Tire Pyrolysis Oil as A Green Alternative to Produce Hydrocarbon Products

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Abstract—**This research paper presents a comprehensive study on transforming waste tires into sustainable hydrocarbons through continuous pyrolysis, fractional distillation, and oxidative desulfurization (ODS). The objective is to evaluate the feasibility of producing gasoline-range, diesel-range, and heavy hydrocarbon fractions from tyre pyrolysis oil (TPO), followed by sulphur reduction using hydrogen peroxide-based ODS. Detailed process flow, yields, reaction conditions, and potential applications are discussed with emphasis on environmental benefits and circular economy integration.**

I. INTRODUCTION

The rising global demand for hydrocarbon fuels coupled with increasing waste tyre generation has created a critical environmental challenge. Pyrolysis of end-of-life tires offers a technologically viable solution for recovering reusable hydrocarbons while reducing landfill accumulation. Tire Pyrolysis Oil (TPO) contains a rich mix of aromatics, aliphatic, and sulphur compounds, making it a promising feedstock for refining into diesel and gasoline equivalents. This paper evaluates the production, processing, and upgrading of TPO for sustainable industrial use.

Continuous Pyrolysis System

Continuous pyrolysis process plant is designed to produce continuous pyrolysis-oil. Depending on the Raw material grades the production of the pyrolysis-oil is around 45% to 65% of the production.

The process contains following of the equipment:

Hopper for Holding Waste Tyres or Waste rubber of big size – HP-101

Rubber Grinder to produce small pieces of 2mm to 5mm in size – GR-101

Magnetic particle Separators to separate metal from the Rubber and from the Carbon – MS-101 & MS-102

Airtight Rotary Valve, to avoid oxygen intake into the process for proper Pyrolysis process – RV-101 & RV-102

Screw Conveyor with Heating coils from continuous pyrolysis process – SC-101 to SC-103 (Quantity may vary depending upon the gear box speed and length of the screw conveyor)

Vertical Separators to remove heavy oil and wax from the process – VS-101 & VS-102

Condenser to condense Pyrolysis-Oil from the process – C-101

Pyrolysis-oil storage tank – T-101

Process Flow of the Pyrolysis System

Steel wires from the Waste Tires are removed before it is processed for Pyrolysis.

Waste tyres are then passed through Grinder where it is cut into pieces of 10mm to 25mm for further action.

Magnetic particle separator removes any metal contains from the grinded rubber and through airtight rotary valve it is send to the Screw conveyor.

Screw conveyors have provision of heating and temperature inside the screw conveyor is set at 400^{0}C.

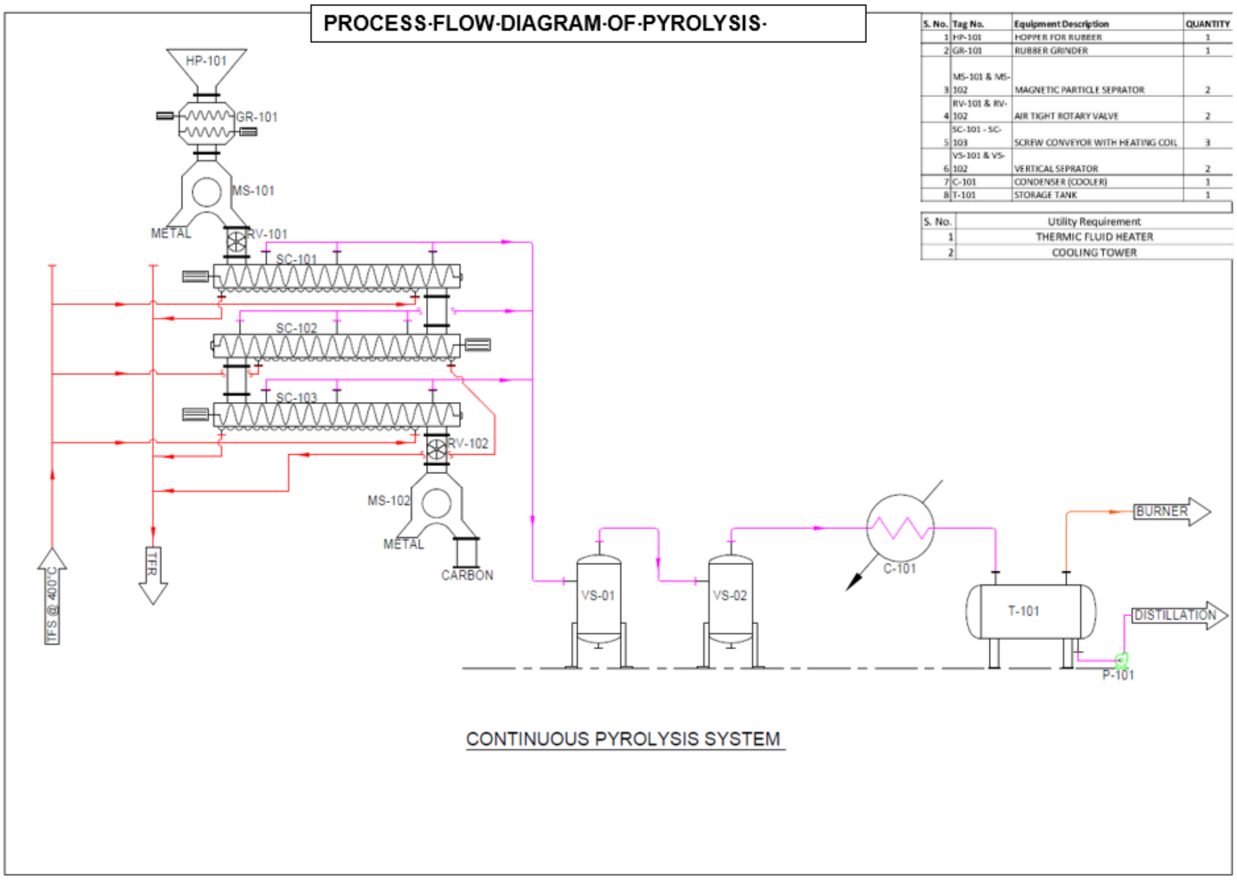
Residence time for Rubber inside the Hot Screw conveyor is around 4hours to extract complete Pyrolysis oil.

Through all the Screw conveyor pyrolysis oil vapour generated is passed through Vertical Separator where heavy oil or wax is collected.

Further vapour is cooled in Condenser and liquid Pyrolysis oil is stored in the storage tank.

Gas generated in the process can be utilized again in the heater to generate energy thereby reducing the fuel consumption in the heater or it can be burn in the atmosphere via flare stack.

Processed rubber is converted into Carbon, and it is passed to Magnetic particle separator through airtight rotary valve where the carbon is collected from the metal present inside.



II. PRODUCTS YIELD FROM PYROLYSIS OIL

Product Yields from 1,000 kg of Waste Tires
Pyrolysis Oil: 400–450 kg
This is the primary product, often used as a fuel or further refined into diesel-like fuels.
This is further distilled to produce light hydrocarbon, diesel and Asphalt/Bitumen.

Carbon Black: 300–350 kg
A solid residue used in rubber manufacturing, pigments, or as a fuel if converted into Briquette.
Steel Wires: 100–150 kg
Recovered from the tire's internal structure and can be recycled.

Pyrolysis Gas: 100–150 kg
A combustible gas mixture (mainly methane, hydrogen, carbon monoxide, and light hydrocarbons) often used to fuel the pyrolysis reactor itself.
Composition of Pyrolysis Gas
The gas typically contains:
Hydrogen (H_2)
Methane (CH_4)
Carbon Monoxide (CO)
Carbon Dioxide (CO_2)
Ethylene and other light hydrocarbons
This gas has a high calorific value and is often reused within the system to reduce external energy needs.

Fractional Distillation
Heating: Gradually heating the Tyre Pyrolysis oil to 250–280°C
Separation: Use a distillation column to separate fractions based on boiling points:
Light fractions (gasoline range)
Middle distillates (diesel range)
Heavy fractions (lubricants or carbon black feedstock)
Distillation Yield Breakdown:
Gasoline-range fractions (boiling point <180°C):
40–70°C: ~1.3%
71–120°C: ~6.35%
121–180°C: ~30%
Total gasoline-range yield: ~37.65%

Diesel-range fractions (boiling point 181–260°C):
181–190°C: ~4.5%
191–210°C: ~6%
211–260°C: ~20%
Total diesel-range yield: ~30.5%

Heavy-Oil – Heavy Oil contains mainly Bitumen or Asphalt, and further heating can also give Carbon black.

Composition Characteristics

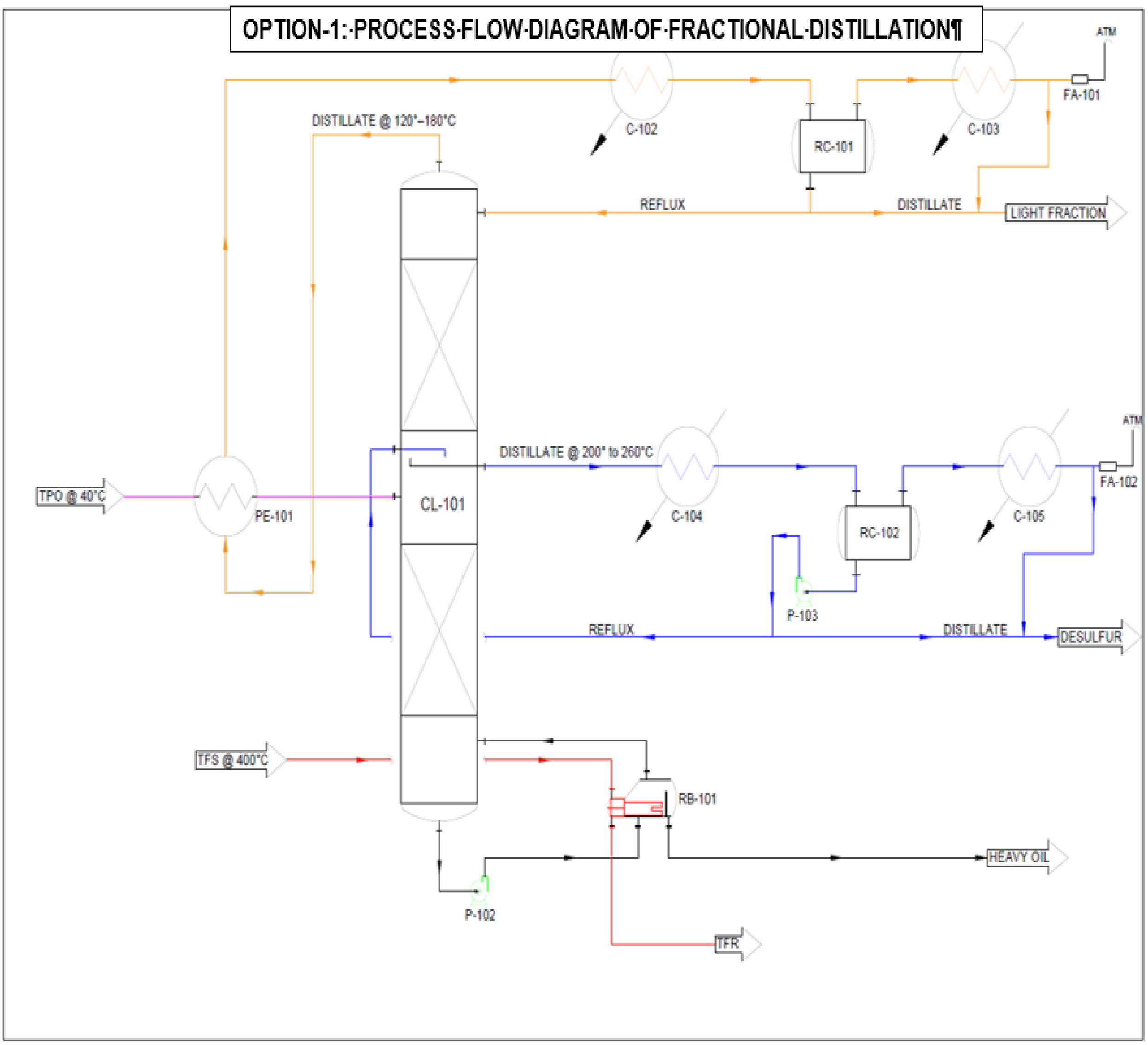
Gasoline fraction: Rich in aromatics like benzene, toluene, xylene, and limonene otherwise also called as BTEX (Benzene, Toluene, Ethyl Benzene and Xylene)

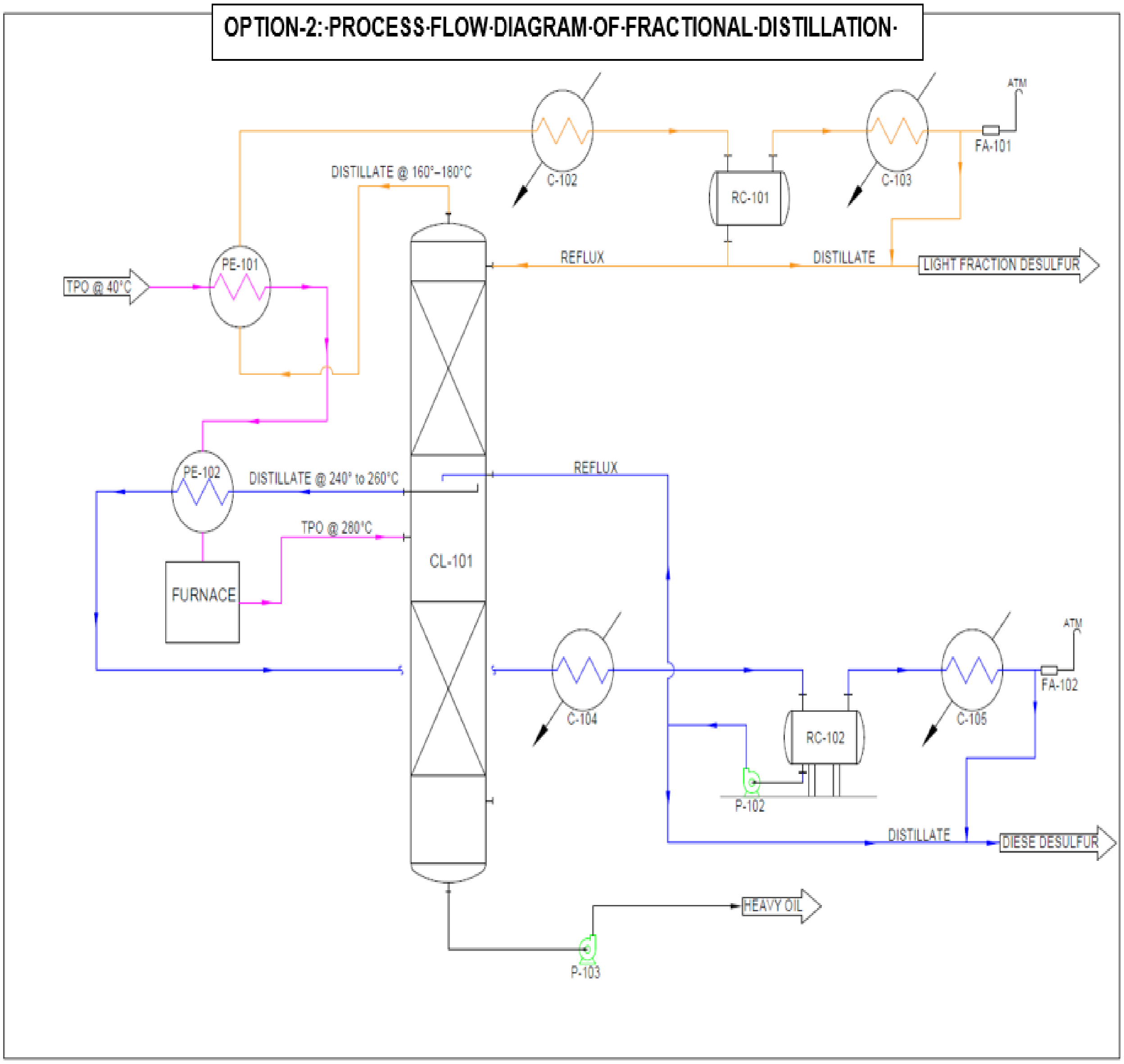
Diesel fraction: Contains long-chain aliphatic hydrocarbons, some aromatics, and sulphur compounds.

Process Flow Diagram of Factional Distillation

Option-1: It is a simple Distillation which contains Reboiler, Condensers and Distillation Column, TPO is heated in the Reboiler.

Option-2: This Process is more like a Crude distillation process, where the TPO is directly heated in the Heater before sending it to the Distillation Column.





OPTION-2: PROCESS FLOW DIAGRAM OF FRACTIONAL DISTILLATION

Oxidative Desulfurization (ODS) using Hydrogen Peroxide

Step by Step process of ODS:

Preparation of the Reaction Mixture

Diesel: Use high-sulphur diesel (e.g., 100 mL).

Hydrogen Peroxide (H_2O_2): Add ~10 mL of 30% H_2O_2.

Catalyst: Choose one organic acid:

Citric acid

Pimelic acid

α-Ketoglutaric acid

Catalyst-to-fuel ratio: Typically, 1:20 by volume.

Reaction Conditions

Temperature: Maintain at ~30–95°C depending on the acid used.

Stirring: Use a magnetic stirrer at 300 rpm.

Reaction Time: Let the mixture react for 5 minutes to 1 hour depending upon the Sulphur removal.

Mechanism: H_2O_2 oxidizes sulphur compounds (like thiophenes) into sulphones, which are more polar and easier to separate.

Separation of Sulphones

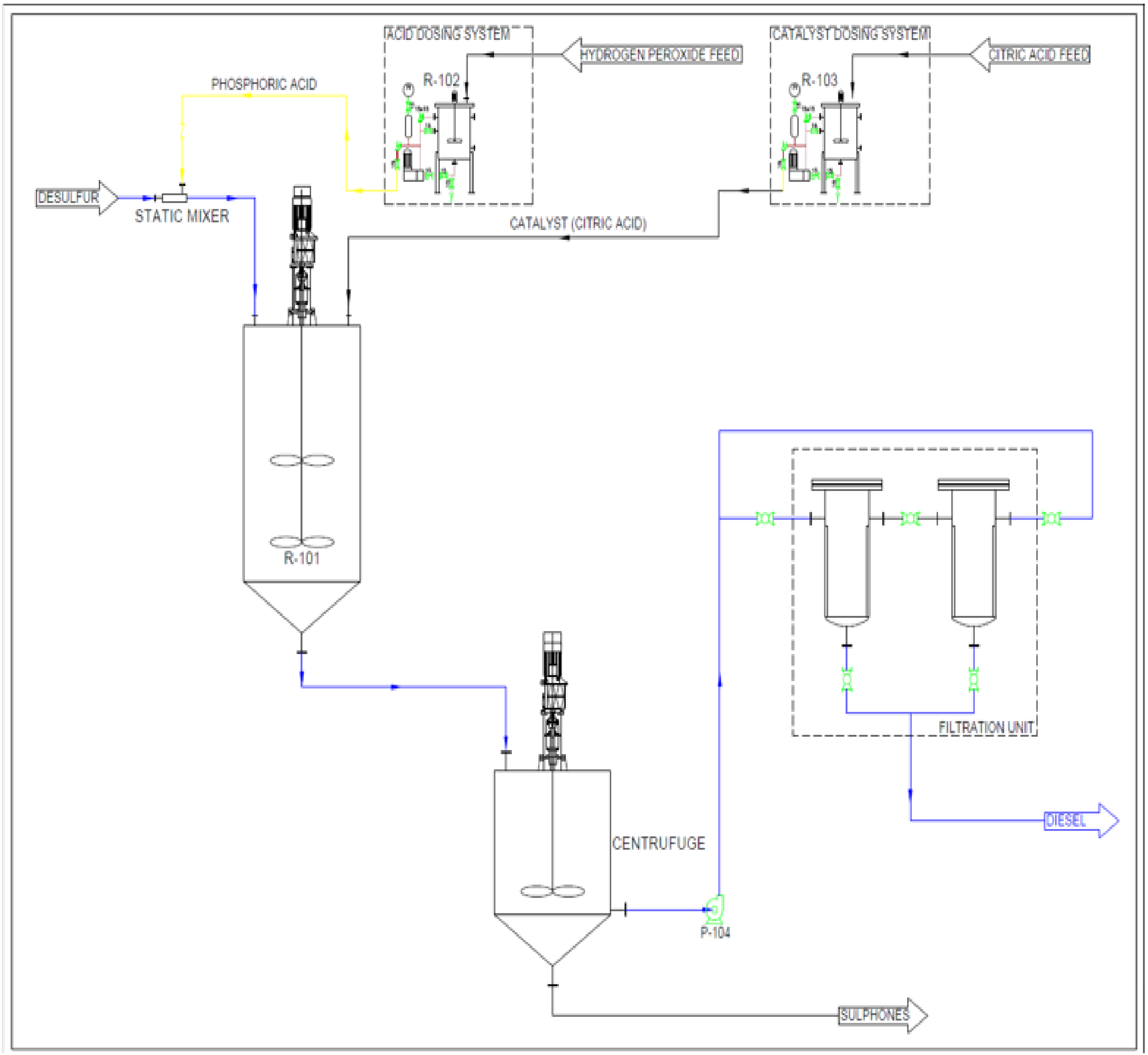
Centrifugation: Spin the mixture to separate sulphones from the diesel phase.

Post - Treatment

Filtration: Optional step to polish the diesel.

Drying: Remove residual water or solvent.

Process Flow Diagram of Oxidative Desulfurization (ODS)



III. CONCLUSION

The combined processes of pyrolysis, fractional distillation, and oxidative desulfurization demonstrate a viable pathway for converting waste tires into usable hydrocarbon products. The approach supports circular economy goals, reduces environmental impact, and provides an alternative feedstock for fuel production. Further research may include catalyst optimization, hydro-treating integration, and emissions analysis.