

# PROCESSING OF SCRAP TIRES: TECHNOLOGY AND MARKET APPLICATIONS

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## ABSTRACT

The processing of scrap tires is a necessary step in the preparation of scrap tire-derived materials for market application. Yet, while market applications are increasing for this secondary material, scrap tires remain a difficult material to process. Furthermore, the manner in which scrap tires are processed may have an impact on the market availability. This presentation looks at some of the technical and market considerations facing the scrap tire processing industry. The presentation looks at the current scrap tire situation, the equipment commonly used to size reduce scrap tires and some of the markets currently using processed scrap tire rubber, and raises some considerations for market enhancement.

## INTRODUCTION

For the past several years, the generation rate of scrap tires in this country has been an estimated 242 million units—or one scrap tire per capita. In 1990, 11 percent, or 25 million of the annually generated scrap tires had markets. The most significant market in 1990 was as tire derived fuel (TDF), which some 24 millions scrap tires were used. By the end of 1993, the percentage of scrap tires with markets increased to 33 percent, or 80 million, of the annually generated scrap tires. The majority of these scrap tires, approximately 70 million, were used as TDF.

The majority of TDF used was in the form of whole tires. As a whole scrap tire, the major markets are as a fuel or in civil engineering applications, such as artificial reefs, breakwaters or side slope stabilizers. While these uses are the current largest markets for whole scrap tires, markets for processed scrap tires are developing or ex-

panding. Consequently, there is an increased interest in the efficient processing of scrap tires. It should be quickly added that the price paid for processed scrap tire material is also greater than that for whole tires, which is also fueling this movement.

Another reason for the increased interest in processing whole scrap tires is Section 1038 of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), a federal law that mandates the use of recycled scrap tire rubber in a prescribed percentage of federally funded highways. According to the provisions of Section 1038, in 1994, five percent of all federally funded highways must contain a minimum of 20 pounds (9.09 kg) ground scrap tire rubber per (US) ton of asphalt used. The percentage of federally funded highways increases by five percent annually until 1997, where it levels out at 20 percent until the year 2000.

In 1992, some 160 million pounds (353.6 million kilograms) of size reduced scrap tire rubber was generated. Of this total, approximately 75 percent were tire buffings, a by-product of the retreading industry. The remainder of this total came from processed whole scrap tires. The new or expanding market demand for size reduced tire-derived material will be met with material generated from whole scrap tires. The over-riding reason for this shift in material source is due in large part to the limited quantity of available buffing rubber.

Before proceeding any further, certain terms commonly used should be defined. One term often used to describe finely processed scrap tires is “crumb rubber”. This is an inappropriately used term; “crumb rubber” is rightfully used in the non-tire rubber industry. The terms preferred by the Scrap Tire Management Council are those terms which are currently being considered as standards by the

American Society of Materials and Testing (ASTM) committees for rubber and asphalt pavement. They are:

**Particulate rubber:** raw, uncured, compounded or vulcanized rubber that has been transformed by means of a mechanical size reduction process into a collection of particles, with or without a coating of a partitioning agent to prevent agglomeration during production, transportation, or storage.

**Buffing rubber:** particulate rubber produced as a by-product of the buffing operation in the carcass preparation stage of tire retreading; characterized by a wide range of particle sizes which are predominately elongated or acicular in shape.

**Granulated rubber:** particulate rubber composed of mainly non-spherical particles that span a broad range of maximum "particle dimension", from below 40 mesh (0.635mm) to 0.47 inches (11.75mm); the key feature of this type of particulate rubber is the fraction of the material in the greater than 0.08 inches (2mm) up to 0.47 inches (11.75mm) maximum "particle dimension".

**Ground rubber:** particulate rubber composed of mainly non-spherical particles that span a range of maximum "particle dimension", from well below 40 mesh (0.635mm) to 0.08 (2mm) inches as a maximum "particle dimension".

**Powdered rubber:** particulate rubber composed of mainly non-spherical particles that have a maximum "particle dimension" equal to or below 40 mesh (0.635mm).

## **PROCESSING OF WHOLE SCRAP TIRES: A PHASED APPROACH**

The processing of a scrap tire is not a one process event. Depending upon the size particle desired, a scrap tire can go through several different phases and types of processing equipment before it is ready for its market application.

While this presentation describes a variety of equipment and a system for processing scrap tires, it should be kept in mind that there is no one way to process scrap tires. The information presented herein is intended to give a general overview of processing equipment, and is not suggesting or advocating a preferred processing system. The various phases of scrap tire processing can be described as follows.

### **First Phase Processing**

First phase processing reduces the whole scrap tire to a "one pass" or "rough shred" material. The size of the first phase shred varies greatly depending upon a series of factors, including, but not limited to the condition of the knives and the rate at which the tire passes through the knives. Typically, however, one can expect a shred three-

to-six inches (75–150mm) in width by three-to-twelve inches (75mm to 300mm) in length.

The most frequently used machines used in primary shredding are slow speed shear shredders. These shredders have been specially designed for size reducing scrap tires, and there are many manufacturers offering a variety of products. Shear shredders usually consist of an in-feed hopper and feed holding area. The in-feed area is typically located on top of, or feeds into, the shredding area, which consists of two, counter-rotating shafts, which often are designed to rotate at different speeds. Hammermills can also be used, although they are not common in this phase of the processing. This type of processing is also referred to as an "ambient grind" or "ambient processing", since the processing of the tire takes place at the temperature of its immediate surroundings.

In some tire processing operations, the bead wire is removed before the scrap tire is shredded. This device, aptly referred to as a "debeader" removes the two sections of the tire containing the bead wire (The primary function of the bead wire is to assist in forming a seal along the tire's rim. This traps the air in the tire, which eliminates the need for inner tubes). While this added step certainly will make shredding easier, it adds another expense and additional time to the process.

The uses for the shred produced in the primary processing phase are very limited. In general, the only use which this type of shred can be applied towards is as a low-grade fill material. Even under the best circumstances, handling of this material is difficult due to the quantity of exposed bead and belt wire, which causes the shreds to interlock and "nest" (form large, roughly shaped wads). The market for primary shreds as TDF is limited due to the handling difficulties.

### **Second Phase Processing**

In the secondary size reduction phase, the rough shred is size reduced to a smaller chip (i.e., two to-three inches in width and length, 52mm–75mm). Once again, slow speed, shear shredders are commonly used in this phase of processing, although other, ambient processing equipment can also be used. Shredders have the advantage that they can handle a fairly high volume of material, but have a limited belt and bead wire removal efficiency.

The other equipment used during this phase of processing includes hammermills, granulators or crackermills. All three of these technologies have a better wire removal efficiency than shredders because they can generate smaller sized particles, which enables the magnets to remove a greater percentage of wire. While more efficient in wire removal, there are other trade-offs. For example, hammermills have a greater energy demand and maintenance costs than shredders. Granulators, which are also referred to as knife mills, can handle comparable capacities as a shred-

der but are not specifically designed for scrap tires. Crackermills are common in scrap tire processing, but have a limited volume capacity.

Markets for second phase processed scrap tires are generally tire-derived fuel (TDF) and civil engineering applications. TDF markets that can accept a two-by-two inch (52mm by 52mm) chip include cement kilns, pulp and paper mill boilers, stoker fired industrial boilers and large-scale utility boilers (stoker or cyclone fired).

Civil engineering applications include, but are not limited to clean fill for road embankments; mixed with dirt as a daily cover for landfills; used in leachate collection system or in septic fields; and as a road bed support material. In all of these application, it is usually necessary for the tire chip to not have wire exposed. There can be, and usually is wire embedded in the chip, but this poses no real problems for these market applications.

### Third Phase Processing (Ground Rubber)

Third phase processing size reduces the two inch (52mm) chip to particles in the 40 mesh (0.635mm) to 0.47 inch (11.75mm) range. The processing equipment used to obtain this size particle are the same as that for the second phase processing, only different screens are used to classify the material.

In this phase, efforts should be made to remove all non-rubber materials (steel and fabric). In order to accomplish this, fabric separators and magnets are employed. Fabric separation typically consists of either a shaker table or a pneumatic (air classifier) system. The metal portion of the tire is typically removed through the use of a magnet, although the point in the process can differ.

In addition to ambient processing, there is a second technology that can produce this size material as well. The second type of processing technology for scrap tires is cryogenics—the use of liquid nitrogen that embrittles the scrap tire particle prior to placing it into a chamber where an impact device shatters the particle.

Before scrap tires are feed into a cryogenic bath, they are size reduced to approximately 3/16 inch (4mm). The size reduced material is then fed into a liquid nitrogen bath. Residence time in the bath is a function of several factors, including, but not limited to the size of the particle and the time it takes to cool the material to the desired temperature. Once the material becomes brittle, it is conveyed to some form of impact device, struck, and then screened. Material which meets production needs is conveyed to either a holding bin or other packing system, while the over-sized particles are returned to the liquid nitrogen bath for further processing.

This technology has the advantage of an efficient wire removal capacity, but is often limited by operational costs. The other critical factor that must be evaluated is the shape of the particle. When using cryogenics to size reduce the scrap tire particle, the surface of the particle is smooth.

Where surface area is a highly desired quality, as is the case in rubber-modified asphalt, then cryogenically size reduced particles are either ill-suited for this application or they must be further processed to “rough-up” the surface area. While this “roughing-up” may open markets for this type of rubber, it can also impact the cost of the material. If, however, smooth surfaced material is sought, cryogenically reduced material would be the only material suitable for that application. Markets for ground and powered rubber will be described later in this presentation.

### Powdered Rubber

The production of powder rubber is generated by the use of cracker mills, wet grinding or cryogenics. In general, the use of cracker mills has been the most proven means of processing scrap tire rubber to a 20–40 mesh particle (1.27mm–0.635mm). The disadvantages associated with this technology are the same as cited earlier. For particle sizes less than 40 mesh (0.635mm), cryogenics appears to be the most prevalent technology, even with the production of smooth surfaced particles. There is also a fairly new technology for size reducing particles below 40 mesh. This is the wet grinding processes, which is currently used in only two facilities in this country. At this point in time, there is little written on this technology, and consequently, not much else can be reported (Forrester, 1993).

### Example Processing System

In order to give some idea of how these different technologies can be placed together to create a processing system, the following example is offered. A whole tire is placed into a twin shaft shredder via a belt conveyor. The first granulator cuts the shreds coming from the primary shredder to a one-inch size. Water contained in the scrap tire is removed by a vibrating dewatering channel. In the same process, an overhead magnet removes the larger pieces of metal. What remains (rubber, metal and fibers) passes a rotary magnet and is transported to another granulator, which size reduces the rubber to a 3/16th of an inch size (4mm). The material is then subjected to another metal removal. The fiber is also removed at this point.

The material which remains is blown into a storage bin. From this intermediate storage site, the rubber is placed on a conveyor, at which time another magnet passes over the material. The material then is fed through a screen. Particles larger than one quarter of an inch (6mm) are retained for additional processing. The remaining material then passes through two additional sizing screens, to further size classify the material. If the material contains a significant amount of moisture, the material can be sent through a drum dryer. This material is then conveyed to another screen to be further size classified. (Ontario Centre for Materials Research, Proceeding, *Recycled Ground Rubber Tires into Plastic Products*, 1993).

## Market Applications for Particulate, Ground and Powdered Scrap Tire Rubber

There are six general categories of markets for ground or powdered rubber. Market availability is a function of cost, product availability, product characteristics and substitute material availability. While all these factors deserve explanation, this presentation will only give a general description of the markets and cite the major obstacles to these niche markets. While economic considerations will obviously impact these markets, the Scrap Tire Management Council, being part of a trade association, has a policy of not providing cost data.

**Molded Rubber Products.** Ground or powdered scrap tire rubber is formed into a set shape, usually held together by an adhesive material or combined with another polymer (e.g., urethane). Products that are molded can include carpet underlay; flooring material; dock bumpers; patio floor material; rail road crossing pads or roof walkway pads.

This market sector could be a very significant growth area since the cost of a blended polymer (plastic and rubber) is reported to be less than that of virgin polymers (i.e., urethane). At present, laboratory research is still being conducted on ways to improve the efficiency of this process. If/when this research yield products with equal or superior characteristics to competing virgin materials or other recycled products, this should expand significantly.

**New Tire Manufacturing.** Powdered scrap tire rubber can be used as a filler material in three components of a tire; the tread, side wall or inner liner. By weight, this equals to one to one and one half percent of the tire.

This is a mature niche market, with supply equal to demand. There does not appear to be any growth potential beyond the increase in new tire sales. Furthermore, this market is limited because tire manufacturing industry tests report that for every one percent increase in the use of recycled scrap tire rubber used, there is a corresponding one percent decrease in the durability of the affect component.

**Rubber Modified Asphalt.** Ground or granulated rubber can be blended with asphalt to modify the properties of the asphalt in highway construction. Particulate rubber can also be used in crack, cape or joint sealants. Granulated rubber can be used as an aggregate material in hot mix asphalt applications. The passage of the Intermodal Surface Transportation Efficiency Act of 1991, as stated in the introduction, has the potential to increase the demand for scrap tire rubber by as many as 17 million scrap tires for every five percent increment.

At present, however, both the private and public sectors of the paving industry have questioned the implementation of this law. Consequently, the 1994 requirement for using a minimum of 20 pounds (9.09 kg) of recycled scrap tire

rubber in five percent of the highways receiving federal funds will not enforced in 1994. The requirements for 1995–2000 still remain in effect.

**Athletic Applications.** Particulate rubber can be used in several various applications, such as mixed with running track material, in grass surfaced playing areas or as a substitution for playground surfaces. Particulate rubber generally makes the playing surface and the running tracks more resilient, less rigid, while allowing the surface material to maintain traction and shape. Case in point is the running track at the White House contains particulate rubber.

This market sector is expected to be a large growth area in the next several years. Currently, however, it's growth is restricted due to budgetary limitation of the largest potential market; schools. Due to budget limitation, many schools are unable to purchase new athletic equipment.

**Friction Material.** Friction brake material uses particulate rubber in brake pads and brake shoes. This is a mature industry with little to no growth expected.

**Plastics/Rubber.** Particulate rubber can be added in a fairly significant quantity to extend or modify properties of polymeric (thermoplastic) materials. Examples of this application are injection molded products and extruded goods. There appears to be a significant market potential for this application but not enough practical experience to suggest whether there will be compounding and/or bonding issues which will require further research. (Baker, 1993).

## Other Market Considerations

Another significant factor, one which affects both the cost of producing processed scrap tires material as well as the availability of scrap tires, is the alternative disposal options for scrap tires in any given area. In areas that still accept whole or processed scrap tires at landfills, the infrastructure and markets for scrap tires are usually adversely affected. The basis for this is not unlike the disposal for any other solid waste; solid wastes, in a free market, will go to the least cost legal disposal option available.

Allowing processed scrap tires to be disposal in a landfill adds to the disposal cost since there is a cost to process the scrap tire before placement into the landfill. Once scrap tires are placed into a landfill, it is unlikely that they can ever be salvaged. The reason is two fold. First, the scrap tire material may be mixed with other solid wastes or contaminated with dirt, which makes them difficult to process. Secondly, pulling them out of the landfill adds another cost to the material, making the economical use of this material virtually impossible. The only exception to allowing scrap tires into a landfill is where there are no viable markets within a reasonable distance.

## CONCLUSIONS

- Processing of scrap tires is not an end unto itself. Rather, it is an intermediate step in the market preparation of a product.
- There are many possible means of achieving the desired size and particle characteristic desired.
- Markets for scrap tire derived materials are expanding, with significant growth expected in the markets for particulate rubber.
- Markets for scrap tires can be sensitive to a series of factors. Two of the more significant factors effecting the marketability of scrap tire-derived materials are the cost and the characteristics of the material. When deciding what type of product to produce, this decision should be based on the market demand, not your production capacity.
- With increasing applications and demand for processed

scrap tire rubber, there is also an increased need for quality control. In this particular case, that refers to a consistently uniformed sized product, free of fiber, dirt and metal. If any processor seeks markets for tire derived materials, then quality control and quality assurance will be of prime importance.

## REFERENCES

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