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ABSTRACT

A strong motivation for recycling used tire beads has been provided by state and federal legislation that provides for tire disposal and use of the tire for fuel after chipping. The chipping process still leaves the bead material to be dealt with because of steel content. This paper summarizes the work done at the University of Northern Iowa of the effects of remelting tire beads as scrap charge materials for the production of cast irons. Experimental research has shown that the bead material when extracted and re-melted produces a steel with a 20 point carbon content after melting. A dramatic loss of carbon occurs as a result of oxidation reactions present in the furnace resulting form bead wire surface area and contaminants present on the wire after post processing. The original wire before melting has a chemistry of 70 point carbon steel. The chemical residuals present in the steel upon post processing were low with the exception of sulphur which was present at the rate of .140% in the re-melt samples. The overall yield for re-processing by induction melting was about 65%.

A second focus of this work centered on bead extraction method using a low temperature pyrolysis method by exposing bead while still encased in rubber by processing the material in the presence sulphur dioxide while treating the rubber with a lead oxide or a zinc oxide to act as a catalyst in the reaction. This work was successful in that the material when treated with either of the catalysts and exposed to the gas at an elevated temperature causing the rubber to become brittle which then allowed it to be removed through tumbling process. However the lead oxides were not acceptable for this process and a mechanical method was derived for removing the bead wire for evaluation.

1.0 Introduction

Current practice of waste tire disposal is based on shredding or land filling of the tire. In the United States each year two hundred and eighty million tires are disposed of annually. Each passenger car tire contains about 5/8 pound of high quality "spring" steel wire. Truck tires contain significantly more wire, ranging up to 22 pounds per tire. If the tire is shredded, the metal fraction is magnetically or mechanically removed from the shredded rubber stream and is land filled. An alternate technique for bead removal is to strip the wire from the bead by a mechanical means and then shred the tire only leaving the belt wires to extract from the chipped rubber. Current scrap steel prices for an average steel are about $160/ton. Processing 280,000,000 discarded passenger tires results in about 175,000,000 pounds of cabled steel wire. This amount, i.e., about 87,500 tons then represents a scrap steel value of about $14,000,000. Added to this would be the landfill fees that are saved by recycling this tire fraction. At a $35/ton tipping fee, this then represents another $3,062,500.

2.0 Experimental Procedure

Initial melts of bead wire materials were done using a 3,000 cycle 200 KW induction power melting source in a 300 pound tilting box furnace. The steel melt was started using a small amount of scrap steel to form a heel in the bottom of the furnace and then bead wire was used for the balance of the melt. During the melting process small additions of silicon carbide were used to "quiet" the melt and keep it from boiling. Subsequent remelt operations were done in a 100 pound hand shank induction furnace using the same power source. The steel was then cast into ingots using a chemically bonded sand mold to produce the ingots. They were subsequently identified as heats A,B,C,D,E, and the initial melt chemistries on the bead wire before melting were identified as "car bead" and "truck bead".

During the melting of the bead wire a small amount of fuming was present as the bead wire went through the blue brittle heat temperatures and through the subsequent melting of the material. No attempt was made to analyze the fumes that were released during the process. No bead wire was melted that was extracted using the low temperature pyrolysis technique to eliminate the variable effect of the sulphur and the catalysts used in the pre-processing of material.

3.0 Results and Discussion

The results of the chemical analysis of the bead wire from car and truck beads is presented in Table I showing the carbon and Table II showing the sulphur present in the bead wire before induction melting was performed to cast the base metal ingots. The results of the base metal ingots is shown in tables III and IV. Micrographs of the cast ingot materials are portrayed in figures 1 through 4 showing the material in both the etched an unetched condition.

Table I. Carbon content of car and truck tire beads.

Sample No.	Car Beads	Steel Truck									
File No.	14420	14421									
Dated	5/7	5/7									
Carbon	.53	.70									
Manganese											
Silicon											
Phosphorus											
Sulfur											
Chromium											
Nickel											
Molybdenum											
Copper											
Vanadium											
Tungsten											
Columbium											
Cobalt											
Aluminum											
Titanium											
Iron											
Tin											
Zinc											
Lead											
Magnesium											
Tellurium											
Boron											
Tensile Strength											
Yield Strength											
% Elongation											
Reduction of Area											
Hardness											
Character of Fracture											

Table II. Sulphur content of car and truck tire beads.

Sample No.	"A"	"B"									
File No.	10191	10192									
Dated	2/28	2/28									
Carbon											
Manganese											
Silicon											
Phosphorus											
Sulfur	.886	1.167									
Chromium											
Nickel											
Molybdenum											
Copper											
Vanadium											
Tungsten											
Columbium											
Cobalt											
Aluminum											
Titanium											
Iron											
Tin											
Zinc											
Lead											
Magnesium											
Tellurium											
Boron											
Tensile Strength											
Yield Strength											
% Elongation											
Reduction of Area											
Hardness											
Character of Fracture											

Table III. Analysis of steel ingots cast from car and truck tire beads.

Sample No	A	B	C	D	E					
File No	10186	10187	10138	10189	10190					
Dated	2/28	2/28	2/28	2/28	2/28					
Carbon	.19	.19	.21	.19	.19					
Manganese	.09	.08	.10	.10	.09					
Silicon	.21	.19	.23	.22	.21					
Phosphorus	.016	.016	.016	.016	.016					
Sulfur	.138	.126	.133	.137	.141					
Chromium	.02	.02	.02	.02	.02					
Nickel	.04	.04	.04	.04	.04					
Molybdenum	.01	.01	.01	.01	.01					
Copper	.10	.10	.10	.10	.10					
Vanadium										
Tungsten										
Columbium										
Cobalt	.01	.01	.01	.01	.01					
Aluminum	.208	.181	.220	.204	.237					
Titanium	.003	.003	.003	.003	.003					
Iron										
Tin										
Zinc										
Lead										
Magnesium										
Tellurium										
Boron	.0006	.0006	.0006	.0006	.006					
Tensile Strength										
Yield Strength										
% Elongation										
Reduction of Area										
Hardness										
Character of Fracture										

Table IV. Analysis of steel ingots produced from industrial tire wire beads.

Sample ID #									
APT File No.	18091								
Date received	7/12								
Carbon	.03				Zinc				
Manganese	.05				Lead				
Silicon	.21				Magnesium	.010			
Phosphorus	.014				Tellurium				
Sulfur	.111				Boron	.000[illegible]			
Chromium	.01				Selenium				
Nickel	.04				Antimony				
Molybdenum	.01				Arsenic	.10			
Copper					Cadmium				
Vanadium					Bismuth				
Tungsten					Zirconium				
Columbium					Mercury				
Cobalt	.01				Calcium				
Aluminum					Beryllium				
Titanium					Nitrogen				
Iron					Oxygen				
Tin	-0-				Hydrogen				
Tensile Strength psi					Charpy ft lbs.				
Yield Strength psi					#1				
% Elongation					#2				
Reduction of Area					#3				
Hardness BHN					Average				
Character of Fracture					Temperature				

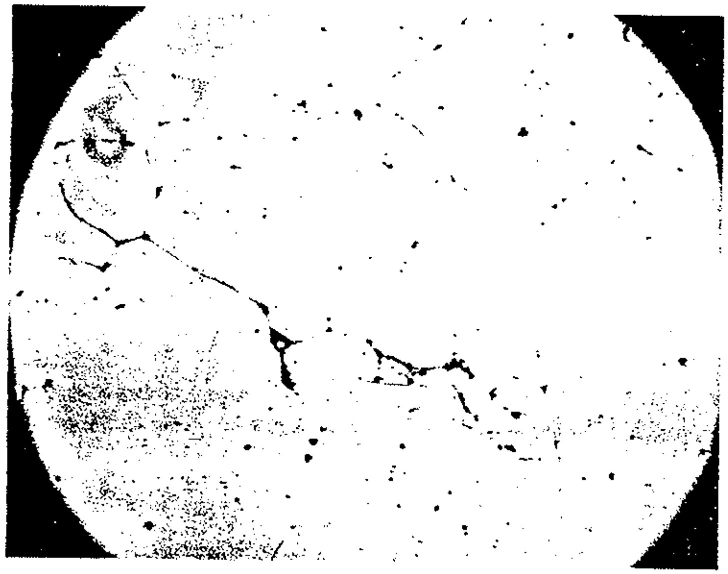

Figure 1. Cast steel ingot micrograph - unetched 100x magnification.

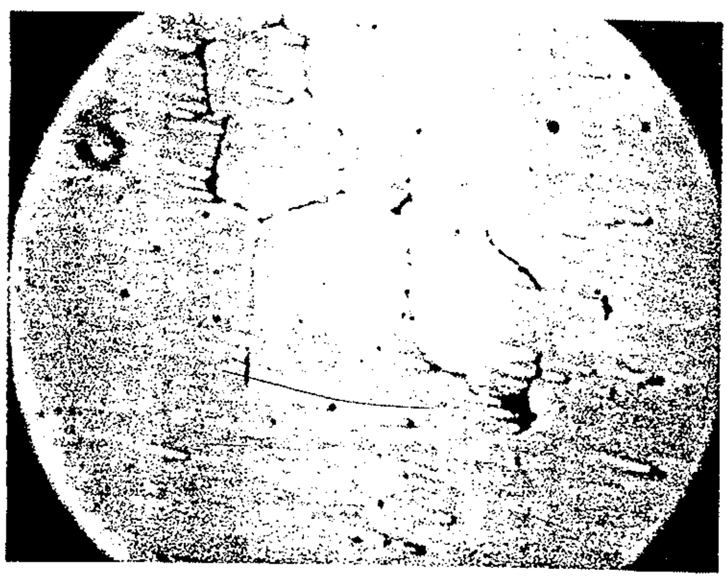

Figure 2. Cast steel ingot micrograph - unetched 200x magnification.

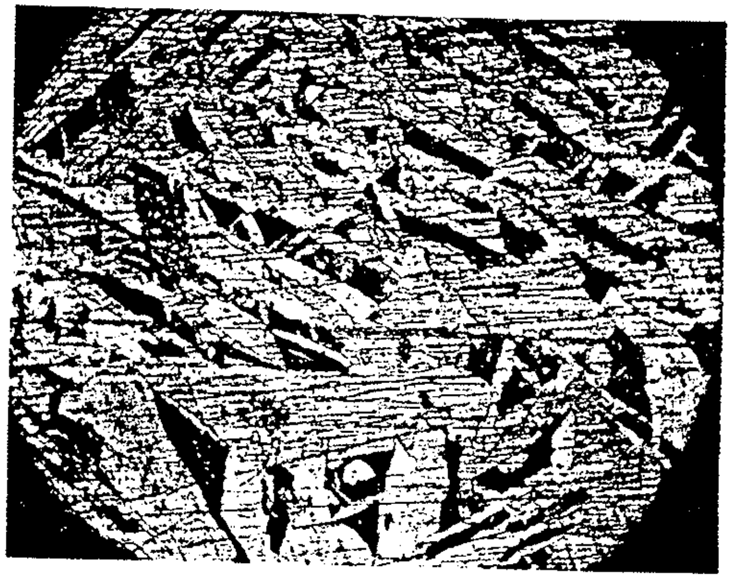

Figure 3. Cast steel ingot micrograph - nital etched 100x magnification.

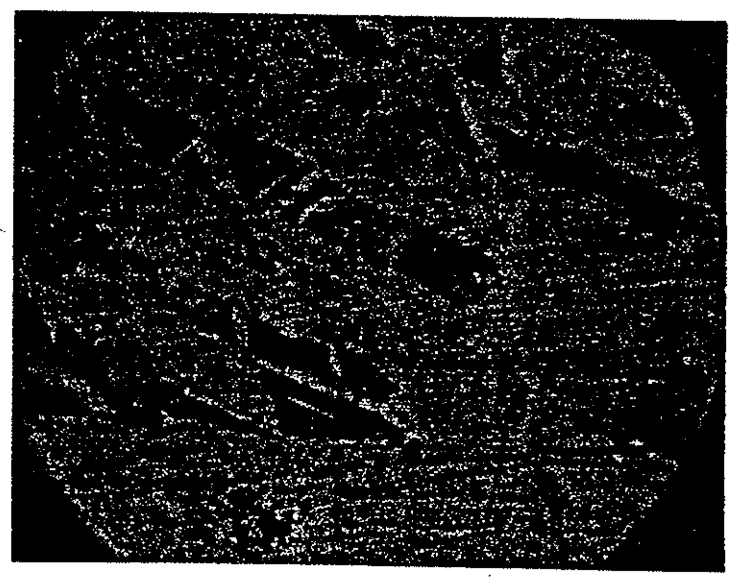

Figure 4. Cast steel ingot micrograph - nital etched 200x magnification.

3.1 Melting Considerations

The ability to compact the tire bead to a sufficient density required for induction melting was a problem as the melting was conducted. The diameter of the bead wire resulted in very poor melting yield and an increased amount of dross on the surface of the heat of steel as produced in the induction melting furnace. The "bailing" of the material with some type of hydraulic compaction unit would greatly enhance the ability to utilize the material as feed stock in the melting operation. Sizing of the bail is critical for both induction and cupola melt operations. Utilization of this material as a feed stock in an arc furnace would be totally unacceptable.

3.2 Low Temperature Pyrolysis

A reaction chamber was fabricated from steel tubing to accommodate bead samples up to ten inches in length. The chamber was sealed and with a mechanical cap that had two fittings for the introduction of reaction gasses and evacuation of air. A type k thermocouple provided the feed back to the temperature of the reaction chamber. The chamber was then heated by an electric fluidized bed furnace. During the testing it was determined that heat alone did not significantly break down the rubber. When sulphur was added to the reaction chamber the rubber was re-initiating the vulcanization process, but not at a rate that would be commercially feasible. When the lead oxide or the zinc oxide were added as an accelerator in the process the rubber became very hard and brittle and could be removed through a tumbling process.

3.3 Summary

The material that was melted as feed stock for the production of cast iron would be acceptable for use as a scrap stream for gray iron but not for ductile base material because of the sulphur content of the resulting material. The scrap stream sulphur content would be acceptable in the gray iron charge makeup to produce the commodity based castings for the iron industry. One aspect of the process that is cause for concern is the amount of arsenic a .1 % in the bead wire sample that was tested. Tire manufacturers that were contacted would neither confirm nor deny the use of arsenic in the production and or coating of the bead wire that they used.