



Design of A Prototype Reactor For Fuel Oil Production From Waste Tires Using Pyrolysis Process

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MANAGEMENT of waste is a comprehensive challenge that effects the sustainability of eco-friendly and economic improvements. This work intended to design a prototype to produce fuel oil from waste tires by Pyrolysis process. Thus, we are looking for a new source of energy to have a benefit from waste tires which is a hazardous waste, and it causes a real problem for health and environment. In the development of the Kingdom of Saudi Arabia which exactly what our government considers, and places as one of the biggest goals that is to find another source for energy in their vision 2030 for kingdom economy's future. The prototype design is a batch reactor, and a try to achieve the best yield of fuel oil product. The result showed that, the average density of the produced fuel oil is 0.783 g/cc, and it is close to the diesel range, which is between 0.8 to 0.95 g/cc, also it is near the range of natural gasoline, which is between 0.711 to 0.737 g/cc. Consequently, the produced fuel oil is comparable with the diesel and natural gas.

Keywords: Fuel oil, Production, Wasted tires, Pyrolysis process.

Introduction

The tire is a circler-shaped part that is connected to the wheel rim, protects the truck from the roughness of the road, gives the driver more comfort, while driving, and works on protection against road fraction. Annually, 1.5 billion tires are made and with time, these tires go to the waste stream representing a major potential waste and environmental problem [1]. Waste tire is a tire dumped in the landfill because it cannot be used anymore for cars and trucks, but it can be recycled, because it is made from rubber and other component and steel wire [2]. Wasted tires became a global problem in the past few years, and it causes risks to the environment, so researchers are looking for solutions to this problem, and there are a lot of ways to recycle used tires such as playground cover, running

track, and decoration. However, we need to find other ways to recycle wasted tires to produce another useful material, that helps environment, and the country economics. Generally, tires are made from rubber and carbon black and steel wire and other chemical compounds, thus to recycle a used tire, it needs to remove the steel wire, and cut the tire into small piece, then tire pieces enter to the process to produce new material that can be used. Recycling tires is an old subject, and research continued working on this subject until now [3-4].

Presently, there is no producer of tires in the Kingdom of Saudi Arabia. All the local demand is satisfied through imports. Currently, there are over 50 brands of tires in the Kingdom market. Bridgestone, Michelin, Goodyear, Yokohama, Hankook, Pirelli, Dunlop and Maxxis are the

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major brands in the market [4, 5]. One of the most countries that have the highest number of cars per person is Saudi Arabia. Around 740,000 different types of cars were sold in the Kingdom of Saudi Arabia, until now Saudi Arabia does not produce cars, There is only a company that assembles the car parts together. Therefore, Saudi Arabia depends on imported cars, and tires to meet the customers' needs. Through the development that takes place in Saudi Arabia, many of car sector companies are attracted to Saudi Arabia. According to, "Saudi Arabia Tire Market Forecast & Opportunities, 2019," published by Report Buyer, the Saudi Arabia market will evolve at a compound annual growth rate (CAGR) of around 17 percent until 2019. While, demand for cars is increasing that attract investors to invest, and as result, tire demand will increase in Saudi Arabia [6-8].

The replacement period in Saudi Arabia for tires is shorter, because of the weather conditions. Mostly cars' tires sold in Saudi Arabia is passenger cars tires then commercial cars' tires. The capital city Riyadh and other cities with a large area, and a large population has the percentage of total tire sales in the Kingdom of Saudi Arabia [9]. According to, Report Buyer including the Chinese brand there are other brands, that compete in Saudi Arabia market such as Bridgestone, Michelin, Continental, Goodyear, and Yokohama [9-10]. Saudi Arabia creates about twenty million scrap tires, that almost dumped in landfill, or burned which is considered a hazardous waste causing diseases to human and pollution to the environment [8-11]. This makes the environment more toxic, and attracts mosquitoes, that transfer the diseases and does a real damage for public health and safety [12,13]. To solve these problems, used tires need to be recycled to produce useful products to clean the environment, and help the economic opportunities [12-14].

The discarded tires will continue to be an environmental concern, and is growing annually, as people must change vehicle tires with new ones. Although, there are applications for discarded tires but represent a very small fraction of the total tires replaced. As, the tires are made of carbon black and multiple hydrocarbon polymers and steel, these elements can all be reproduced in a more beneficial form by subjecting the tires to a pyrolysis process, and convert them back to useful products, namely: light fuel oil, carbon

black, steel and light gases [15,16].

Pyrolysis of waste tires is a competent thermo-chemical resource for producing high-value energy and fuels [17, 18]. Pyrolysis of waste tires has been widely investigated using various reactors, for example fixed-bed (batch), screw kiln, rotary kiln, vacuum, and fluidized-bed [1, 19]. The pyrolysis processes of waste tires have been extensively applied to the fixed bed, and batch reactors. Usually, an electric furnace used for heating the reactor outwardly besides nitrogen, or another inert gas used as a carrier gas. Regularly, the pyrolysis process probes are in the range of 450–700 °C, because the tire thermal degradation occurs at about 350°C [20-22]. The condensable resulting gases were collected in the downstream, while the non-condensable gases collected and analyzed. The residual char and any steel collected after experimentation.

The fuel requirement for certain industries in the Kingdom of Saudi Arabia is huge, and have a broad fuel specification making the pyrolysis products a perfect fit. The two main applications of the liquid fuel produced from the process are utility companies producing both desalinated water, and electrical power, and cement companies [23-24]. The heavy fuel oil now used in both utilities, and cement companies are becoming in short supply, while the demands continue to increase due to increased need for water, electricity, and housing projects [23-26].

This work is a challenge to take advantage of the wasted tires, available in Saudi Arabia and became hard to disposal . While, now they are burnt or dumped in the landfill, and they cause health problems for humans, and pollution for environment. Therefore, this work is environmentally friend to reduce pollution, and be economically useful, if implemented helps to get career opportunities. In this work, a simple pyrolysis process have been used to produce liquid and solid fuels, by subjecting the wasted tires at elevated temperature in the absence of oxygen. This process causes the hydrocarbon content in the tires to decompose. Where, a long polymer chains break into smaller molecules of hot gas stream, when exiting the reactor system, and passing through a water condenser where liquid is collected, and gas can be recycled. As, fuel in the reactor system, or used to produce electricity, if a gas turbine, or a boiler is available. The steel remains in its form, and segregated using a magnet after the carbon black cooled. The

pyrolysis behavior and fuel product properties of the waste tire were determined in this work. The obtained data will provide important reference information for energy, and fuel generation from waste tire pyrolysis.

Material and Method

Material

Wasted tires of cars from Saudi Arabia are used; the sample of tires must be shredded into a suitable size, and not containing any metal. Digital balance was used to weight the shrouded tires.

Design of prototype reactor

The main parts of the reactor are tank, flanges, filter and cap; these parts are shown in Fig. 1. The tank and cap have been made locally, while flanges have been brought. The reactor tank is shown in Fig. 2, it was made from carbon steel sheet, and the sheet has been shaped to cylindrical shape. The cap was made from carbon steel sheet, the cap has conical shape, and it has been joined to flanges to connect to the tank shaped as shown in Fig. 3. The filter has been made from stainless steel, it has an oval shape, and it has been penetrated by drill machine to make small holes as shown in Fig. 4.

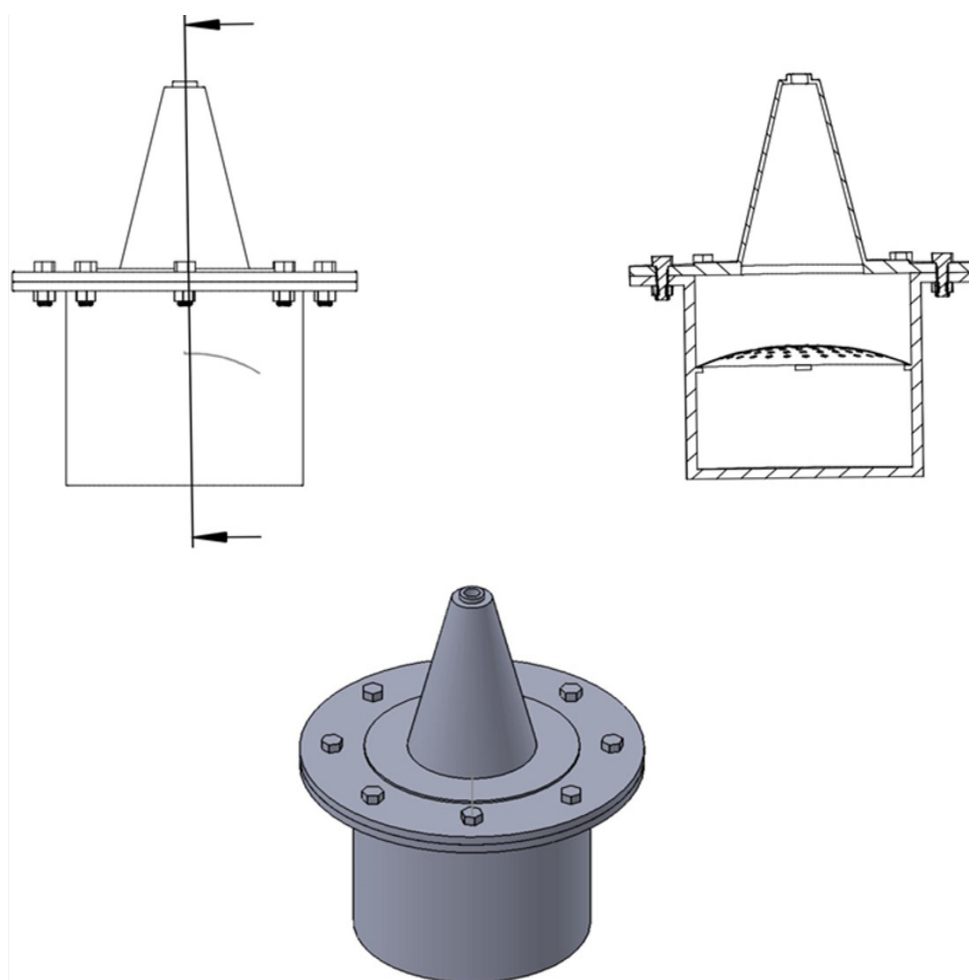


Fig. 1. Reactor design .

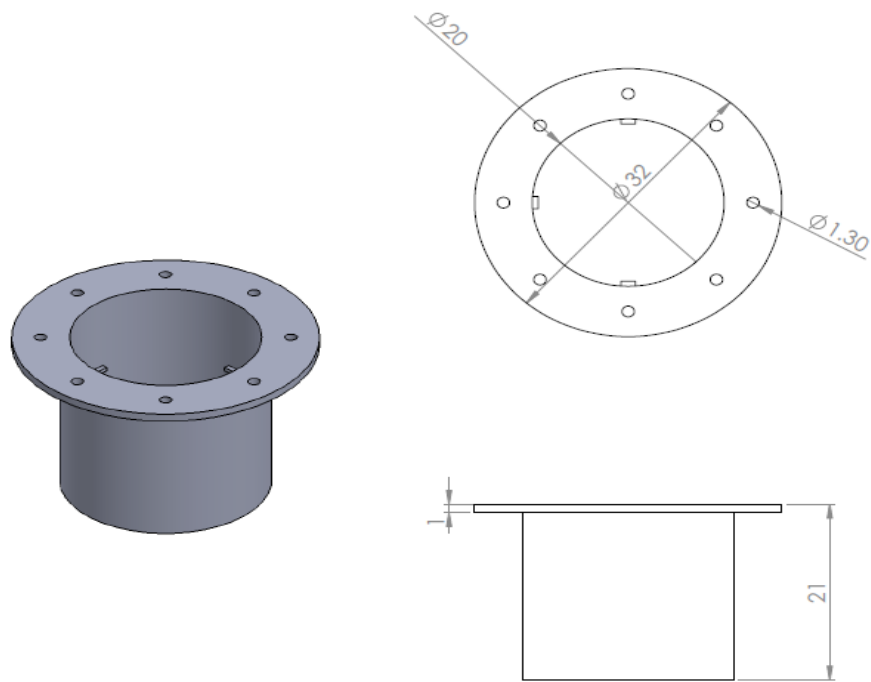


Fig. 2. Reactor tank Design .

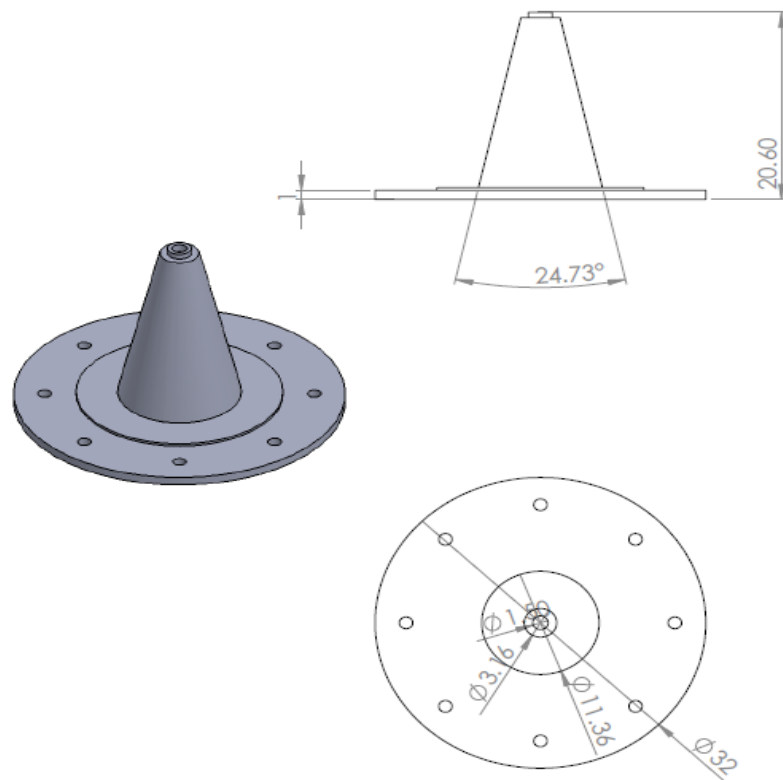


Fig. 3. Reactor cap design.

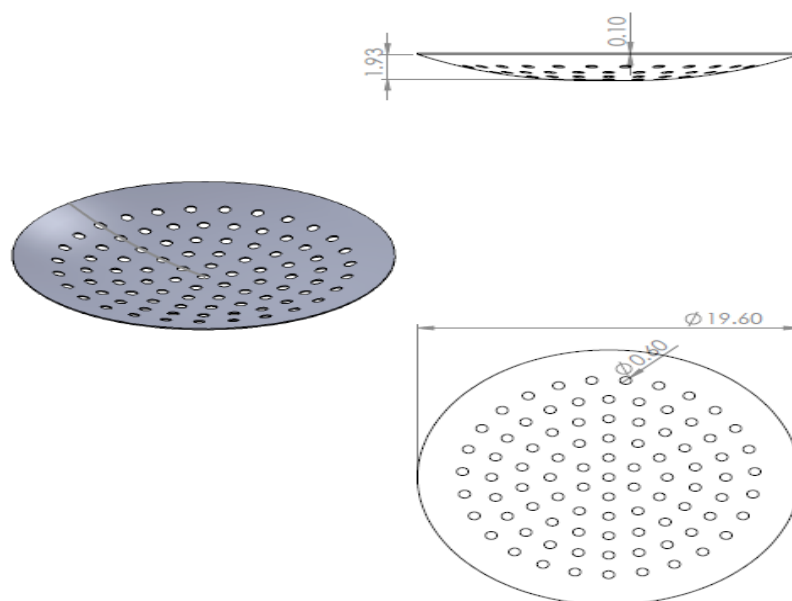


Fig. 4. Reactor filter design.

Experimental work

Pyrolysis process is used to produce fuel oil from wasted tires. The sample of wasted tiers is prepared, the wasted tiers must be shredded, and not containing any metal. Wasted tiers are shrouded into a suitable size for reactor. A digital balance was used to weight 1kg of the shrouded tires to be used in the reactor. The weighted shrouded tires were introduced to the reactor. Then, the reactor was closed with its cap. The condenser was connected to the reactor cap to condense the product oil. The burner was insulated to heat the furnace and the temperature in the furnace were controlled by a thermocouple. The temperature inside the reactor was measured by the thermocouple. The condensed oil was collected in a beaker to know the collected volume at each run. These steps were repeated for each run. The simplified schematic diagram for experimental work procedures steps is shown in Fig.5. In addition, the set-up schematic is shown in Fig.6.

Result and Discussion

Fuel oil product

Four runs were performed; in each run, 1kg of shredded tires was used. In each run, the amount of the fuel oil, and carbon black was recorded. Based on the fuel oil produced, the efficiency of the reactor was calculated by using equation (1.1). Table 1 shows the values of the efficiency of fuel oil, and carbon black for the four runs.

$$\eta = (\text{weigh of the fuel oil produced/ weight of shredded tier}) \times 100 \quad (1.1)$$

Fuel oil density

Four exterminates were performed to estimate the density of the fuel oil obtained from wasted tiers. In each run, a certain weight, and its volume of the fuel oil was recorded, and the oil density was estimated. The density of the fuel oil from the four runs is shown in Table 2, the average density of the four run is 0.783 gm/cc.

It is obvious from the obtained results, that the four runs were performed with 1 kg of discarded tires. The product was a fuel oil, and carbon black with an average value of approximately 36 wt. % fuel oil, and approximately 43 wt. % of carbon black. The rest 21 wt. % are loses gas that did not condense through the operation process. The experiment was performed in an average temperature of 321 °C, and this temperature was satisfying to the required objective. The efficiency was calculated for the reactor, the average efficiency is 38.875% for the fuel oil, and 42.775% for the carbon black. It is cleared from Table 2, that the average density of produced fuel oil is 0.783 g/cc, and it close to the diesel range, which is between 0.8 to 0.95 g/cc, also its close the range of natural gasoline, which is between 0.711 to 0.737 g/cc. Consequently, the produced fuel oil is comparable with the diesel and natural gas.

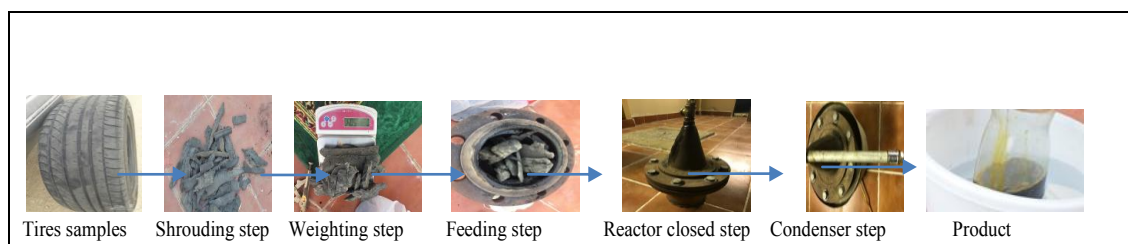


Fig. 5. The simplified schematic diagram for experimental work procedures steps.

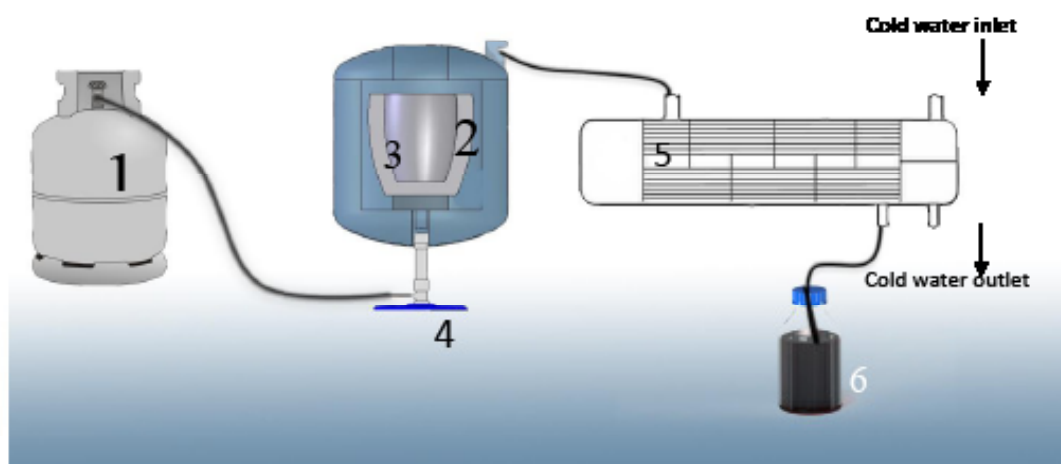


Fig. 6. set-up schematic where; 1- Energy source. 2- Reactor 3- Furnace. 4- Burner 5- condenser. 6- Fuel container..

TABLE 1. The fuel oil and carbon black result.

| Run No. | Liquid fuel (Wt. %) | Carbon black (Wt. %) | Fuel oil Efficiency, η (%) | Carbon black Efficiency, η (%) | Temperature ($^{\circ}$ C) |
|----------------|---------------------|----------------------|---------------------------------|-------------------------------------|-----------------------------|
| 1 | 36.1% | 41.2% | 36.1 | 41.2 | 319 |
| 2 | 35.8% | 43.2% | 35.8 | 43.2 | 320 |
| 3 | 36.4% | 42.7% | 36.4 | 42.7 | 322 |
| 4 | 35.2% | 44.0% | 35.2 | 44 | 324 |
| Average | 35.875% | 42.775% | 35.875 | 42.775 | 321.25 |

TABLE 2. Density Calculation.

| Run No. | Weight (g) | Volume, cc | Density g/cc |
|----------------|--------------|------------|--------------|
| 1 | 11 | 15 | 0.733 |
| 2 | 12 | 15 | 0.800 |
| 3 | 13 | 15 | 0.866 |
| 4 | 11 | 15 | 0.733 |
| Average | 11.75 | 15 | 0.783 |

Conclusion

In this work, fuel oil was produced from discarded tires using homemade uncomplicated pyrolysis process set up. The fuel oil was about 360 g and the carbon black product was about 430 g from 1kg of discarded tires. In addition, the fuel density was measured to be about 0.783 gm/cc, which is close to the density of the diesel and the density of the natural gasoline.

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تصميم مفاعلٍ أوليٍّ لإنتاج زيت الوقود من إطارات النفايات باستخدام عملية الانحلال الحراري

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تعتبر إدارة النفايات تحديًا شاملاً يؤثر على استدامة التحسينات الصديقة للبيئة والاقتصادية. يهدف هذا العمل إلى تصميم نموذج أولي لإنتاج زيت الوقود من إطارات النفايات بواسطة عملية الانحلال الحراري. كما يهدف هذا العمل إلى البحث عن مصدر جديد للطاقة للاستفادة من نفايات الإطارات. حيث ان النفايات الخطرة تسبب مشكلة حقيقية لصحتنا والبيئة. تصميم النموذج الأولي هو مفاعل دفعي، ومحاولة لتحقيق أفضل إنتاج لمنتج زيت الوقود. ووجدت النتيجة أن متوسط كثافة زيت الوقود المنتج هو ٠,٧٨٣ جم / سم^٣، وهو قريب من نطاق الديزل، الذي يتراوح بين ٠,٨ إلى ٠,٩٥ جم / سم^٣، كما أنه قريب من نطاق البنزين الطبيعي الذي يتراوح بين ٠,٧١١ إلى ٠,٧٢٧ جم / سم^٣ مكعب. وبالتالي، فإن زيت الوقود المنتج مشابه للديزل والغاز الطبيعي.