ADVANCING GASIFICATION-COMBINED UP AND DOWN DRAFT GASIFIER-BASED TREATMENT OF TEXTILE WASTE: ASSESSING FEASIBILITY, ENVIRONMENTAL IMPACTS AND ENERGY RECOVERY POTENTIAL

P VIJAYAKUMAR [1], R. Dhilipkumar ME., [2]

[1] P VIJAYAKUMAR, P.G student, Dept. of Civil Engineering, The Kavery Engineering College, Salem.

[2]R. Dhilipkumar ME., Assistant Professor, Dept. of Civil Engineering, The Kavery Engineering College, Salem.

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Abstract- This paper presents a study on the feasibility, environmental impacts, and energy recovery potential of advancing gasification-combined up and down draft gasifier-based treatment of textile waste. The objective of this study was to assess the technical and economic feasibility of this process for generating energy from textile waste as a sustainable waste management solution. The Technology used in this study is Advancing gasification, which combines Up and Down Draft Gasifiers. It can be used to treat any type of waste and in this process, textile waste is treated. The methodology involved conducting laboratory experiments to evaluate the performance of the gasification process using a Envirocycler. The study concludes that this technology can be an effective solution for managing textile waste while also generating energy from textile waste. The tar content in the flue gas of the Envirocycler has been reduced to a negligible amount compared to that of conventional models. This is because the tar particles are being arrested within the Envirocycler and burnt along with the fuel, thereby reducing downstream loading and its environmental impacts.

***Key Words*: Gasifier, Textile Waste, Fuel, Envirocycler, Environment…**

1. INTRODUCTION

Textile production is constantly increasing together with population expansion and economic development of the society. Fabrics are largely made of synthetic fibers, which place the 3rd largest end-use market of plastic production, while it is the 2nd largest plastic waste generator, after the packaging sector. Textile products are mostly incinerated and landfilled at the end of life, operating almost in a linear path. For the case of clothing, only 1% are closed-loop recycled, and barely 12% is reused. Understanding the composition of the textile stream is essential to assess potential recycling methods. Blends make more demanding material recovery, they can be mechanically processed, but the material composition of the recycled yarn is difficult to control. Thermo-chemical recycling of textiles could constitute an important alternative to recycling hydrocarbons from synthetic textiles, thus enabling a more sustainable life cycle. For instance, plastic gasification can produce a gas that can be further synthesized into energy-rich gas, e.g. H2, to different kinds of biofuels, e.g. methanol, or to base chemicals e.g. olefins and Benzene, Toluene, Xylene, Styrene (BTXS), for the generation of new products.

1.1 Textile waste

The city of Surat is the commercial capital of the vibrant state of Gujarat and predominantly hosts textile and diamond industries. Surat has about 425 textile-dyeing and printing mills, over 15,000 textile-weaving units, and about 75,000 textile shops which cumulatively generate about 180-200 Metric Tons Per day (MTPD) of such waste.

The industry is labor-intensive, consumes huge quantities of water, and generates hazardous as well as non-hazardous waste.

Fig -1: Illegal dumping of textile waste

The textile industry generates textile shredding waste at various processing steps. The industry in Surat is mainly processing polyester-based textiles and hence the waste generated is not bio-degradable and cannot be disposed of in landfill. Figure 1 shows the illegal dumping of textile waste in Surat. Moreover, this waste has a calorific value in the range of 2500-5000 Kcal/kg. Hence, many dyeing, and printing mills have been enticed to use this waste as fuel in their boiler. These have led to higher emissions of particulate matter and possible emission of carcinogens which may be produced due to uncontrolled burning of contaminants/dyes attached to the textile waste. Gujarat Pollution Control Board (G.P.C.B.) has taken strict actions time and again, against such units and has given closure orders to such units. However, there is a need to find a technically competent and economically viable solution for the disposal of textile waste (Textile waste). The dumping of such waste on the ground has created heaps and heaps of waste on open ground at various places. Also, such rags clog the drainage lines and other water conduits.

1.2 Aim of the Project

The aim of this project is to assess the feasibility, environmental impacts, and energy recovery potential of a gasification-combined up and down draft gasifier-based treatment of textile shredded waste. The project will focus on advancing the current gasification technology by optimizing the operating conditions of the up-and-down draft gasifier. The study will also evaluate the effectiveness of the gasification process in reducing environmental impacts and recovering energy from textile-shredded waste.

1.3 The main objective of this project

This paper focuses on the treatment of textile waste using an advancing gasification technology that combines up and down draft gasifiers. To the best of our knowledge, no studies have been conducted on this specific combination of gasifiers.

The combination of gasifiers in the advancing gasification system achieves simplicity and high internal heat transfer, similar to that of the updraft gasifier, as an advantage. It rectifies the demerits of a down draft gasifier, which is unable to operate on the majority of unprocessed fuels, and the demerits of an updraft gasifier, in which explosive situations may arise if there is channeling in the equipment.

This technology can be used to treat any type of waste by converting it into a valuable product. In this paper, an advanced gasification system is used to treat the textile waste of the Envirocycler to reduce the tar content in the flue gas to a negligible amount compared to that of conventional models. The tar content is arrested within the Envirocycler and burnt along with the fuel, thereby reducing downstream loading and its environmental impacts.

2. THE TECHNOLOGY AND ITS FUNCTION

2.1 Gasification Technology

Gasification is a technological process that can convert any carbonaceous (carbon-based) raw material such as coal into fuel gas, also known as synthesis gas (syngas for short). Gasification occurs in a gasifier, generally a high temperature/pressure vessel where oxygen (or air) and steam are directly contacted with the coal or other feed material causing a series of chemical reactions to occur that convert the feed to syngas and ash/slag (mineral residues). Syngas is so called because of its history as an intermediate in the production of synthetic natural gas. Composed primarily of the colorless, odorless, highly flammable gases carbon monoxide (CO) and hydrogen (H_2), syngas has a variety of uses.

The syngas can be further converted (or shifted) to nothing but hydrogen and carbon dioxide (CO_2) by adding steam and reacting over a catalyst in a water-gas-shift reactor. When hydrogen is burned, it creates nothing but heat and water, resulting in the ability to create electricity with no carbon dioxide in the exhaust gases. Furthermore, hydrogen made from coal or other solid fuels can be used to refine oil or to make products such as ammonia and fertilizer. More importantly, hydrogen-enriched syngas can be used to make gasoline and diesel fuel. Polygene ration plants that produce multiple products are uniquely possible with gasification technologies. Carbon dioxide can be efficiently captured from syngas, preventing its greenhouse gas emission to the atmosphere and enabling its utilization (such as for Enhanced Oil Recovery) or safe storage.

Gasification offers an alternative to more established ways of converting feedstock's like coal, biomass, and some waste streams into electricity and other useful products. The advantages of gasification in specific applications and conditions, particularly in the clean generation of electricity from coal, may make it an increasingly important part of the world's energy and industrial markets. The stable price and abundant supply of coal throughout the world make it the main feedstock option for gasification technologies going forward.

The technology's placement markets with respect to many techno-economic and political factors, including costs, reliability, availability and maintainability (RAM), environmental considerations, efficiency, feedstock and product flexibility, national energy security, public and government perception and policy, and infrastructure will determine whether or not gasification realizes its full market potential.

2.2 Processes of Gasification

Four distinct processes in the gasifier -

1. Drying:- In this stage, the moisture content of biomass is typically reduced to 5-35%.In the drying zone, the temperature is about 100-200°C.

2. *Pyrolysis*:-It is the first step in the combustion or gasification of biomass. When biomass is heated in the absence of air to about 350-600°C, it forms charcoal, gases, and tar vapors.

Fuel + heat → solid, liquid, gases products (H_2, H_2O, CO, CO_2)

3. Combustion: - In this process the reaction between solid carbonized biomass and oxygen in the air, results in the formation of CO_2. Hydrogen present in the biomass is also oxidized to generate water. A large amount of heat is released with the oxidation of carbon and hydrogen.

$C + O_2 \rightarrow CO_2$

4. Reduction: - In the absence of oxygen, several reduction reactions occur in the temperature range of 600-1000ºC. These reactions are mostly endothermic. The majors in this category are as follows:

$C + H_2O \rightarrow CO + H_2$

$C + CO_2 \leftrightarrow 2CO$

$CO_2+H_2 \leftrightarrow CO+ H_2O$
$C + 2H_2 \leftrightarrow CH_4$

2.3 Features of Gasification

The features such as mentioned below allow for considerable leeway in processing varied-source solid wastes without having to make any changes in the design:

Capability to distribute air and/or oxygen within the gasifier to create localized conducive conditions and optimum gas-solid contact to enhance the utilization of waste and maximize gasification efficiency.

Ability to introduce air in stages to create high-temperature zones within the gasifier to destroy tars formed during the gasification of wastes.

Ability to co-process high-moisture waste with other waste fuels such as used tires, paper, and plastic. Ability to generate constant quality of gas regardless of the type of waste fed into the gasifier. Turndown capability exceeding a 5 to 1 ratio. These capabilities of the gasifier make it suitable for accepting non-uniform but suitably sized waste, to operate the system at varying gas flow rates and throughput. It is a tested and proven reliable and robust gasifier system.

2.4 Up And Down Draft Gasification

An updraft gasifier is one of the oldest and simplest of all designs. Here, the gasification medium (air, oxygen, or steam) travels upward while the bed of fuel moves downward, and thus the gas and solids are in counter-current mode. The gasifying medium enters the bed through a grate or a distributor, where it meets with the hotbed of ash. The ash drops through the grate, which is often made moving (rotating or reciprocating), especially in large units to facilitate ash discharge.

Updraft gasifiers are suitable for high-ash (up to 25%), and high-moisture (up to 60%) biomass. They are also suitable for low-volatile fuels such as charcoal.

Tar production is very high (30150 g/nm^3) in an updraft gasifier, which makes it unsuitable for high-volatility fuels. On the other hand, as a counter-current unit, an updraft gasifier utilizes combustion heat very effectively and achieves high cold-gas efficiency. Updraft is more suitable for direct firing, where the gas produced is burnt in a furnace or boiler with no cleaning or cooling required. Here, the tar produced does not have to be cleaned. Updraft gasifiers find commercial use in small units like improvised cooking stoves in villages and in large units like South African Synthetic Oils (SASOL) for the production of gasoline from coal. The following is a brief description of two important large-scale commercial updraft gasifier technologies.

2.5 Downdraft Gasifiers

A downdraft gasifier is a co-current reactor where air enters the gasifier at a certain height below the top. The product gas flows downward (giving the name downdraft) and leaves from the lower section of the gasifier through a bed of hot ash (Figures 8.4 and 8.5). Since it passes through the high-temperature zone of hot ash, the tar in the product gas finds favorable conditions for cracking. For this reason, a downdraft gasifier, of all types, has the lowest tar production rate. Air from a set of nozzles, set around the gasifier's periphery, flows downward and meets with pyrolyzed char particles, developing a combustion zone of about 12001400 C. Then the gas descends further through the bed of hot char particles (zone IV), gasifying them. The ash produced leaves with the gas, dropping off at the bottom of the reactor.

Downdraft gasifiers work well with internal combustion engines that need cleaner gas. The engine suction draws air through the bed of fuel, and gas is produced at the end. Low tar content (0.0153 g/nm^3) in the product gas is another motivation for their use with internal-combustion engines. A downdraft gasifier requires a shorter time (20 to 30 min) to ignite and bring the plant up to working temperature compared to the time required by an updraft gasifier. There are two principal types of downdraft gasifiers: throatless and throated.

2.6 Envirocycler

The Envirocycler first stage contains a large, V-frame grate with ash troughs located in centre of the envirocycler at the bottom of the grate. This grate mechanically moves the fuel to maximize thermo-oxidation of the Textile Waste (fuel) and continuously removes the ash from the first stage. Underwire air is admitted uniformly through the risers of each step over the entire stepped grate surface.

The fuel, EFB is supplied by a series of hydraulically operated ramp feeding mechanisms above the apex of the V-frame grate. As the fuel works its way down the stepped V-frame grate, the fuel's moisture evaporates, the volatiles are distilled, and the residual char is oxidized on the grate surface providing the heat to drive the gasification of the biomass in the fuel pile into producer gas.

The residual ash collects in the ash troughs on the bottom of the V-frame grate. The ash is removed from the troughs by a screw conveyor located in the ash trough. The first stage producer gas (consisting of water vapor, volatiles, carbon monoxide, carbon dioxide, nitrogen, and methane) rises up into the second stage.

Over fire air admitted at the top of the first stage, burns some of the first stage "producer gas" so that the temperature of all the first stage producer gas is raised above the ignition temperature of that particular gas mixture before the gas enters the second stage. The second stage contains an outer vortex of downward spiralling, combustion air, inside which is an inner vortex of, upward spiralling, burning first stage producer gas. Secondary combustion air is admitted through a number of tangential openings (called "tuyeres") in the walls of the second-stage combustion chamber. Secondary combustion air ignites the preheated producer gas & destroys most of the tar content in 2nd stage the wet combustor Envirocycler can combust almost any biomass residue in an environmentally friendly manner. Heuristic Engineering Inc. of Canada provided the technology of the 2-stage wet combustors. This technology was transferred from Canada and the fabrication took place in Malaysia through Meridian Utilities Sdn Bhd. The advantage of the technology is that it can burn biomass with a moisture content of up to 60%. Particulate matter carried up into the Envirocycler's 2nd stage is removed centrifugally out of its walls for deposition into a hopper. It will be removed from the hopper by a mechanized airlock and screw conveyor system. Any ash carried over into the WHRB will be removed by steam soot blowers. Once the above process is completed, the Waste Heat Recovery Boiler recovers the heat produced by the Envirocycler to produce steam. The cooled-down gases will go through a series of gas cleaning systems which consist of a Wet scrubber in order to further purify and cool down the gases.

Physical Combustion Requirements

Combustion is the rapid oxidation of fuel in a mixture of fuel and air with heat produced and carried by the mass of flue gas generated. Combustion takes place, however, only under the conditions of Time, temperature, and turbulence are known as the three “T”s of combustion. A short period of time, high temperature, and very turbulent flame indicate rapid combustion. Turbulence is key because the fuel and air must be mixed thoroughly if the fuel is to be completely burned. When fuel and air are well mixed and all the fuel is burned, the flame temperature will be high and the combustion time will be shorter. When the fuel and air are not well mixed, complete combustion may not occur, the flame temperature will be lower, and the fuel will take longer to burn. Less turbulence and longer burning have, however, been found to produce fewer nitrous oxides (NOx). In some cases, combustion is delayed or staged intentionally to obtain fewer nitrous oxides or to obtain desired flame characteristics.

The fuel must be gasified. In the case of natural gas, this is automatically true. For oil, the fuel must be atomized so that the temperature present can turn it into a gas. When coal is burned, the coal must be pulverized so that it can be gasified by the furnace temperature or distilled in suspension or on the grate by the furnace temperature if a stoker is used. The ignition temperature and the flame temperature are different for different fuels if all other conditions are the same. Measurements of either the percentage of carbon dioxide or the percentage of oxygen in the flue gas or both are used to determine the percentage of excess air, but the percentage of oxygen is preferred for the following reasons:

(1) Oxygen is part of the air- if oxygen is zero, then excess air is zero. The presence of Oxygen always indicates that some percentage of excess air is present.

(2) The percent of carbon dioxide rises to a maximum at minimum excess air and then

Decreases as air is further reduced. It is thus possible, with the same percentage of carbon dioxide, to have two different percentages of total combustion air. For this reason, the percentage of carbon dioxide cannot be used alone as a flue gas analysis input to a combustion control system.

(3) To determine excess air with the same precision, greater precision of measurement is required for the percentage of carbon dioxide method than for the percentage of oxygen method.

(4) The relationship between the percentage of oxygen and the percentage of excess air

Changes little as fuel analysis or type of fuel changes, while the percentage of carbon dioxide-to-excess air relationship varies considerably as the percentage of carbon-to-hydrogen ratio of the fuel changes.

The heat loss in the flue gases essentially depends upon the difference between the temperature of the flue gases and that of the incoming combustion air, the amount of excess air and the fuel analysis. There is an optimum amount of excess air because less air will mean unburned fuel from incomplete combustion, and more air will mean complete combustion but more heat loss in the flue gas due to the greater mass of the flue gases.

Benefits of the Envirocycler technology

• Over 99.9% combustion efficiency resulting in lower emissions.

• Gasification at low temperature avoids ash fusion and clinker.

• Fast response to fire and slumber mode. Ability to respond even after hours of

• slumber.

• Low capital and maintenance cost.

• Clean heat output at 1010°C reduces tube cleaning and emissions at boiler.

• Modular and compact.

3. EVALUATION OF MATERIAL

Feed Material: Textile waste

It is estimated that around 60,000 textile shops, 15,000 textiles weaving units and 425 dying and printing units exists in Surat. These facilities by and large uses Man Made Fibre (MMF) like polyester fabric, polymer and non-biodegradable fabrics and generates about 180 to 200 metric tons per day of textile waste which goes as illegal fuel in various industrial boilers or being dumped at various locations which ultimately fills up the landfill sites of Surat Municipal Corporation (SMC). Textile waste is a very low bulk density material and hence occupies large tracts of land otherwise available for more productive use. Therefore, SMC is looking for an alternative method for the disposal of waste in a scientific manner. Textile waste is normally collected in bundled bags and delivered to the processing plant. Figure 3 shows the textile waste delivered to the processing plant.

Bundled bags of textile waste are shredded to a size of 1-2 inches to be used as feed material for the gasification. Shredding of the material is required to be conveyed through the feed system. It is a waste with a good calorific value. Ultimate and Approximate analysis of Textile waste is in Table 1.

Table -3.1: Analysis of Textile waste

Proximate Analysis (Dry Basis)		
Parameters	**Values**	**Unit**
Volatile Matter	82.8	%
Fixed C	10.39	%
Ash	4.07	%
Moisture	2.74	%
HHV	5,662.00	kcal/kg
Ultimate analysis (Dry Basis)		
Parameters	**Values**	**Unit**
Carbon	70.84	%
Hydrogen	5.25	%
Nitrogen	0.26	%
Oxygen	17.11	%
Sulphur	0.59	%
Chlorine	1.85	%
Ash	4.11	%

4. EQUIPMENT AND ITS DESCRIPTION

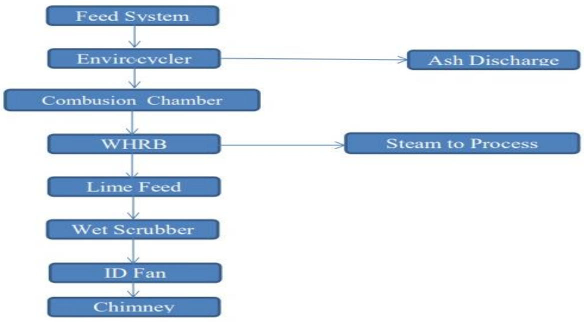


Fig – 4.1: Process Methodology

4.1. Feed System

The feed system consists of an inclined belt conveyor, a hopper, and a hydraulic pusher. Textile waste bundles weighing between 15 and 20 kg are transferred manually through the inclined belt conveyor and fed to the hydraulic pusher through the hopper. The hydraulic pusher then pushes the textile waste bundles into the furnace (Envirocycler).

Advantages

The Envirocycler can effectively treat wastes of Medium size (1.5 sqft / 15 to 20 Kg), making the shredder unnecessary for this system.

4.2. Envirocycler

The environment operates using a two-stage gasifier and two-stage combustor system. The textile waste gasifies in a very large first stage of gentle updraft gasification which results in the formation of the producer gas. The formed producer gas is vigorously burned in the Envirocycler's second stage, the Cyclonic combustion chamber located immediately above its first stage, which is downdraft char gasification.

The envirocycler heated by introducing the textile waste from the Feed system where even distribution of the textile waste is achieved by the partial or total opening of the gate systems on chain conveyors. After even distribution of textile wastes is achieved, little volume of diesel is added and a fire through a lighter is initiated. After 10-15mins the fire is observed to be rising. More textile wastes are introduced gradually.

As the temperature begins to rise the 5 psi motor is switched on to blow primary combustion air through the flame holder at the bottom of the second stage into the system to enhance burning and to ignite the producer gas.

High-velocity secondary combustion air is injected tangentially through the nozzles in the brick-lined walls to complete the combustion of the burned producer gas by switching on the 10psi motors. By splitting combustion up into two stages, with two different, tightly controlled, sources of combustion air injected into each stage, the envirocycler is operated with excess air levels as low as 17%. This enables the disposal of very wet wastes while maintaining discharge temperatures of at least (700-900°C). However, the temperature is allowed to rise by adding more textile waste's following a pattern. The temperature readings are obtained by thermocouples attached to the envirocyclers at various levels. The level of the textile waste's in the system is manually checked and through the use of infrared sender and receiver sensors connected opposite each other at the required allowable level in the system. Infrared Signals would be obstructed if the textile waste level is above the desired level and it is indicated by a red light seen in the control panel located down. A green light indicates there is successful sending and receipt of the signals thus envirocycler is not full yet.

Residence time (also known as removal time). It is the average amount of time that a particle spends in a particular system. This measurement varies directly with the amount of substance that is present in the system. Residence time begins from the moment that a particle of a particular substance enters the system and ends the moment that the same particle of that substance leaves the system. If the size of the system is changed, the residence time of the system will be changed as well. The larger the system, the larger the residence time, assuming the inflow and outflow rates are held constant. The smaller the system, the shorter the residence time will be, again assuming steady-state conditions.

The enviro cycle was designed to burn at a rate of 250 Kg/hour

Capacity of the enviro cycle =Residence time = volume or capacity of the envriocycler / rate of flow of textile waste into the system.

With the Envirocycler's large grate and low-temperature grate, ash do not vapourize and enter into the heat exchanger the Envirocycler fires. Rather, these alkalies or ashes stay in the Envirocycler's first stage as potash and soda and are removed by the first stage's built-in ash removal system.

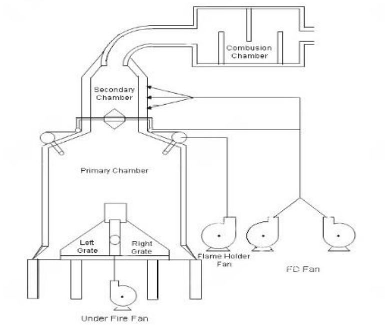


Fig-4.2: Envirocycler

4.3 Flame holder

Flame holders are a necessary component. The flame holder is a cylindrical structure that helps keep the flame inside it strong by creating eddies of air that feed the flames. The flame holder also blocks high winds that could put the flame out.

4.4 Fire damper

These are used to ensure even air or heat distribution through the use of ducts. Dampers balance air to follow. Fire dampers are used in the vertical ducts that carry the fumes and flames from the environmental fire. They should be inspected and tested at least once a year to be sure they are in proper working order. They are usually held open by a fusible link.

The Air movement is usually produced by forced airflow. Fans are normally located in the inlet of the air conditioner. Air is moved by creating either a positive pressure or negative pressure in the ductwork.

4.5 Grade system operation

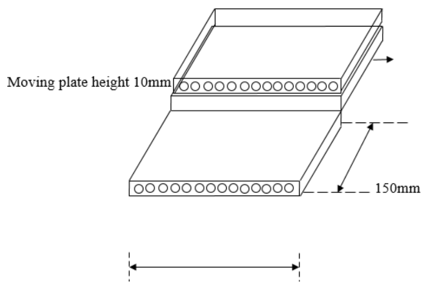


Fig-4.2.3: Grade System

The grate system is controlled by a control panel located beside the envirocycler. The system is used to shake off the ashes into a built-in conveyor system controlled by a hydraulic system. This is necessary to avoid the solid formation of ashes in the system. The grate system is switched on and off in an interval of 30 minutes.

It is made from large stainless steel comprising horizontal bars connected to the plates. As the fuel burns the ashes hang on the plate and the grate system is switched on. It shakes it off down to the ash cylindrical conveyors which take it out.

4.6. Ash Discharge System

The inorganic residue from waste, which is commonly known as ash, resulting from the gasification reactions is discharged from the gasifier using a Flap Valve for Ash Discharge. The flap valve is connected to the Ash Conveyor to transfer the ash from the gasifier to the Ash Bin for the gasifier. The ash discharges from the gasifier at very high temperatures (in the range of 1600 ^{0}F) so water spray in the ash conveyor is utilized to cool the ash to about 300 ^{0}F. The flap valve prevents the entry of vapors generated from ash cooling into the gasifier. The water for ash cooling is provided from Process Water Tank. Process Water Pump provides the water supply pressure for spraying water into the ash conveyor. The temperature control loop controls the amount of spray to the ash conveyor. The ash is continuously discharged and collected by Ash Bin for Gasifier. The diverter valve is utilized for switching between the Ash Bin and Ash Bin.

The vapor from the ash conveyor is sent to the vent. The vent is provided with a Vent Filter and the suction is provided by Vent Fan. Solids collected by the vent filter are discharged via Lock Hopper for Vent Filter and are collected in Ash Bin for Vent Filter.

There is also a provision to discharge and to collect material from the gasifier at the bottom section of envirocycler using the Flap Valve and Ash Bin.

The ash discharged by double flap is conveyed to the ash-bin using the Ash Conveyor. The conveyor is provided with water spray nozzles in order to quench the hot ash from the gasifier.

All associated vapors during ash cooling are directed to the vent system. The conveyor capacity is 90 kg/hr. The material of construction is carbon steel.

4.7. Combustion Chamber

The combustion of syngas in the combustion chamber of a gasifier typically produces flue gas. The composition of the flue gas depends on various factors, including the composition of the syngas and the combustion conditions. The flue gas from the combustion of syngas may contain carbon dioxide (CO_2), water vapor (H_2O), nitrogen (N_2), and other trace gases. The exact composition and quantities of these gases can vary depending on the specific gasification process and operating conditions.

4.8 Waste Heat Recovery Boiler

A waste heat recovery boiler is a device that uses the heat from waste gases to generate steam or hot water. This heat can then be used for a variety of purposes, such as heating buildings, generating electricity, or driving industrial processes.

Waste heat boilers work by passing the waste gases from a combustion process through a series of tubes filled with water or steam. The heat from the gases is transferred to the water or steam, which is then used to generate steam or hot water.

Waste Heat Recovery Boiler Operational Working

Though in this case, you are not using extra fuel in your equipment still there are a huge amount of flue gas losses. This heat can be utilized somewhere in a process where you are currently using fuel to generate heat either to produce steam or even for local heating of water or air or any other fluids. Remember energy is precious, even small saving in energy costs will save you a lot of money which can usually be seen over a period of 5 years. Due to this, Thermo dyne provides novel products like Waste herm, the Waste Heat Recovery Boilers (WHRB). As the name suggests, the heat going to waste from the process like flue gases of Diesel Generator sets is utilized in these boilers to generate hot water or steam. Since no fuel is fired, whatever heat we recover in the. Waste heat recovery boiler design.

Waste Heat Recovery boilers are designed to recover heat from waste flue gases from DG exhaust, Furnace exhaust, Kiln exhaust, incinerator exhaust, etc. to produce steam or hot water based on the application requirements of the plant.

There are 4 basic requirements or inputs for calculating your waste heat from the source. These are:-

Type of fuel and its composition

Amount of flue gases leaving the exhaust per hour in Kg/hr or Nm3/hr

The temperature of flue gases at the exhaust in °C

The process where you want to utilize this waste heat.

The amount of steam generators or Steam Boilers of heat transfer is controlled by the quantity of heat available in the flue gases. Waste herm can be fire tube or water tube type as per the design requirements.

Tailor-made solutions are offered based on the specific requirements of customers and the Waste herm boiler (waste heat recovery boiler) design is integrated into the system requirements. Since these boilers operate on waste heat, there are no fuel bills to operate these and hence they offer a very handsome payback of investments.

Was tether can be either a smoke tube design or a water tube design. Depending upon the amount of waste heat available and the process where you want to utilize this waste heat say for instance for producing steam, the required capacity and pressure of steam will help to determine the design of a waste heat boiler.

Waste Heat Recovery Boilers (WHRB) Benefits:

- Highly Reliable in operation and robust in construction.
- Quick Payback Returns are achieved.
- One-time investment with lifetime returns.
- No combustion, No emission hence Eco-friendly.
- The energy was being put to use, which was getting wasted anyway.

4.9. Lime Feed System

Lime Hopper is used for storing lime powder meant for scrubbing H_2S and HCl. The capacity of the hopper is 25 kg. The material of construction is stainless steel.

4.10. Wet scrubber

A wet scrubber or wet scrubber system is one type of scrubber that is used to remove harmful materials from industrial exhaust gases—known as flue gas—before they are released into the environment. It was the original type of scrubbing system and utilizes a wet substance to remove acidic gases that contribute to acid rain.

When using a wet scrubber, flue gas is funneled through an area and sprayed with a wet substance. Water is used when dust and particulate matter are to be removed, but other chemicals can be added. These chemicals are chosen to specifically react with certain airborne contaminants—generally acidic gases. This process adds significant amounts of vapor to the exhaust—which causes the release of exhaust that appears as white smoke when vented.

4.11. ID Fan

The clean and cooled flue gas from the flue gas Reheated is subsequently directed to the ID Fan. ID Fan is used for assisting an unimpaired flow of flue gas through the entire gasification, gas cooling, and gas cleaning subsystems. While the gasifier also utilizes an air blower with a pressure rating of 40 inches of water; ID Fan makes up for any additional pressure drop beyond that provided by the gasifier air blower. The ID Fan is equipped with a variable frequency drive to control the speed and its attendant pressure rating.

5. RESULTS AND DISCUSSIONS

5.1 Process Profile

Elemental analysis was carried out to determine the properties of biomass materials according to the standard procedure which is presented in Table 5.1 (Analysis of Textile waste).

The equivalence ratio reflects the combined effect of air flow rate and fuel flow rate. Performance parameters were tested at varying equivalence ratios by changing the air velocity setting. The equivalence ratio was calculated by using (1), (2) & (3).

(A/F) a = Mass flow rate of air/ FCR = (A/G) / (G/F) (1)

(A/F) s = Stoichiometric air flow rate/ Stoichiometric fuel flow rate (2)

ER = (A/F) a / (A/F) s (3)

Where,

A/G – Ratio of air and gas flow rate

G/F – Ratio of produced gas and fuel flow rate

ER - Equivalent ratio

Equivalent ratio Figure 8.1 represent producer gas composition of three biomass types at distinct equivalence ratio values.

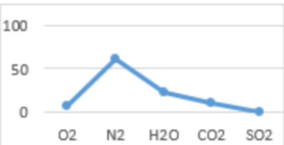


Fig- 5.1: Flue gas Composition at ER 0.3

Table 5.1: Flue gas Composition at ER 0.3

S.NO	COMPONENT	ER 0.3
1	O2	6.29
2	N2	61.54
3	SO2	0
4	CO2	9.79
5	H2O	22.38

5.2. Gas Flow Rate

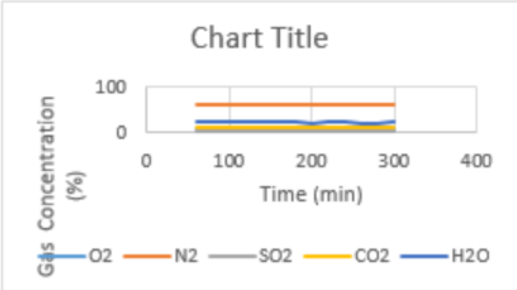
As shown in Figure 8.4, the actual gas flow rate during the gasification process was stabilized at the setting value of 0.7 m^3/s. and the Flue gas yield was 10.8 m^3/kg

Producer gas property

The volume concentrations of the main gas components in the producer gas (i.e., N_2, CO2, H_2O, SO2, and O_2 were pretty stable during the gasification process (Fig. 5), the producer gas was composed of about 61.54 % N_2, 9.79% CO2, 22.38% H_2O (water vapor), 0% SO2 and 6.29 O_2. In addition to the main gas components, the producer gas also contained some water vapor and trace amounts of other gases. The LHV (lower heating value) of the producer gas (or flue gas) was calculated by Eq. The calculated LHV of the producer gas was 4802 kcal/kg. The HHV of Textile waste was 5662 kcal/kg.

5.3. Material Balance

Fig-5.2: Flue gas concentration vs. Time



It was assumed that all the ashes and bio chars produced during gasification were collected into the char bins. The ashes and tars that were trapped inside the gasification system were neglected when calculating the material balance and energy balance. The flow rate of the producer gas was set at 0.7 m3/s for corresponding Equivalence ratio. The consumption of Textile waste was 250 kg/hr with a Flue gas yield of 10.08 Nm3/kg Textile waste. The carbon conversion rate were calculated based on Eq. The carbon conversion rate were calculated based on Eq.8.4. The carbon conversion rate from Textile waste to gaseous products (CO2) was 79.9 % About 9% of carbon in Textile waste was converted to other types of products, mainly char and Ash. Compared to carbon conversion rate.

$$X_c (\%) = [12Y \times CO2 \% / 22.4 \times C \%] \times 100 \%$$

Where Y is gas yield (N m3/kg), C % is the mass percentage of carbon in ultimate analysis of Textile waste feedstock, and the other symbols are the molar percentage of components of product gas. From this carbon conversion rate was 79.9 %

5.4 Cold-Gas Efficiency

Cold-gas efficiency is the potential energy output over the energy input. The following equation was used to determine the conversion efficiency of the gasifier:

$$\eta \% = \frac{Hg \times \text{gas flow rate}}{Hw} \times 100$$

Where,

η is the cold gas efficiency, Hg is the gas heating value and Hw is the average calorific value of wood. From this cold gas efficiency was 84 %.

Table 5.2: Results

Description	Results	Unit
Textile Feed rate	250	kg/hr
Volumetric air flow rate	20.5	m^3/s
Air flow through grate (70%)	14.3	m^3/s
Air flow through overfire & fuel spreader air system (30%)	6.2	m^3/s
Maximum Gasifier Temperature (Secondary Chamber)	950	°C
Minimum Gasifier Temperature (Primary Chamber)	730	°C
Ash from Gasifier	17.5	Kg/hr
Product gas flow rate	0.7	m3/s
Ash from Gas Clean-up System	5	Kg/hr
Total Ash	22.5	Kg/hr
Total Feed	250	Kg/hr
Percentage Ash Generation	9	%
Carbon conversion rate (%)	79.9	%
Cold gas Efficiency	84	%
Lower Heating Value of Gas	4802	Kcal/kg
Flue gas Yield (Nm3/Kg)	10.08	Nm3/hr
Percentage ash entering dust collector	77.7	%
Higher Heating value of Textile waste	5662	kcal/kg

5.5. Environmental impact

Environmental impact of the gasification process Environmental performance of gasification technology is essential for the overall feasibility of the process. According to recent technical reports, in comparison to common industrial or commercial processes, thermochemical and biochemical solid waste conversion processes can be operated with no greater threat to human health or the environment.

Biochemical processes, particularly anaerobic digestion, are accepted widely by the environmental science community. However, misperceptions about the gasification processes – that they are an insignificant variation of incineration – cause disagreement within the environmental community. Gasification is an intermediate process for generating fuel gas that can be utilised for wide variety of applications.

It is now evident that Textile waste has potential in the near future for onsite thermal energy production. Installed air pollution control equipment and used energy recovery systems control the atmospheric emissions of gasification systems. Therefore, it is difficult to compare the impact of air pollution of Envirocycler gasification systems with a conventional process. However, the gas allows more successful combustion control than solids, and consequently there is a marked reduction in the emission of CO, NO_x, dioxins and unburned compounds.

Moreover, to remove pollution precursors such as nitrogen and chlorine compounds and improve emissions gas pre-treatment can be performed. As compared to conventional gasification this type of Combined up and downdraft process has several key aspects which make air pollution control less costly and complex than in conventional processes.

It reduce the downstream loading as it arrest the dust particle within the reactor because of Air flow through over fire & fuel spreader air system. So the product gas emission will be improved by emissions gas pre-treatment.

CONCLUSION

An advanced gasifier has been proposed to overcome the weaknesses of conventional gasifiers by combining both updraft and downdraft gasifiers. In this work, an Envirocycler was used for the thermochemical process of textile waste, and its feasibility, energy recovery potential, and environmental impacts were assessed. The technical and economic feasibility of this process for generating energy from textile waste was observed as a sustainable waste management solution. The performance of the gasification process using an Envirocycler was evaluated. The resulting values of cold Gas efficiency and Carbon conversion efficiency were 84% and 79.9% respectively. The study concludes that this technology can be an effective solution for managing textile waste while also generating energy from it. The tar content in the flue gas of the Envirocycler has been reduced to a negligible amount compared to that of conventional models. This is because the tar particles are being arrested within the Envirocycler and burnt along with the fuel, thereby reducing downstream loading and its environmental impacts.

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