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Design of Distillation Column for Liquid Fuel from Waste Tire

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***Abstract*— In this study, tire chips (without steel cords) obtained from waste tire were used as raw material to prepare valuable products; liquid fuel, char and gas. Two-stage reaction system was used in this experiment. Three types of catalyst pellets (volcanic ash, dolomite and Mabisan clay) were prepared by activation in furnace about 3 hours and temperature range from 800˚C to 850˚C.These catalyst were analyzed by using X-ray Diffraction (XRD) and gravimetric analysis method. There were four experiments in this study. The final product, liquid fuel was measured its density, viscosity, kinematic viscosity and refractive index. The experiments were carried out at temperatures between 210 - 400 ˚C with and without using any catalyst. Yield percent of liquid fuels were 50.12%, 51.34%, 48.54% and 44.65% for using Mabisan clay, volcanic ash, dolomite and without catalyst respectively.Moreover,yield percent of char and gas fuel of the experiment was obtained 40% and 10 % respectively.**

***Keywords*—waste tire, catalyst pellets, liquid fuel, XRD, gravimetric analysis method**

I. INTRODUCTION

Around the world, there are initiatives to replace gasoline and diesel fuel due to the impact of fossil fuel crisis, hike in oil price and stringent emission norms. Millions of dollars are being invested in the search for alternative fuels. On the other hand, the disposal of waste tyres from automotive vehicles is becoming more and more complex [1]. As a result of rapidly growing number of car owners, among others, also the production of used tires increases. Most of the used tires accumulates in landfills, they are bulky and do not degrade. Currently, it is preferable to reduce filling the landfills and focus on recycling methods, the use of tires as a valuable source of energy and chemical substances. The pyrolysis is one of the conventional methods, however in the field of processing of used tires is a relatively new technology. This is the decomposition of organic material at high temperatures in an inert atmosphere (or vacuum). The pyrolysis of waste tires represents an alternative environmentally-friendly processing and at the same time enables you to gain useful products [2].

Pyrolysis is the chemical conversion or breakdown of organic compounds by heating in the total or partial absence of oxygen. Energy recovery from pyrolytic gas , the valuable liquid products and char are obtained, which may become commercial products after additional processing [3]. Another solution of removing tires from the waste stream is incineration. A serious consequence of burning tires is that it may release toxic chemical compounds such as dioxin, furans, and aromatic hydrocarbons into the atmosphere. The final products from the open combustion of waste tires are ash, particulates, tar, and exhaust gases, which are blamed for several physical health problems such as eye irritation and respiratory problems. The high levels of pollution generated from open tire burning are unacceptable to the public [4]. The aim of the present research work was to study the fuel oil derived from the waste tires .

In Myanmar, liquid fuel from the waste tire is potentially increased as a National project. In this study , the tire chips (without steel cords) from waste truck tire was used as a raw material to prepare valuable products such as liquid fuel ,char and gas.

II. MATERIALS AND METHODS

A. Raw Materials

Tire chips (bulk density = 0.87g/cm^3, thickness = 0.9 cm, average volume = 1.4 cm^3) were obtained from waste tire of truck cars. These were purchased from local market. Different natural catalysts (Mabisan clay Mhawbe township, Yangon division, volcanic ash from Popa region, Mandalay division and dolomite from Kyaukse, Mandalay division) were used to pyrolyse the waste tire.

B. Preparation of Tire Chips from the Waste Truck Car Tire

Tire chips were obtained from waste truck car tire. But it is impossible to pyrolyse the whole tire in the thermal reactor. Firstly, steel cords were removed from waste tire. And then, waste tire were washed and cleaning to remove dust and sand. Moreover, these were dried in the oven at 60˚C for two hour. Finally, waste tire was chipped into cylinder shape with 1.4 cm^3 in volume. The moisture content, bulk density and ash content of truck car tire were initially determined. Tire chips from waste tire are as shown in Fig 1.

Fig. 1 Tire chips from waste tire

C. Preparation of Natural Catalyst Pellets

In this study, three types of catalyst were used. These were Mabisan clay, dolomite and volcanic ash. The catalyst powder was moulded to make required shape. Prior to use, all the natural catalysts were crushed and sieved. Particle sizes having (< 495µm) were used and pelletised by moulding. And then, these catalysts were activated by heating at the temperature range from 800˚C to 850˚C for 3 hours. The catalyst pellets (a) Mabisan clay, (b) dolomite and (c)volcanic ash are as shown in Fig 2. The chemical compositions such as SiO_2, Al_2O_3, $CaCO_3$ and Fe_2O_3 contents of all catalyst samples were determined by using the gravimetric analysis method at the Department of Technology Promotion and Coordination Metallurgical Research and Development Centre in Ela.

Fig. 2 Catalyst pellets of Mabisan clay dolomite and volcanic ash

D. Preparation of Crude Liquid Fuel from Waste Tire

The two-stage reactor for waste tire cracking was set-up as shown in Fig 6. The weight ratio of raw material and catalyst was 10:1 ratio. To do catalytic cracking, 200 g of waste tire chips were loaded into the reactor and 20 g of each natural catalyst was placed in the catalytic bed. The thermal reactor was heated to 250˚C with the heating rate of 5˚C min^{-1} and then to reach the final setting temperature 400˚C by using the heating rate of 2˚C per minute. The thermal reactor was purged with nitrogen gas throughout the process. The catalytic bed was heated to 300˚C. The organic vapours thermally cracked from waste tire chips were passed through the catalytic bed for catalytic cracking. After that, the vapour were condensed as liquid fuel in the 1^{st} and 2^{nd} condenser. The yield percent of liquid fuel from the condenser were determined. And then, density, refractive index and kinematic viscosity of product liquid fuel were determined.

III. Results And Discussion

The result of characteristics of waste tire are shown in Table1. After activating by heating at the temperature range from 800˚C to 850˚C for 3 hours, the natural catalyst pellets were analyzed by using XRD at the Department of Technology Promotion and Coordination Metallurgical Research and Development Centre in Ela. The XRD patterns of natural catalysts are shown in Fig 3, 4 and 5. Chemical compositions of natural catalysts are shown in Table 2. Table 3 illustrates the densities, refractive indices and kinematic viscosities of product liquid fuels obtained from the process by using with and without catalysts. The colour of product liquid fuels obtained by using catalysts and without catalyst were nearly the same in greenish brown colour. According to Table 3 and 4, the yield (%) and colour of liquid fuel depend on the usage with and without catalyst. It was found that the yield (%) of product liquid fuels using catalysts were higher than the yield (%)of product liquid fuel using without catalysts. Among them, the highest yield of liquid fuel can be obtained using volcanic ash catalyst . The odour of liquid fuel without using catalyst was worse than using catalysts. According to the literature, during the pyrolysis process, 33-38 wt. % of pyrolytic char occur, 38 -55 wt. % of pyrolytic oil and 10-30 wt. % of gases[2]. According to Table 4, the result of yield percent of liquid fuel from the two-stage reaction system were found to be nearly 50%. And then, liquid fuel from the pyrolysis of waste tire will be the qualified product. And then, the yield (%) of char was found to be high carbon content. Therefore, it could be suggested that activated carbon should be produced from this high carbon content.

TABLE 1
CHARACTERISTICS OF RAW MATERIAL

Parameter	Unit	Value
Total moisture	%wt	1.2
Bulk density	g/cm^3	0.87
Ash content	%wt	5.50

TABLE 2
CHEMICAL COMPOSITIONS OF NATURAL CATALYST

Components	Mabisan clay	Volcanic ash	Dolomite
SiO_2(%)	58.9	45.87	20.12
Al_2O_3(%)	27.8	17.6	3.23
Fe_2O_3(%)	1.34	10.12	5.12
$CaCO_3$(%)	-	0.054	51.67

TABLE 3
COMPARISON OF QUALITATIVE ANALYSIS OVER PRODUCT CRUDE LIQUID FUEL

Catalyst	Density (g/cm^3)	Refra-ctive index	Kinematic viscosity (mm^2/s)	Colour	Odour
Mabisan clay	0.807	1.498	3.57	Greenish brown	Like diesel
Volcanic ash	0.805	1.487	3.32	Greenish brown	Like diesel
Dolomite	0.87	1.497	3.71	Greenish brown	Like diesel
Without catalyst	0.88	1.496	4.54	Brown	Strong

TABLE 4
COMPARISON OF PRODUCT YIELD BY USING NATURAL CATALYSTS
Reaction temperature: 210 – 400 ˚C
Reaction time : 3.5 hours

Catalyst	Liquid fuel yield (%)	Char yield (%)	Gas yield (%)
Mabisan clay	50.12	42.12	6.12
Volcanic ash	51.34	40.43	6.01
Dolomite	48.54	41.54	6.45
Without catalyst	44.65	39.78	8.12

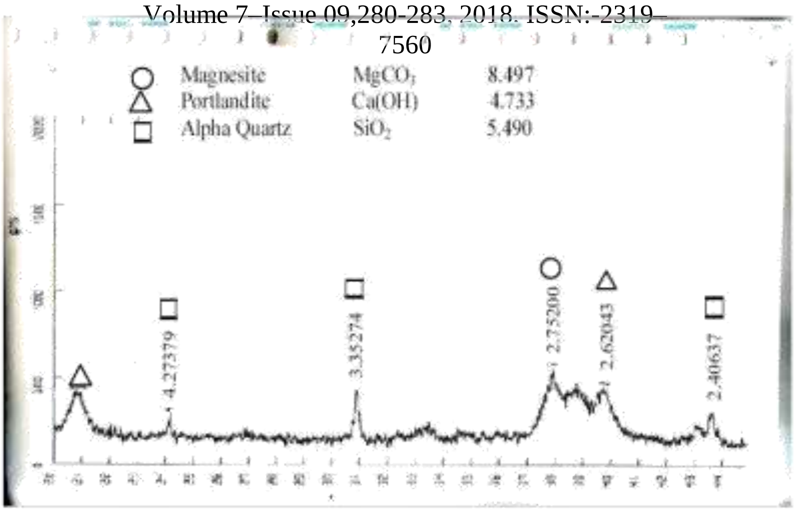

Fig. 3 XRD pattern of dolomite after activating

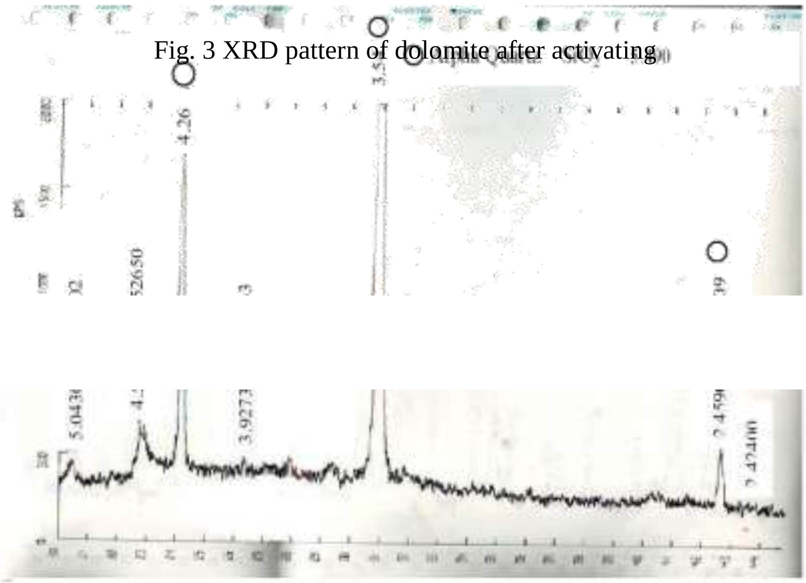

Fig. 4 XRD pattern of Mabisan clay after activating

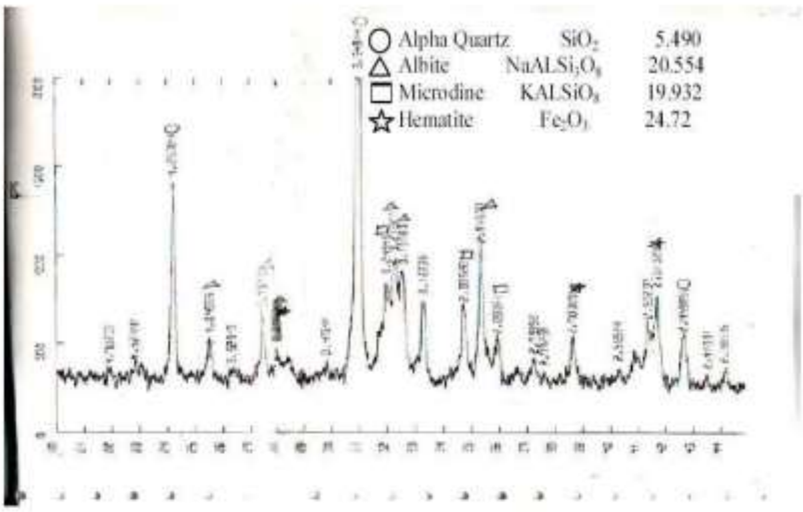

Fig. 5 XRD pattern of volcanic ash after activating

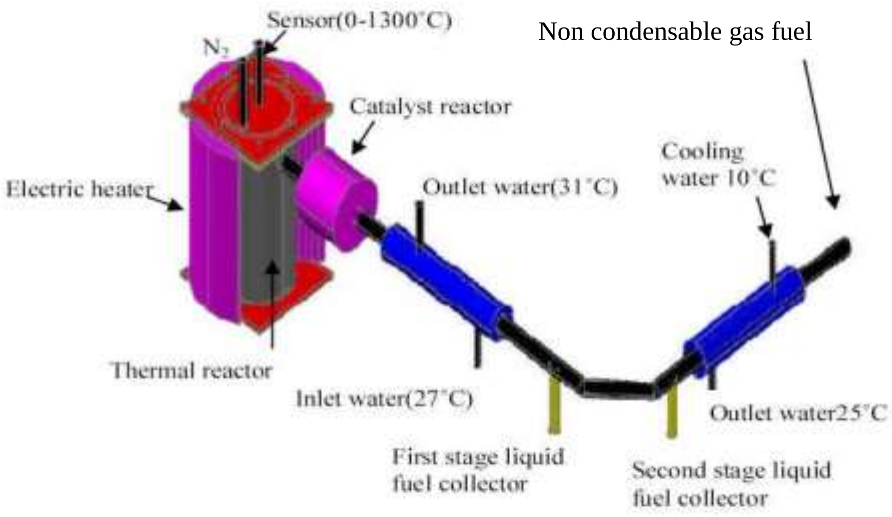

Fig. 6 Schematic representation of the two-stage reaction system[5]

IV. CONCLUSION

In this study, the liquid fuel from waste tire pyrolysis experiment can be given crude oil. Therefore, the crude oil should be needed to distillate for the pure fuel properties. The pyrolysis results showed that the waste tire degradation takes place at temperature from (210˚C-400˚C). Upon reaching the final pyrolysis temperature about 50yield% of liquid fuel, 40 yield% of char and, 10 yield% of non condensable gas fuel were obtained. Oil obtained by pyrolysis can be used directly as a fuel or admixture to the products of petrochemical industry. Gases can also be used as a fuel. Char can be used either as a smokeless fuel, carbon black or activated carbon, or can be gasified to obtain gaseous fuels. Moreover, this research can be beneficial for environmental control and can also support to solve the shortage problems of fossil fuels at the near future.

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