

IMPROVEMENT OF PRODUCER GAS QUALITY BY STEAM INJECTION IN GASIFICATION PROCESS: A REVIEW

¹Henish Maheta, ²Kandarp Kavishwar, ³Darshit Upadhyay

¹Research Scholar, ²Research Scholar, ³Assistant Professor

^{1,2}Mechanical Engineering Department,

^{1,2}Nirma University, Ahmedabad, India

Abstract— Owing to the increasing requirements of fossil fuel for electricity generation, it is necessary to move to another alternative fuel sources. Gasification is one such process which uses carbonaceous feedstocks such as biomass, agriculture waste, industrial waste, etc as input. This technology is ideal for offgrid electricity and may helpful in rural electrification. In spite of very old technology, several challenges are facing with this system mainly contaminants in producer gas such as tar, particulates, dust, soot etc. **Higher the hydrogen content and lower the tar content are expected in producer gas**, Steam gasification is one of the effective technique which can fulfill these requirements. Different fuels and gasifier system are compared and analyzed for optimum conditions in order to obtain the maximum hydrogen content and minimum undesired products. Producer gas components and tar are the major parameters which are compared for various system.

Keywords: gasification, steam injection, producer gas quality, tar

I. INTRODUCTION

1.1 Energy Scenario

With the rising population, the energy resources are used at an alarming rate. It is well known fact that the non-renewable resources would get exhausted. The present energy scenario of energy resources is much dependable on the non-renewable resources.

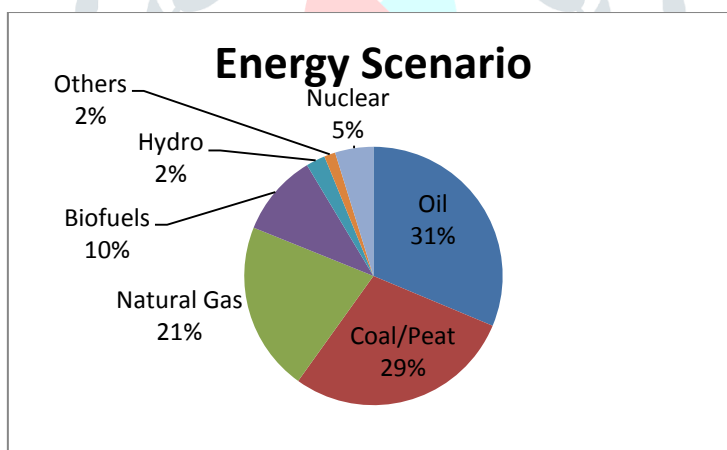


Figure 1 The world energy Resources scenario [1]

According to International Energy Agency (IEA-2016), 13699 Million tonnes of oil Equivalent (Moe) thermal energy was produced [2]. The major energy resources for consumption are the oil (Petrol, Diesel) and coal (Electricity in Power plant) which account for 60% of the total energy resources. The solar energy is only 1% of the total energy resources. It is discouraged due to high initial cost as well as dependency on radiation.

Observing the above energy distribution, it can easily conclude that the renewable resources have very good potential and easily meagre 20% of the total energy resources. One of the fastest growing country, India is the third largest coal producer in the world with a share of 8% in the total coal production but it is also the fourth largest coal importer of the world. This data shows the heavily dependency on coal. With the growing population, it is expected that the non-renewable resources would get exhausted by 2050. This is a warning to start looking for alternative resources for the energy requirement. [3].

In a developing country like India, where there is absolutely no electricity in some parts of the country. It may due to absence of power grid in few interior areas where power grid is not much feasible. Stand-alone off grid gasifier may help to provide the energy source for basic electricity needs.

1.2 Gasification

Gasification is a process of converting solid carbonaceous biomass such as organic waste, agriculture waste, industrial waste, kitchen waste etc. into producer gas. This gas is a mixture of nitrogen, hydrogen, carbon-monoxide, and carbon-dioxide [4]. As this gas is rich in H₂, it can be utilizing in fuel cell. [5][6]. It may also possible to get liquid hydrocarbon fuels or chemicals by the Fischer-Tropsch synthesis method [7][8]. Gasification process is generally taken place at higher temperature and less air is involved in reaction compared to combustion process [9]. During World War II, gasification technology was widely developed because of the shortage of petroleum products.

Growth of this technology was reduced due to cheaper petroleum fuels available after year 1950s. Gasification process is again boom in market nowadays as cost of depleted petroleum product hikes continuously [10].

The advantages of gasification is that the syngas obtained in the process can be combusted efficiently to get the highest value of fuel, so that the thermodynamic upper limit to the efficiency defined by Carnot's rule will be higher. Producer can be converted directly into combusted product by combusting it with oxygen or converted via the Fischer–Tropsch process into synthetic fuel. This process is also possible with waste products as it is converted biomass to useful product. In addition, the high-temperature process refines out corrosive ash elements such as chloride and potassium, allowing clean gas production from otherwise problematic fuels. Gasification of fossil fuels is currently widely used on industrial scales to generate electricity.

Major aim of this paper was to study the effect of steam gasification by various parameters. In this paper, parameters such as gasification temperature, gas composition, tar etc. were compared for different gasifier. Effect of steam injection and role of catalyst were also studied.

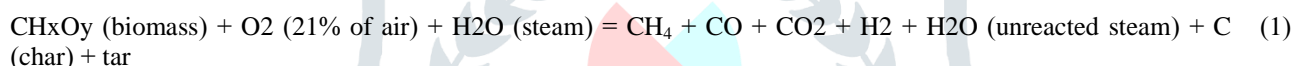
II. PRODUCER GAS POLLUTANTS AND DIMINISHING METHODS

Being a century old technology, gasification process is not much matured process. Limited uses of gasifiers are generally found in ceramic or rubber industries. For electricity generation, gasification process is rarely used. It may due to its higher pollutant contaminant such as tar, particulate matter (pm), dust, soot etc. Among these pollutants, tar is a major contaminant drawn from gasification process. Tar is a complex mixer of combustible hydrocarbon which is carried by producer gas [11]. Tar can create various problems at the downstream of gasifier by choking and plugging as it condenses at lower temperature. Higher amount of tar can create unacceptable maintenance to engine or generator system.

There are various way to diminish tar such as physical, non-catalytic, catalytic, steam gasification etc. Air used as an oxidizer is called air gasification while steam used as an oxidizer is called steam gasification. Steam gasification will helpful not only to destruct tar from producer gas but intuitively it has potential to increase hydrogen yield in producer gas. At higher temperature, hydrogen and oxygen molecules are separated from steam. Hydrogen is helpful to increase calorific value of producer gas while oxygen is helpful in complete combustion of solid feedstock. These are the reason behind higher calorific value of producer gas as well as clean producer gas when steam is injecting in gasifier reactor [12].

Pure air or steam, steam and air, steam and nitrogen are the various oxidizer which are generally used in gasification process. For fixed bed gasifier, combination of steam and air as an oxidizer is preferable as compared to pure steam. It may due to the fact that steam reduces combustion zone temperature which may restrict rate of reactions in gasifier. For different fuels, there are different optimum temperature, different steam to biomass ratio and different catalyst requirements for maximum hydrogen content and tar minimization [13].

Following reactions may occur during gasification process when steam is injected to the combustion chamber of gasifier reactor [14].



Influence of steam on gas quality depends on various factors such as gasifier reactor, gasification medium, biomass/fuel ratio, temperature, pressure etc. It is generally preferred to keep optimum temperature of combustion zone is 850°C. Higher the temperature of the steam, better the gasification reactions. However, a very high temperature of the steam also affects the process as it interferes with the reactions and gives lower heating value.

Steam gasification is only advantageous if steam is available at free or very nominal charge. In medium or higher scale gasifiers have capability to generate low pressure steam by keeping water jacket surrounding to the gasifier reactor. Moreover some process industries have excess amount of steam that are thrown to atmosphere. Using this surplus steam as an oxidizer will boost gasifier performance. Steam gasification could not be beneficial if steam is produced from a high energy source. It is because of the fact that energy which is used to generate steam such as electric steam generator etc. is not compensate by the energy obtained from the gasifier by steam injecting

III. COMPARISOM OF VARIOUS PARAMETERS IN STEAM GASIFICATION

From table 1, it was observed that feedstock such as pine particles has lower tar content (10.2 mg/m³ at S.T.P) and sewage sludge has higher tar content (46 mg/m³ at S.T.P) when used as a feedstock in gasifier reactor. Hydrogen yield was found better when pyrolysis char was used as a feedstock and Ni-Al oxide (75%) as a catalyst whereas sewage sludge as a feedstock was responsible for lesser hydrogen (24.2%) yield in producer gas. From, these results, it was noticed that sewage sludge is not much preferable feedstock for fluidized bed gasifier, however as it is waste product, more research is required such as use different catalyst for maximizing calorific value and minimizing pollutant level in the producer gas etc. Catalysts like Ni-Aluminum oxide, Ni-Magnesium oxide, Ni-Dolomite, Potassium chromate, Ferrous oxide-Cerium oxide enhance the hydrogen yield. Catalyst was also helpful to increase rate of reaction which may boost temperature as well as gas yield in gasification system. Highest Tar conversion efficiency (98%) was achieved when algal biomass was used in presence of steam + nitrogen as gasifying-agents.

The least amount of methane (2% volume at S.T. P) was obtained when biomass gasified with air-steam as the gasifying agents in a fluidized bed reactor in presence of sorbents like Ni, Calcium oxide, Rhodium, Aluminum oxide whereas the highest amount of methane was obtained for bio slurry with steam-nitrogen as the gasifying agents at 700°C. In the temperature range of 700°C-850°C in combustion zone, satisfactory amount of hydrogen yield was obtained (40%-60%) whereas at 850°C to 950°C, highest

Table 1 Comparison of various parameters in steam gasification

No	Temperature (°C)	Gasifier Type	Medium	Fuel	Eff. (%)	Catalyst	H ₂	CO	CO ₂	CH ₄	Tar (mg/m ³)	Re f.	
1.	770	Fluidized Bed Reactor	Steam+air +O ₂	Sewage sludge	N.A.	N.A.	13.6	7.7	19.8	3.4	45.3	[15]	
	850						24.2	8.7	17.1	3.1	44.9		
2.	700	-	Steam +N ₂	Bio Slurry	N.A.	N.A.	56.5	22.1	4.8	16.4	N.A.	[16]	
	900						61.2	21.6	10.8	6.5			
3.	727	Fluidised Bed Reactor	Air-Steam	Wood	82.4	Sorbents (Rh,aluminium oxide,Ni,Calcium Oxide)	41	10	20	2	15.9	[17]	
4.	660	Dual fluidised bed	Steam	Wood pellets	N.A.	N.A.	70	8	7	12	N.A.	[18]	
5.	820	Fluidised reactor	Steam+O ₂	Almond shells	N.A.	N.A.	30	28	22	9	12	[19]	
6.	950	Fixed bed	Steam+N ₂	Pyrolysis char	N.A.	10% Ni-dolomite	60	25	12			N.A.	[20]
						10% Ni-aluminium oxide	75	15	8				
						10% Ni-magnesium oxide	72	18	5				
						No Catalyst	57	25	16				
7.	250	Fixed bed type	Steam+N ₂	Dealcoholised grape	N.A.	N.A.	38	22	20	11	N.A.	[21]	
			Steam				34.4	26	25	7			
8.	850	Fixed bed type	Steam+N ₂	Petroleum Coke	N.A.	Potassium chromate	60	15	25	-	18.9	[22]	
						Without catalyst	50	30	15	5	20		
9.	200-850(Bed 1)	Fxed bed reactor	Steam+N ₂	Algal Biomass	N.A	Ferrous oxide-Cerium oxide	69	3.3	26.6	0.6	N.A.	[23]	
10.	850	Quartz tubular reactor	Steam+N ₂	Wood	N.A.	N.A.	50	15	22	8	N.A.	[24]	
				Rapeseed			54	21	22	2			
				Sewage			56	14	25	3			
				Miscanthus			55	16	24	5			
11.	900	Conical Spouted Bed Reactor	Steam+O ₂ + CO ₂	Pine wood Saw Dust	N.A.	Sand	37	32	15		N.A.	[25]	
						Olivine	40	28	18				
						γ-alumina	43	26	17				
12.	700	Batch Flow type	Steam	Paper,yellow pine,woodchips, pittsburg bituminous coal	N.A.	N.A.	40	25	25	8	N.A.	[26]	
13.	900	Downdraft gasifier	Steam(flow rate 0.3 kg/hr)	Pine particles	82.97		38	23	18	13	10.2	[27]	

amount of hydrogen yield (i.e up to 75%) can be achieved with some minor exceptions. It is due to the fact that sufficient energy is available to breakdown steam particles and convert it in H₂ and O₂ molecules in much effective way. Fluidized bed reactor offers moderate amount of hydrogen up to 41% however dual fluidized bed reactor can give up to 70% hydrogen yield. Fixed bed reactors are preferred for high

hydrogen yields (60%-75%). Other types of reactors such as Quartz tubular, Batch flow type, Conical Spouted Bed Reactor, Downdraft gasifier provide moderate hydrogen yield (around 40%).

IV. CONCLUSION

General conclusions based on present studies are described below:

Steam gasification has huge potential to increase hydrogen yield and to destruct tar from producer gas. It is one of the effective method for H₂ production. Steam gasification is effective when availability of steam almost free or cheaper cost. Catalytic steam gasification will helpful to maintain temperature in combustion zone as well as to boost the reaction. With catalytic steam gasification, hydrogen yield may increase 20% to 40% at 750°C or above combustion zone temperature.

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