 mesh	2%	2%	10%
40 mesh	15%	10-12%	35%
60 mesh	60-75%	35-40%	40%
80 mesh	15%	35-40%	10%
100 mesh	5%	20%	5%
Pan	5-10%	2-10%	N/A





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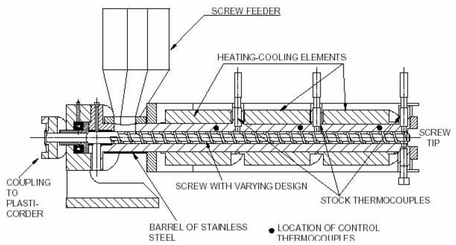
ENPRO 352

Tire Recycling for a Better Future

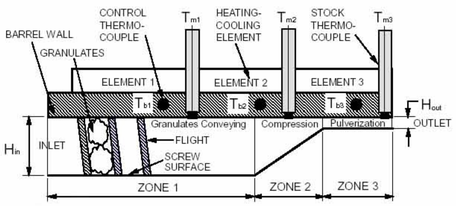
Our Solution
Novel Technology:
Solid State Shear Extrusion
IIT Patented



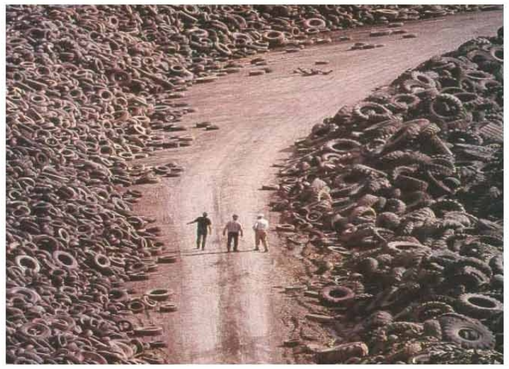
How does it Work?

The Solid State Shear Extrusion (SSSE) process uses a modified screw extruder to grind rubber chunks into very fine particles.

- 1/4" crumb rubber is fed into the extruder
- screw provides compression through three temperature zones
- counter-rotating plates provide additional shear
- rubber catastrophically shears into fine particles



Which would you rather see?



The Problem:

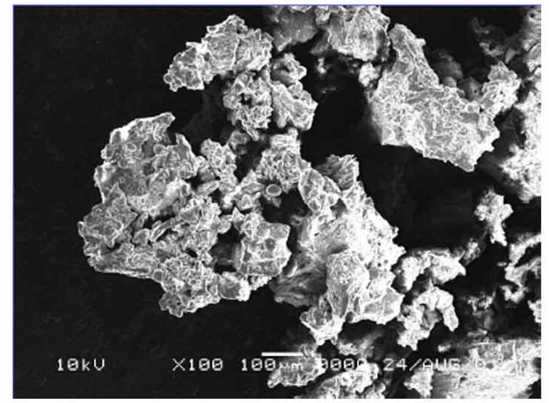
- Each year, more than 280 million scrap tires are generated in the US.
- It is estimated that 2-3 billion tires are stockpiled illegally.
- Scrap tires are very difficult to recycle. They cannot be recycled through melting and conventional processing.
- Large, uncontrolled fires, breeding of vermin, and hazardous human diseases such as malaria, West Nile virus, and Dengue fever occur in tire landfills

Perference Ranking for Sustainability

Rank	Processing Method	Examples
1	Use **PRODUCT** for its originally intended purpose as long as possible.	Design rubber compound and tire geometry for maximum durability. Keep tire properly inflated at all times to ensure maximum service life. Reuse partly word tires. Regroove or retread tire casings.
2	Use **MATERIAL** for its originally intended purpose.	Grind scrap tires into crumb rubber, separate steel and fiber. Sell rubber as raw material.
3	Use whole scrap tires for energy recovery.	Burn whole scrap tires as fuel supplement in cement kilns.
4	Use mechanically processed tires for energy recovery.	Tire chips added to coal as fuel supplement in power plants, paper mills, cement kilns, etc.
5	Alter the chemical structure of scrap tires and use the products for energy recovery.	Pyrolysis, Supercritical Extraction.
6	Storage for possible recovery at a later time.	Monofilling.
7	Disposal without any current or future use.	Landfilling.

The Purpose:

The team will show the business potential of using SSSE technology to convert waste rubber into higher value added products. The team will also develop real market applications using PPIPN technology which may offer improvements in existing rubber based products or dramatically reduce the cost of an already existing product without compromising quality.



Our Solution
Novel Technology:
Particulate Phase Interpenetrating Polymer Network
IIT Patent Pending

How does it Work?

Natural rubber, unlike latex or other acrylics, does not mix well with water. Particulate phase interpentrating polymer network (PPIPN) technology chemically modifies rubber particles to dispserse in water.

- rubber particles are swelled using acrylic acid and an additional solvent
- the acrylic acid strings together, allowing rubber particles to mix with water
- the smaller the particles, the better this works