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Residual gas recycling at waste tyre pyrolysis plant

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Abstract
The Pyrolysis is an useful technique for recycling of scrap tyre into (i) Fuel oil (40%-45%), (ii) Carbon black (30%-40%), (iii) Steel wire (10%-15%), (iv) Residual Gas (8%-12%). Out of Four components as recovered from Pyrolysis process, first three are well established, recovered & utilized successfully whereas fourth component that is residual gas is partially recycled and partially vented into atmosphere causing air pollution and loss of energy value.
This paper study aims to find out composition and caloric value of residual Pyrolysis gas, identify opportunities to recycle, realize its energy value and minimize discharge into atmosphere thus avoid air pollution.

Keywords: Pyrolysis, waste tyre, Pyrolysis gas, residual gas

Introduction

Every year over one billion tyres are manufactured worldwide, and equal number of tyres is permanently removed from vehicle, become waste.
According to reports, globally 15 million tons of waste tyres are generated annually, out of which India contributes one million tones [1].
The Pyrolysis technology provides opportunity of recycle of such huge quantity of waste tyres into useful end products. The Pyrolysis is a thermo-chemical decomposition of organic material at elevated temperature in the absence of oxygen [2].
The thermo-chemical decomposition of waste Tyre result into formation of gases, these gases are passed through condensers placed in series to condense gases and recover condensed liquid as liquid fuel oil.
Pyrolysis of Tyre has been established for many years but it is currently receiving renew attention due to increasing price of conventional fuel and more awareness on waste recycling and pollution prevention.
The gas obtain from outlet of the reactor is defined as pyrolysis gas (synthetic gas) where as the gas obtained from outlet of the condenser is defined as residual gas.
The products obtained from Pyrolysis of waste Tyre are mainly:

Fuel oil (40% to 45%):
The product liquid consists high gross calorific value 44 Mj/kg [2-5]. Which could be encouraging their uses as conventional fuel, added to heavy oil generator to produce electricity, transferred into diesel or gasoline oil distribution equipment. Fuel oil is having high caloric value and it mainly contributes to the commercial viability of the waste tyre recycling plant.

Black carbon (30%-35%)): This is used for various industrial application like printer ink, upgraded for used as activated carbon or black carbon etc.

Steel wire (10%-15%): This is used in various metal industries as raw material and easily sold in the market.

Residual gas (8%-12%): In a batch type pyrolysis plant, the process is initiated through external fuel and once the thermal decomposition started, the residual gas is recycled back to maintain the temperature in the reactor and external fuel uses are stopped.

But the process does not require full quantity of the residual gases and some surplus volume is vented into the atmosphere. Similar situation occurs with continuous type of waste tyre pyrolysis reactors. The release of residual gas into atmosphere causes air pollution and spread pungent smell in the surrounding atmosphere. This is a normal practice at all tyre pyrolysis plant to recycle the residual gas partially without knowing its calorific value and exact composition.
In this paper efforts have been made to arrive at accurate composition and caloric value of the residual pyrolysis gas so as to realize its value and more efforts may be made in recycling the fraction of residual gas that is presently being vented out by the plant operators.

Method and material
This paper present a case study of a prototype plant installed for recycle of residual gas at one of the batch type pyrolysis reactor located in Mumbai, India, and study data are presented:

Proto type set up
The pyrolysis gas after condenser is diverted into either atmosphere or to the reactor through a water sealed vessel & valve arrangement. From this vessel outlet pipe that takes gas to reactor furnace, a three way valve installed to divert residual gas either to the reactor or to a horizontal cylindrical balloon for storage of surplus residual gas with the objective to avoid its release into the atmosphere and recycle it when reactor cycle of operation commences The valve arrangement is shown under figure 1.
From the balloon stored gas is drawn out by using a roots type gas blower that generates pressure of 1000 MMWC to 5000 MMWC. The blower operation was kept on auto through a pressure switch installed at the discharge bottle just at the outlet of blower.

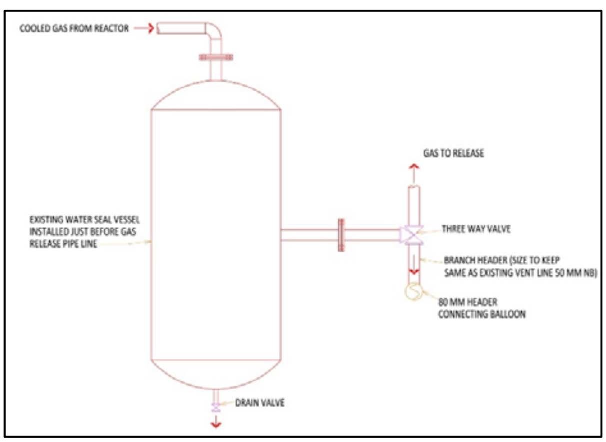

Fig 1: The valve arrangement

The gas via three way valve is transferred to the balloon when this gas is not required at the reactor. With this arrangement the venting of gas is avoided and buffer storage of the residual gas is created in the balloon.
The arrangement is described as process flow diagram under figure 2

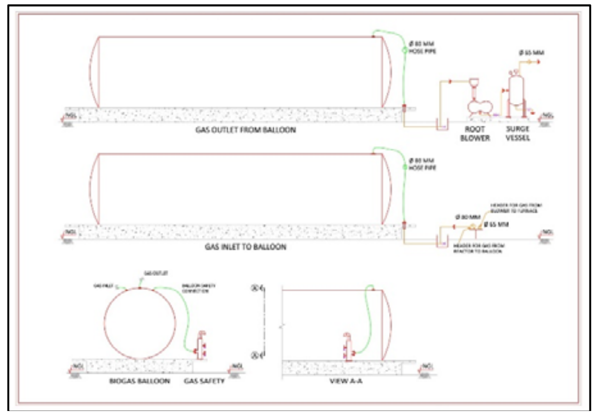

Fig 2: Process flow diagram

This gas from the balloon is transferred to the reactor with the help of root type blower and connected with the reactor furnace with manual isolation valve.
The transfer of gas from balloon storage system to the reactor was operated manually by operating ball valve as and when required to achieve desired temperature inside the reactor
This arrangement resulted into saving of wood fuel that was required to commence the heating cycle and entire wood fuel requirement was eliminated. The per batch wood required was 1200 to 1400 kg, having calorific value of 3000-4500 Kcal/kg, There was no direct measurement available for the quantity of residual gas transferred into the reactor, however a rough estimate of gas recovered and utilized was obtained from the cylindrical balloon hold up volume, that was 200 SM^3 and the entire volume was consumed in reactor during each cycle at the beginning of firing of cycle and eliminated the use of external fuel (wood).
Similarly there was no direct measurement available for quantity of gas diverted from water sealed vessel to balloon however estimate of quantity was obtained from the volume of the balloon and found that from each cycle of operation full balloon was filled that is equivalent to 200 SM^3. This quantity of gas is received from the system when batch size of the reactor is 9.0 to 10 tons of tyre per batch.

Data analysis
The data are available for the Pyrolysis gas that is the gas at the outlet of reactor, same is reproduced under table no.1

Table 1: Composition of Pyrolysis gas at outlet of reactor [3-4].

Composition of Pyrolysis gas at outlet of Reactor in %					
S No.	Gas type	Composition at different reactor temperature (°C)			
		500	600	600-800	above 800
1	CH4	24.18	7.12	8.63	9.4
2	CO	6.24	0.38	0.65	0.82
3	CO2	8.23	0.18	0.19	0.21
4	C2H4	7.4	5.33	6.8	4.48
5	C2H6	9.28	0.2	0.48	0.56
6	C2H2	-	0.29	0.36	0.89
7	C3H8	6.21	0.71	0.97	0.52
8	C4H10	18.28	0.59	0.62	0.39
9	H2	11.71	6.95	12.31	18.1

Residual gas composition determination
The composition of pyrolysis gas is studied and found that only few gases are getting condensed and most of the gases are not possible to condense due to their very low condensation temperature. Such low temperature does not

prevail at reactor- condensers. The table no. 2 is listed with the details of gases not possible to condense and that are travelling beyond the condenser as it is.
The mixture of all such gases is defined as residual gases.

Table 2: Composition of residual gas

Composition in Volume of residual gas /Kg of tyre at outlet of the reactor (Nm3/Kg)					
S. No	Gas Type	Composition at different reactor temperature (°C)			
		500	600	600-800	above 800
1	CH	0.36197605	0.10658683	0.129191617	0.1407185
2	CO	0.05356223	0.00326180	0.005579399	0.0070386
3	CO2	0.04467970	0.00097720	0.001031488	0.0011400
4	C2H4	0.05873016	0.04230159	0.053968254	0.0355555
5	C2H6	0.07341772	0.00158228	0.003797468	0.0044303
6	C2H2		0.00265568	0.003296703	0.0081501
7	H2	1.30255840	0.77308120	1.384701912	2.0133481
					6
	Sum	1.89492425	0.93044657	1.581566841	2.2103815
					4

The above data are derived from table no.-1.The condensers at the pyrolysis plant are using cooling water and maintaining a space temperature of 70 degree centigrade, therefore all those gases that are having condensation temperature above the operating temperature of 70 degree centigrade are assumed to be condensed and converted into the liquid oil and balance gases are taken into consideration for the residual gas composition.

Residual gas caloric value determination

The individual gas calorific value and their density are taken from engineering tool box [7]. Based on these value the composite gas calorific value that represent the residual gas, is determined based on the data as listed in table no. 1 & 2.
The calculated calorific values of the residual gas at various operating temperature of the reactor are listed under table no.3

Table 3: Caloric value of residual gas

caloric value of residual gases after condenser in Kcal/sm3		
S.N	Reactor Temperature in °C	C.V (Kcal/m^3)
1	500	4471.916847
2	600	3774.624843
3	600-800	3462.598013
4	above 800	3163.06485

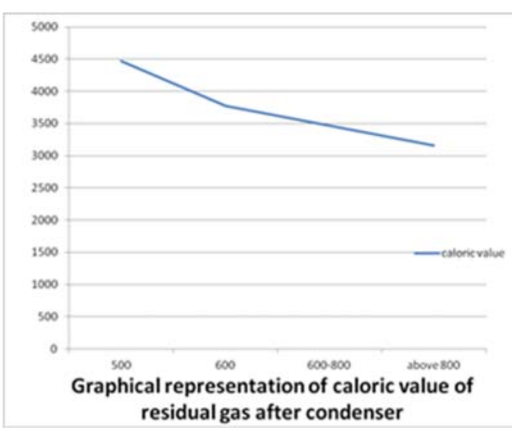

Fig 3

Result and discussions

Table 3 and figure no.3 provides a clear pattern that there is a decreasing CV in the residual gas with the increase in operating temperature of the reactor. As per site study of existing tyre recycling Pyrolysis plant they are mostly operating at reactor temperature of 500 to 650 degree centigrade, at this temperature the calorific value of the residual gas is ranging from 3774 to 4471 KCal/SM^3. This is a very good calorific value and paper study suggest to use it for captive use to eliminate external fuel as being used to initiate heating with in the reactor at the beginning of the process.
The prototype set up as tried by one of the plant owner got failed just in one month of its operation due to reaction of gases with the balloon material. The first failure occurred at the joints and later on coating from the fabric surface of the balloon also got reacted and started leaking.
The reason for reaction of gas with balloon was analyzed and found that H2S is getting condensed and liquid carried forward along with the gas in balloon. The resulting liquid out of the condensation taking place across pipe line as well as balloon is highly corrosive and reacting with the balloon.
The system therefore scrapped after operation of three month, however use of residual through balloon recovery system for this period of three months paid back the cost of system by elimination of external fuel. The reduction in release of residual into atmosphere was another significant benefit noted. This paper suggest to work further on development of sustainable residual gas recycling system to achieve above benefits in a consistent manner.

Conclusion

The study concluded that Quantity of residual gas produces per MT tone of tyre = 1894.92 SM$^{3/}$Kg.
Caloric value of residual gas when reactor is operated between 500°c to above 800°c = 3700 to 4500 Kcal/M^3.
The gases that contributes to the heating value in the residual gas are

S. No	gas	Composition (%)
1	CH_4	11.27
2	CO	0.96
3	C_2H_4	3.16
4	C_2H_6	1.12
5	C_2H_2	0.23
6	H_2	82.61

These are the comparison in residual gas when reactor operated between 550°c to650°c.
The condensation of corrosive gas is the barrier for achieving sustainable recovery of the residual gases for thermal application within the pyrolysis plant as captive use in the set-up tried with PVC coated balloon type storage system.
It is therefore concluded that storage system with metallurgy that should be resistive to the corrosive liquid, the emulsion of water, H_2SO_4, & oil fraction may be used.
The study suggest to continue efforts for development of sustainable residual gas storage and utilization system looking into huge potential saving of conventional fuel and avoidance of corrosive, toxic, green house gases emission into atmosphere.

References

1. http://rubberasia.com/2016/06/11/need-to-regulate-end-of-life-tyres-market-in-india/https://en.wikipedia.org/wiki/Pyrolysis.
2. Bianchi M, Bortolani G, Cavazzoni M, De Pascale A, Montanari I, Nobili M *et al*. Preliminary design and numerical analysis of a scrap tires pyrolysis System Energy Procedia. 2014; 45:111-120.
3. Natália Jasminská, Tomáš Brestovič, Mária Čarnogurská. The effect of Temperature pyrolysis process of used tires on the quality of output product.
4. M/s Shreyans Energy P Ltd, Caravs, 15, Civil lines, Jabalpur MP 482001, P +91 9300644224, F +91 761 2678784, www.shreyansenergy.com
5. Royal Carob Black P Ltd, New Era House, Mogul Lane, Matunga (W), Mumbai-400016
6. www.engineeringtoolbox.com/gas-density