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Design, Fabrication, Manufacture &Installation of Pyrolysissystem For Waste Rubberpieces.

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ABSTRACT-The present study focuses on the design, fabrication, manufacture & installation &optimization of a 10 Ton capacity per day for a pyrolysis system for waste rubber pieces. This pyrolysis system generatesoil & gases as a final product. Itis used as an alternative option over furnace oil / LDO / Gases used for industrial heating. The indirectly heated furnace is initially fired by LDO. The furnace may run with PNG / LPG/ by product gas generated by the system / Electric heating as an alternative fuel by making necessary changes in combustion system only. The best option is to run on oil initially &turning on to by product of gas which is formed by the system itself to enhance better efficiency. The furnace called indirectly heated rotary reactor with maximum temperature of 450°C. The rotary shell is heated by means of heating chamber with refractory lining insulation & combustion system.

Combustion system is designed to achieve the required temperature of 550°C with better temperature uniformity inside the combustion chamber. Automation by Auto ignition &Auto temperature control system is done for safety & quality of the final product derived from the system. Raw material feeding is done @ 400kg/hr. with the help of Z type of bucket elevator. The final outputs arecarbon black &Hydrocarbon gases (condensed to oil). The additional credit is the project can be set up in an industrial area & finished product can be sold to nearby industries which saves handling cost over traditional purchase of oil. Economical final product & recycling of waste rubber like automobile tires are the key factors for consideration. Quality issues need to be considered while selecting the final product by the purchaser for their use.

Index Terms: Pyrolysis, LDO (Light Distillate Oil), Rubber, Rotary Reactor, Furnace, Combustion, Temperature, Recycle.

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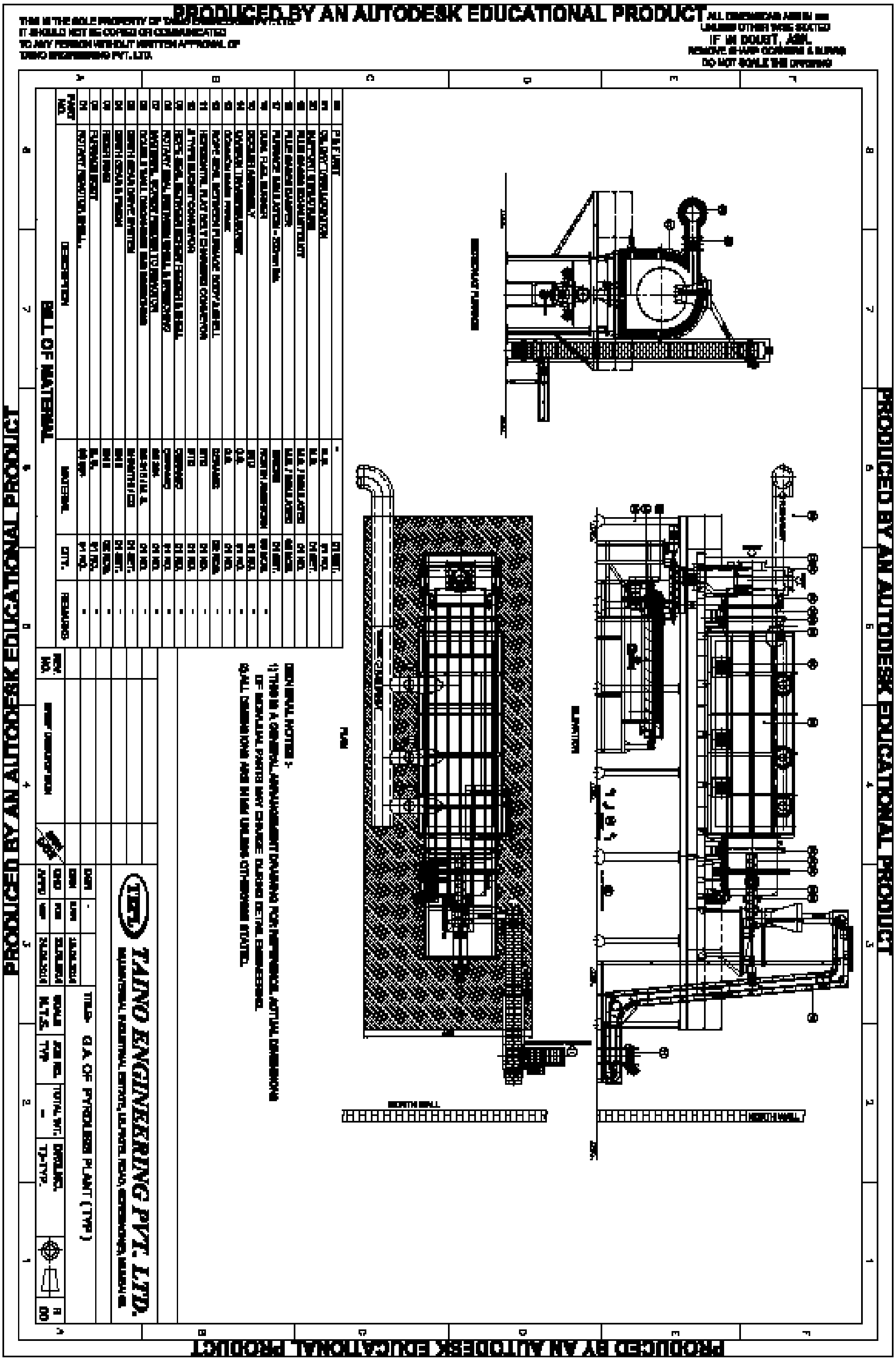
Fig. 1.1–Pyrolysis PlantPhotograph

Fig. 1.2 –GA (GeneralArrangement) Drawing of Pyrolysis System.



I. INTRODUCTION

Pyrolysis is a Thermo-chemical treatment or thermal decomposition of the material at elevated temperature which can be applied to any organic (carbon-based) product. In this treatment, material is exposed to high temperature, and in the absence of oxygen goes through chemical and physical separation into different molecules.

This allows receiving products with a different, often more superior character that original residue. Thanks to this feature, pyrolysis becomes increasingly important process for industrytoday – as it allows bringing far greater value to common materials and waste.

In contrary to combustion and gasification processes, which involve entire or partial oxidation of material, pyrolysis bases on heating in the absence of air. This makes it mostly endothermic process that ensures high energy content in the products received.

This project covers the use of waste rubber for example:used & non bio-degradableautomobile tires converted to oil by the end of the process. This final product is sold to many industries as a fuel for their industrial heating process.

II. DESIGN OF SYSTEM

The pyrolysis system consists of:
1 Raw material feeding equipment
2 Reactor with flue gas handling system
3 Carbon &Steel handling system
4 Hydrocarbon gas handling system
5 Oil handling system
6 Gas cooling system
7 Safety devices
8 Electrical & Instrumentation.

1. Raw material feeding equipment: Z type bucket Elevator
Capacity –To convey 500 kg/hr. of waste rubber pieces.
Belt width –400 mm
Inclination –30° appx.
Height of delivery –5M. Appx.
Belt drive – 1 hp

The Z type bucket elevator will be provided to transfer the rubber pieces from the ground to the hopper of the screw feeder. At the feed point a hopper will be provided for manual dropping of the material.At the ground level, horizontally, the buckets will carry the material at a distance of 1.5 mtrs...Then the material will be lifted to an elevation of 5mtrs...Again the bucket will travel at a distance of 1.5 mtrs.. The movement of the bucket will smoothly transfer the material into the hopper.

2 Reactor with flue gas handling system:
An Indirectly heated Rotary Reactor: Application for pyrolysis of waste rubber pieces40 mm max., bulk density 0.7 gm/cc, feed rate 400 kg/hr. with motorized screw feeder.
Technical specifications:
Shell temperature – 450°C
Combustionchamber Temperature– 500°C to 550°C.
Rotary shell size –5.5m³
MOC of shell – BQ.
Heating Chamber – Refractory lined, with consideration of above shell size.
No. of burners – 03 nos. Dual fuel.
Rotary drive – 5 hp motorized reduction gear unit with VFD.
Rotary speed –0.5 to 1 rpm step less control.
Fuel – LDO (starting)/ self-gas
Combustion system- burner, blower, pumping unit for firing 03 zones, LPG cylinder with pilot burner & UV flame detector &
independent burner control with digital temperature PID controller, Air/Oil ratiotrol, Air/Gas ratio regulator, Thermocouple.
h. Product output – Carbon black, Hydrocarbon gases condensed to liquid fuel.
Utilities–Power 400/440 Volt, 3 phase, 50 Hz,
AC supply.

Design / Installation / Commissioning – Description

Design of Combustion Chamber: Combustion chamber is designed by taking into consideration of rotary shell to accommodate the charge+ Combustion volume + furniture &access volume to handle the rotary shell smoothly.

i. Design of Combustion System: Combustion system is designed as per heat input required by using academics formula of heat transfer. (HI = MST/ 0.3*) * -Efficiency considered to be 30% considering heat losses.

ii. Design Of Piping–Recommended Pipe class for air is A, for oil is B & for gas is C for safety consideration. Further piping size can be calculated from academics formula of flow (Q = AV)

iii Design Of bucket elevator/ rotary shell / Other accessories – All fabrication work is carried out in-house with IS marking preferably to save on foreign exchange & cost.

Installation Work: Reactor shell and Tires/ Rollers– Reactor shell are fabricated from BQ material having 12 mm thickness. The shell issuitably reinforced &padded at required locations as per design requirement. The reactor shell is provided with flights w.r.t.to the travel of material in different configuration.The kiln shell is provided with two tires(rider rings)on extreme ends. The tires are totally machined & true for all its faces. These arefixed on shell with the help of supporting arms. The MOC of rider ring IS 2708 GrII. The tire location is properly engineered to take total load of the shell. These aresupported with 04 Nos. of rollers of IS 2708 Gr IThere will be 02 nos. thrust roller assemblies, to hold & guide the rotation of the shell axially.

Reactor Drive: The girth gear for providing the drive to the rotary shell will be mounted on the rotary shell at the charging end side. The girth gear will be mounted on supporting arms connected to the rotary shell. The drive system consists of electric motor, worm reduction gear box, heavy duty couplings, and pinion, to transfer the power to the main girth gear.

Furnace/ Heating / Combustion Chamber: The furnace chamber isfabricated from MS plate of 3 mm thickness, in rectangular form. It will be divided into two halves for easy mounting of rotary kiln shell...The furnace chamber will be suitably lined with refractory bricks on bottom & sides. Ceramic fibre modules in the upper circular half. The furnace wall thickness may be designed as per academic formula of heat transfer ($Q = K A dt/dx$).

Burners: 03 burners are required on the main furnace shell of capacity selected for as per heat requirement are located on one side for ease of piping &minimizing bends to reduce pressure drop.Similarly 03 nos. Flue gases outlets will be provided for outlet of flue gases.

Material Feeding: The material is charged inside the shell through a screw feeder. The bucket conveyor drops the material into the Hooper of the screw feeder .A slide gate valve above the nozzle of screw feeder to prevent the entry of air into the screw feeder & further to the reactor to maintain inert atmosphere.

Discharge end breeching: The discharge end breaching will be of double wall construction, duly insulated. The breaching will be mounted on sturdy supports & provided with nozzles for following purpose.

- To take away hydrocarbon gas for further processing.
- For discharge of carbon black.

Temperature Monitoring: The temperature will be sensed in three zones &at least 4 different points in the furnace chamber for the purpose of recording & controlling. The Temperature will be sensed at the discharge point of calciner & cooler.

Combustion System & Temperature control:It consists of

- 03 nos. Dual fuel burner.
- 01 no. centrifugal air blower 05 hp for combustion.
- 03 nos. Oil Solenoid valves.
- 03 nos. Gas Solenoid Valves.
- 03 nos. Air/ Gas ratio regulators
- 03 nos. Combination valves.
- 03 nos. Limiting Orifice Valves
- 03 sets of isolation valves for oil, gas & air.

The furnace temperature will be controlled by way of controlling the fuel to the burner. Initially firing is done with LDO. The temperature is controlled with Air/Gas ratio regulator. After the start of part of hydrocarbon gas generated from waste rubber, is supplied to the burner for firing & oil supply is cut off. The switch over is done manually& instantly.

Auto temperature control system: The pre-set temperatures for all the burners will be set as per the zone & process requirement. The safety controller is provided for each burner. In case of failure of the main PID controller, the safety controller will stop the power to the sequence controller.

The temperature of the reactor & chamber is controlled automatically by a thermocouple & PID temperature controller in conjunction with air/gas ratio regulator. Temperature attainment & control will be achieved by a closed loop system shown in flow chart 1.1

Auto Ignition & Flame monitoring system: Consists of

- 03 nos. Pilot burner
- 03 nos. UV sensor
- 03 nos. Solenoid valve for gas pilot
- 03 nos. Ignition transformer
- 03 nos. Air by-pass valve
- 03 nos. Gas by-pass valve

The auto ignition system will primarilyatomize the firing of the main burner in a specified sequence. It also includes monitoring of the main flame permanently& pilot flame temporarily during entire operations of firing. In the event of flame failure due to any reason, the sequence controller will make two attempts to start the burner. After failure of the same the sequence controller will shut off the gas solenoid valves &system will go in lock out mode. This lock out mode can be reset after analyzing the cause of flame failure.

Stack for Flue gases: 01 no. flue stack will be provided for exit of flue gases out of the furnace chamber. It will be self-supporting type. The stack will be provided with nozzles & inspection doors at the required level for testing.

Flue duct from the furnace chamber will be connected to the stack. The stack location is considered as maximum 20 mtrs. from theequipment. The ducting will be lined with insulating bricks or cast able.

3 Carbon & Steel handling system:

Carbon discharge screw: Carbon from reactor will be discharged by carbon discharge screw to the carbon cooler. The MOC of the carbon discharge screw will be carbon steel. It will be driven by a flame proof gear motor.

Carbon cooler:
Purpose – To cool carbon black.
Capacity (Input) –200 kg/hr.
Inlet material–carbon black from main reactor @ 0.4gm/cc.
Material temperature – Inlet 350°C max. & Outlet 50°C/60 °C
Cooling Media – Air.
Cooler Size –700 mm dia x 9000 mm length.
MOC of cooler – IS 2062

The cooler will be an indirect air octagonal rotary cooler. The shell of the cooler will be fabricated from carbon steel. The material will be received inside the cooler through the carbon discharge screw. The cooling will be effected by the octagonal shape which will be exposed to ambient air externally as the material travels from the feed end to the discharge inside the shell. Stationary breeching will be provided at the discharge end to discharge the cooled carbon black on to the horizontal conveyor.

Horizontal conveyor with magnetic separator: The carbon from cooler will be dropped on to the horizontal conveyor. The horizontal conveyor will drop the carbon into a pit of the size 4mtrs x 4 mtrs..While travel of the carbon on the conveyor, magnets will be provided to separate out magnetic materials from the carbon & then discharge them into a trolley.

4 Hydrocarbon gas handling system:This gas handling system is provided for handling the hydrocarbon gas generated in the reactor. The gas will be tapped out from the main reactor from the stationary breeching& there will be two parallel gas lines further connected to the onward system. The gas pipeline will be covered by a water jacket for the purpose of cooling hot gases. These gas lines will be connected to a gas tank1. There will be outlet nozzles in the gas tanks for oil & gas. Condensed oil will be tapped from the bottom.All the tanks will have provision to tap the oil from the bottom& they will be connected to common oil tank. The oil will flow from all the gas tanks to the oil tank by gravity.

Gas Fiters & Blowers: Gas filters &blowers will be mounted after the gas tanks to take out non condensable gases & forward them to burner for firing. One set of blower & gas filter will be standby for any maintenance work on the other. Thefinal gas tank will have two outlets. One outlet will be connected to the dual fuel burner through flame arrestor & gas filter. Required pressure switches, isolation valves, pressure gauges will be provided in the system & will be interlocked with each other for safety purpose. The other outlet will be to incineration chamber for burning of excess gases.

Oil handling system: Oil received from the gas tanks will be received by gravity & stored in an oil storage tank. The tank will have approximate capacity of 4000 liters. The tank will be provided with inlet, outlet nozzles, level gauge with contacts & drain valve. The tank will have a man hole for cleaning purpose. The tank will be fabricated from 5 mm thick carbon steel plates, suitably reinforced. This will be a horizontal dish end tank.

The oil tank will be connected to an oil pump which will transfer oil further to the one more storage tank of 4000 liters capacity.

Gas cooling system: A 150 TR cooling tower is provided along with centrifugal water pumps for circulation of the water for condensation of the gas coming out of the reactor. Water lines to & from the cooling towers are connected to the gas lines connecting all the gas tanks in the condensation system.

Water isolation & control valves areprovided at appropriate locations for the proper transfer of water in the system. The cooling tower will be located outside the shed on a water basin.

Safety Instruments: The safety instruments which will be mounted in the field for monitoring & control of the process are as under.
Pressure Transmitter– 02 nos.
Flame arrestor –02 nos.
Solid level switches – 02 nos.

Electrical & Instrumentation: Electrical Panel –The electric panel for the system will be of free standing type, made of sheet metal cubicles, dust & vermin proof, suitable for housing all the necessary switch gears for the complete system. The panel will have terminal strip for connecting incoming & outgoing cables, with proper identification. The panel will be completely powder coated before assembly of the switch gear &shop wired.

The electric panel consists of:

- On/Off Switch fuse unit.
- VAF meter.
- D.O.L. starter& VFD for reactor shell.
- D.O.L. starter & VFD for product screw feeder.
- 12 point Digital Temperature scanner.
- 03 nos. PID Temperature controller.
- 03 nos. Safety on/off temperature controller.
- D.O.L. starter for combustion blower.
- D.O.L. starter for oil pumping & filtering unit.
- 02 nos. D.O.L. starter for water pumps.

- D.O.L. starter & VFD cooler drive.
- D.O.L. starter for carbon discharge screw.
- 03 nos. Starters for modulating motors.
- 02 nos. D.O.L. starter for gas blowers.
- D.O.L. starter for magnetic conveyor.
- D.O.L. starter & VFD for carbon conveyor.
- D.O.L. starter & VFD for Z bucket elevator.
- Indicating lamps & control switches

Burner Control Panel:

As the name suggests, this control panel is used for startup operation & shutdown of burners. This is mounted on the support platform of the reactor. It consists of Sequence controller, Indication lamps, MCB for isolation, Push button and Selector Switch.

Utilities required @ end user:

- Power supply – 400/440 V, 50 Hz, 3 phase AC supply.
- HP – 60 HP power required for the system.
- Fuel – LDO for initial startup.
- Water –For cooling tower.
- Compressed Air – 5 kg/cm2.

Estimated cost of the system – Rs. 1,18,00,000/-*
*Terms & conditions apply.

Total heat input required for the furnace is calculated with the universal formula of heat input required.

$$\text{Heat Input} = \frac{\text{Mass} \times \text{Sp. heat (rubber)} \times \text{Temperature}}{\text{Furnace efficiency} \times \text{Cycle time}}$$

= 400 x 2.2 x 0.48 x (1000 - 50) / 0.3 x 1
=33.44 LPH*
= 33.44x Factor of safety (1.5)
= 50.16 LPH (Firing capacity of all burners in liters per hour).

*Std. numerical values in required units.

Hence03 burners of 16.72 LPH capacity maximum to 6 LPH** minimum each are selected&installed on one side ofthe Furnaceto heat up the charge to the required temperature.

**** -** The necessary turn down 1:3 is required once the maximum temperature is reached. The furnace initially to be fired on oil & once the gas is produced; it can be switched over the self-gas generated by the system.

Commissioning: The Furnace was ready to start. Initially all equipment checked for proper heating, maintaining uniform pressure & supply of Air &oil/gas through piping. Then elevator functioning is checked for supply of rubber pieces inside the reactor. Proper functioning of mechanical equipment checked prior to loading of the charge. Initial trial of burner without load is also done to ensure proper heating &generate theheat inside the combustion chamber. Leakages in the piping line were arrested. Supply of signals through control panel to all equipment is checked. After checking is over the commission is done is following steps.

i. All mechanical &electrical operations were checked.

ii Door opening & charge is placed inside the reactor to start the process.

iii. Purging is done to escape any trapped gases inside the combustion chamber.

iv .Oil supply is started in the ring main to ensure uniform pressure in the ring main by keeping oil valve closed at burner point. Blower pressure to the burner is checked. The blower is started initially for 02 to 05 minutes by opening all valves. Then by adjusting air/oil supply less than ¾ opening, sequence of auto ignition followed to start all burner. On reaching ignition point burner are fired with main supply & pilot supply of LPG is closed automatically by sequence controller. The firing is done on high fire during starting. After reaching required temperature in the combustion chamber & inside the reactor as well the burners are turned down on low fire automatically by controlling air flow through PID controller & then impulse line from air piping to the air/oil ratiotrol which is diaphragm type valve controls the oil flow also. Thus burners are turned on low & high fire automatically depending upon temperature requirement inside the furnace. The charge (waste rubber pieces) gets heated & in the absence of oxygen the decomposition of the charge occurs.

v. Water circulation through cooling tower through necessary piping ensures condensation of gases & formation of oil in the tank scientifically.

vi Once the output of gas & oil is started, the burners can be switched over instantly to self-gas generated by the system. The maximum temperature requirement in the furnace chamber is 550°C & around 450°C inside the rector to achieve perfect decomposition & necessary output.

vii All interlocking &functioning of all equipment's needs to be monitored continuously with the help of temperature, pressure flow measurement by digitally or analog means.

viii Monitoring of system continuously is an essence & important for term running of the system & safety point of view.

OBJECTIVEOFTHEWORK:

Decomposition for Bio green solution & recycling are the key aspects. Further there is continuous price inflation in the market of crude oil. This could be an alternative as a resource & economy. Finally this is business opportunity for those who are already having their operations & require oil in industrial area to save on transportation cost also. Development over the current trend &Economy of world society are the important objective of the work.

Temperature Control: The most commonly control process parameters which are measured & monitored /controlled are temperature & pressure in all kind of furnaces.

Temperature control system consists of the following elements:

- Temperature sensors
- Controllers
- Heating Elements for heating the Furnace Electrically.
- Control equipment of Automation

SENSORS:

Temperature:

i) Bi-metallic strips: Uses the difference in coefficient of thermal expansion of two different metals. The principle is used in simple thermostats.

ii) RTD: Resistance of most metals increase in a reasonably linear way with temperature. Resistance measured is converted to temperature.

iii) Thermocouples: The thermocouple is based on the thermoelectric effect/e.m.f. generated when two conductive wires of different metals at different temperatures are connected to form a closed circuit. In classical physics this is known as siebeck-peltier effect.

Because of the wide range of temperatures covered, good sensitivity to change of temperatures and linearity of output [over a wide span of temperature], thermocouples is widely used for measurement of temperature.

The composition & maximum use temperatures for various standard thermocouples are given in the Table1.1.

Type	Composition	Useful Temperature range [°c]
J	Iron - Constantan	-180 to +760
T	Copper - Constantan	-200 to +350
K	Chromel - Alumel	-180 to +1200
R	Pt-Pt/Rh 13%	0 to 1400
S	Pt-Pt/Rh 10%	0 to 1450
B	Pt/Rh6% -Pt/Rh30%	0 to 1700

Table 1.1 – Types of Thermocouple

B] Fluid flow measurement:

Differential pressure method:Most widely used method of measuring fuel/air flow in furnace. Common instruments Orifice plate, Venturi tubes etc.

Direct flow measurement: Equipment used are Rota meter, Turbine meter, Vortex flow meter etc. Under very special case ultrasonic flow meter may be used.

CONTROLLERS:

In closed loop temperature control the temperature is measured by using a suitable sensor. The controller compares the temperature signal to the desired set point & actuates the final control element. The final control element varies the amount of heat added to the process by varying power supply to heating elements.

Four types of control actions are

- ON/OFF [Two position]
- Proportioning [Throttling]
- Proportioning plus integral [Automatic reset]
- PID [Rate]

CONTROL VALVES:Control elements popularly used are automatic flow control valves. The valves may be motorized /pneumatically operated & work in conjunction with controller signal. Mechanically operated diaphragm type fuel flow control valves commonly known as ratio regulating valves are widely used in volumetric flow control circuits. Pressure control scheme of a furnace works on a principle similar to temperature control scheme. The entire temperature control system is done though a linking of thermocouple inside the combustion chamber, PID controller & power supply to the heating elements.

The requirement of the job was to achieve the desired temperature& creating the inert atmosphere inside the reactor so as to achieve proper decomposition of waste rubber pieces.By controlling the temperature inside the furnace, efficiency of the furnace was increased when the furnace was loaded with full capacity & in operation.

Heat Losses: At high temperature, the dominant mode of heat transfer is wall radiation. The heat losses should be minimum to increase the furnace efficiency. This is done by maintaining the proper insulation in refractory lining - Ceramic module 160 kg/m3 density for temperature 950ºc to get required refractoriness & minimum heat losses from the furnace wall. Further heat leakages thru' doors, furnace wall opening were arrested by sealing to upgrade the furnace performance.

For oil/gas firing, control of exhaust flue needs to be done by placing the damper in the passage of exhaust flue & controlling the same by closing the passage of exhaust flue. Initially the damper closed the ¼ passage & results to be checked which can shows the improvement in fuel saving. The action repeated by closing the damper till maximum improvement is done.

By arresting leakages through various openings, controlling the Damper of exhaust gases, Proper Insulation etc., efficiency of the furnace was optimized while the furnace was loaded with job & in operation.

III. FINAL RESULT:

The self-gas& oil is generated from waste rubber pieces by necessary decomposition at elevated temperature.

IV. CONCLUSION:

This research &study of formation of oil & gas through recycling of waste rubber pieces has proved again that the recycling process is nature's law. Moreover there is a business opportunity for aspirants who are searching for doing business in this line & thereby help the society to offer employment & grow comfortably.

Decomposition of many materials can be done to generate resources artificially rather than naturally only. Plastic is also such material where study is required to solve the current issue of disposal of wastage.

SCOPEOFFUTURESTUDY

Better quality product needs study &understanding of operating temperature, cycle time, and impurity content. It is suggested to trial of using the furnace with other fuels.

RECOMMENDATIONS

There is always scope of further development. In order to improve on the design, it is recommended to the end user to monitor the operation of furnace continuously& find further feasibility to improve furnace efficiency.

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FACTORS FOR OPTIMIZATION

Design of combustion system, temperature control, incomplete combustion(for Oil/Gas fired furnace), design of combustion chamber, design of wall thickness, design of chimney, heat losses, overall equipment effectiveness are major consideration while designing any furnace.

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FEASIBILITY REPORT 10 TONS / DAY WASTE RUBBER PIECES

A] PLANT EXPENDITURE

S.N	Description	Cost (`)
1	Plant Equipment's	15,000,000.00
2	Erection &Commission	3,000,000.00
	Total	18,000,000.00

B] WORKING CAPITAL / MONTH

S.N.	Description	Cost (Rs`)
1	Raw Material (Rs 15 / kg).	3,900,000.00
2	Manpower	240,000.00
3	Consumable & Maintenance	75,000.00
4	Electricity Charges	80,000.00
5	Administrative Cost	50,000.00
Total		4,345,000.00

Manpower Details

S.N.	Description	Qty.	Salary (`Rs.)
1	Shift Engineer	8	25,000.00
2	Operator Cum Fitter	3	46,000.00
3	Electrician	2	30,000.00
4	Labour	8	80,000.00
5	Office Assistant	1	20,000.00
6	Miscellaneous		39000.00
Total			240,000.00

C] ESTIMATED PAY BACK

1	Revenue Per Month	
i)	Oil (Rs. 50 / kg.)	5,850,000.00
ii)	Carbon Black (Rs.3.5 / kg.)	345,800.00
iii)	Steel (Rs. 10 / kg.)	260,000.00
Total		6,455,800.00
2	Net Profit Per Month	2,110,800.00
Net Profit Per Year		25,329,600.00
3	Pay Back Period (Years)	0.71* Appx.

* - Payback period may vary on plant efficiency, Resources availability, market trends&other factors.

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