CO-PROCESSING OF SCRAP TIRES AND WASTE OILS

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ABSTRACT

In industrialized countries, new scrap tires are generated at approximately one tire per capita per year. In the past, land filling and stockpiling of tires were the most significant means of disposal. Today, both of these methods of disposal are environmentally unacceptable and pose a significant health and fire hazard. The disposal of waste oils represents another environmental problem. Hydrocarbon Technologies Inc. is developing a new process that offers an economically viable solution for converting both these waste materials into marketable products, namely oils and carbonous solids. The oils are easily hydrogenated to yield gasoline and diesel fuel components, while the solids have a potential market as modifiers for paving grade asphalt, filler/coloring agents for rubber goods, and a carbon black replacement. Asphalt testing has shown that the carbonous material is effective in addressing three major sources of roadway failure: rutting, moisture damage and embrittlement. This paper discusses the pilot plant results and preliminary economic assessment.

INTRODUCTION

In an industrialized country new scrap tires are generated at approximately one passenger car tire per capita per year. For the USA this amounts to 250 million tires per year and for the European Community it amounts to 300 million tires per year. In addition, the USA alone contains over one billion tires stored in scrap tire stockpiles. This is a problem that is continuing to grow with the increase in population and the increase in the number of cars per capita. Until a long term solution is found to the large number of scrap tires collected each year, this problem will continue to grow worse.

Less than half of the new scrap tires being generated are used as a fuel supplement in power plants, cement kilns, industrial boilers, etc. Land filling, a significant source of tire disposal in the past, is becoming both less viable and more expensive. More and more landfills are refusing to accept waste tires and many of those that still do also require the tires to be reduced in size by shredding. The only other significant source of tire disposal is stockpiling. Land filling and stockpiling are not environmentally acceptable and pose a significant health and fire hazard. Using tires as a fuel source recovers less than a quarter of the energy used to produce the rubber in the tire.

Waste oils from industrial sources and from automobiles represent another environmental disposal problem, with very little incentive to reprocess the waste oil. These oils are unpopular for reprocessing/upgrading as they have a high solids and metals content. They are typically burned for fuel with the requisite environmental treatment of the exit streams from the burning facility. One of the significant difficulties in using a catalytic process to upgrade waste oil to higher value products such as gasoline, diesel and home heating oil is the metals content of the waste oil. The high metals content normally seen in these streams has a major detrimental effect on the catalyst being used for upgrading. HTI has a long history of testing coal/oil co-processing using oil streams with very high metals content. In a co-processing environment the unconverted coal and the coal ash act as superb scavengers of the metals and the final light product oil is very low in metals content. It is expected that the much higher surface area of the carbon black will act as an even better medium for removing the metals in the waste oil, providing an easy method for improving the quality of the waste oil so that it would make a better feedstock to an upgrading facility.

HTI's new process offers an economically viable solution in converting both of these waste materials into marketable products, namely oils and carbonous solids. The process involves two-stage pyrolysis at moderate temperature. The process was originally developed at the University of Wyoming and thoroughly tested with a wide variety of scrap tires and waste oils allowing for a tailoring of the product slate to meet market demands. The product oils are easily hydrogenated to yield gasoline and diesel fuel components, while the solids have a potential market as a modifier for paving grade asphalt, a filler/coloring agent for rubber goods and as a carbon black replacement.

MATERIAL AND METHODS

This work was performed in a 0.3 ton/day unit. A simplified overview of the process is shown in Figure 1. Waste tires are cut into pieces less than six inches long, preheated and then mixed with lime and preheated filtered waste oil before entering the first of two steam heated screw conveyor reactors in series. The primary screw conveyor reactor dissolves the rubber shreds in the waste oil and allows the steel and fibers to separate out at temperatures under 400°C. The upper zone of the first screw conveyor reactor is maintained at 425°C to 450°C and permits the ready removal of gases and light oils. The first reactor also permits the use of additives to modify the final product or to assist in the dissolution of the tires and to control the gas yields. One such additive that has been used is CaO. The heavy oils, carbonous material, steel and fibers move to the second reactor which is maintained at nearly 480°C. This second reactor is fine tuned to drive off most of the remaining oil, leaving behind just the residue and producing a solid carbonous residue material. The typical oil content of the carbonous product is less than 1 W%.

RESULTS AND DISCUSSION

The product oil was evaluated to determine its initial quality as a feedstock to a refinery or for hydrotreating. Table 1 summarizes the results indicating that the material would be acceptable for either use.

Modified asphalt was evaluated with the addition of 10 W% carbonous residue to the AC-10 asphalt. The four main criteria of asphalt quality that were investigated were rutting, oxidative ageing, embrittlement and moisture sensitivity. The improvement in rutting performance is measured by the improvement in the complex viscosity between a control sample and the modified sample. This showed a 50% improvement indicating that the modified sample should be less susceptible to rutting. The ageing effect was determined by looking at the change in the complex viscosity after the sample had been aged in an oxidative environment (163°C for 1.4 hr). The age index for the control sample was 2.65 while it was only 2.33 for the control sample. Embrittlement was determined by observing the change in the complex viscosity after 2 hours and after 4500 hours. The control sample showed an increase of 39% while the modified sample showed an increase of only 2%. Moisture sensitivity was determined by measuring the number of freeze-thaw cycles required for failure. This test was performed with five different aggregates. In all cases the modified samples shows a significant increase in the number of cycles required for failure.

Another potential commercial avenue for the carbonous product is as a carbon black replacement. An analysis of the carbonous product is shown in Table 3. As indicated by the composition analysis, the material is nearly entirely carbon black or ash, only a small amount of extender and polymer is still present. The ash content is significantly higher than that found in commercial carbon blacks which are normally less than 1%. This does not severely impact on the quality of the carbon black as measured by the surface area and DBP No. (dibutyl phthalate absorption number in cc dibutyl phthalate / 100 gms carbon black). The carbonous product has properties very similar to N660 which is a general purpose furnace black with a DBP No. of 90 and a surface area of 35 m^2 / gm.

ECONOMICS

The commercial size plant being evaluated is 30 tons/day of waste tires or roughly 1 million tires annually. Using current government statistics, this would be about 10% of the annual number of tires discarded in the three-state Delaware Valley region or in the New England region. The plant would also be sized to process 7 tons/day of waste oil. This is less than 5% of the market for the annual waste oil from 5 million cars, assuming four oil changes per car per year, and assuming each oil change produced four quarts of useable oil. Output would be 12 tons/day of solids and 114 bbl/day of oil and 5 tons/day of steel and fiber byproducts. The cost of erecting a 30 ton/day plant was estimated to be $5.0 MM. The waste oil is considered to be available at no cost. The base case for the scrap tires is that they are also available at no cost and also at no tipping fee.

There are four significant product streams to be considered, two minor and two major. Of the two minor streams, the recovered steel fibers have a ready market in the recycle industry. The other very minor product stream is the reinforcing fiber present in tires. A market has not yet been identified for this stream and at present no value is placed on it. Even with a value it would have a very minor impact on the total process economics as it is such a small process stream. In order for this process to be economical a market needs to be found for the two main product streams, the oil product and carbonous residue material. The oil products can be readily upgraded and should have at least an equivalent value to crude oil. For this evaluation this was taken as $20/bbl. The carbonous material is the main product variable effecting the economics of this process.

In order to determine the required selling price of the carbonous product a sensitivity on the carbonous product price vs the main feed component in the carbonous product (ie. the scrap tires) was performed. The sensitivity was performed for two different rates of return, 10% and 15% (Figure 2). As the curves show, a selling price for the carbonous product of only $0.12/lb to $0.13/lb is required to make this process economically feasible.

CONCLUSIONS

The co-processing of waste oils and scrap tires is a viable method for dealing with the continuing disposal problem for both waste oil and scrap tires. The product oil is suitable as either a feedstock to a refinery or for subsequent hydrotreating for upgrading. The carbonous product has been demonstrated to have a positive impact on asphalt improving moisture resistance, embrittlement, rutting and ageing. It is expected that these improvements would substantially lengthen the useful life of a surface paved with an asphalt modified with this carbonous product. The carbonous product is also a potential replacement for a general purpose furnace black. The economics of this process are favorable even without a tipping fee for the scrap tires at a carbonous product price of $250 / ton or higher. Further work is being planned to improve process economics.

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TABLE 1: PRODUCT OIL ANALYSIS

Elemental Analysis, W%		Distillation, W%	
Carbon	85.91	IBP-177 °C	15.8
Hydrogen	11.60	177-343 °C	32.8
Nitrogen	0.36	343-538 °C	50.6
Sulfur	0.60	538 °C+	0.3
Oxygen	0.83		
Physical Properties			
API Gravity	26		
Aromatics Carbon, W%	27.8		

TABLE 2: ASPHALT TESTING RESULTS

	Control	Modified
Complex Viscosity ($\eta^* 10^5$), poise	20.3	30.4
Oxidative Aged Complex Viscosity ($\eta^* 10^5$), poise	53.8	70.7
Age Index	2.65	2.33
Embrittlement as Measured by Complex Viscosity ($\eta^* 10^5$), poise		
After 2 hours cure	0.78	1.21
After 4500 hours cure	1.09	1.23
% increase	39.2	2.0
Moisture Sensitivity as Measured by Freeze-Thaw Cycles to Failure		
Brokaw Aggregate	3	13
Hardigan Aggregate	4	10
9th Street Aggregate	6	>50
Simon Pit Aggregate	4	>50
Southbend Aggregate	>50	>50

TABLE 3: CARBONOUS PRODUCT ANALYSIS

Composition Analysis, W%		Elemental Analysis, W%	
Extender	0.24	Carbon	79.72
Polymer	3.36	Hydrogen	1.30
Carbon Black	80.40	Nitrogen	0.24
Ash	16.00	Sulfur	2.74
Quality Assessment			
BET Surface Area, m^2/gram	53		
Dibutyl Phthalate Absorption Number	84		
Oil Content, W%	<0.1		

FIGURE 1: SIMPLIFIED PROCESS DIAGRAM

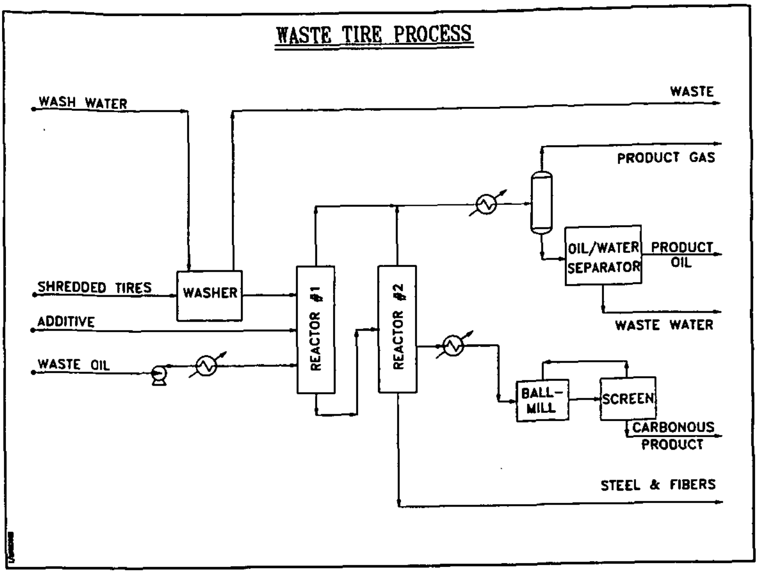

FIGURE 2: SENSITIVITY OF CARBONOUS PRODUCT PRICE AND TIRE COST