Solar Thermal Biomass Pyrolysis-A Review Paper

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Abstract—Environmental, economic and strategic reasons are behind the rapid impulse in the deployment of renewable energy sources that is taking place around the world. In addition to overcoming economic and commercial barriers, meeting the ambitious objectives set by most countries in this field will require the development of novel technologies capable of maximizing the energy potential of different renewable sources at an acceptable cost. The use of solar radiation and biomass for power generation is growing rapidly, particularly in areas of the globe where these resources are plentiful, like Mediterranean countries. However, solar energy plants necessarily suffer from the intermittency of day/night cycles and also from reduced irradiation periods (winter, cloudy days, short transients). Biomass power plants have to confront the logistic problems associated with the continuous supply of very large amounts of a relatively scarce and seasonal fuel. Hybrid systems may provide the solution to these limitations, maximizing the energy potential of these resources, increasing process efficiency, providing greater security of supply and reducing overall costs. This paper focuses on the brief discussion about solar thermal, solar biomass, pyrolysis process, products and their characteristics.

Index Terms— Biomass, Solar thermal energy, Pyrolysis, Reactors, Syngas, Bio-oil, Biochar..

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1 INTRODUCTION

Demand for energy is increasing due to population growth, technological progress and urbanization. By2100, worldwide energy demand is forecast to be five times greater than today. We are also seeing a continual upward trend in energy prices. Government agencies and researchers are pursuing different options to fill the impending energy gap caused by increasing demand per capita, population growth, and the need to curb greenhouse gas(GHG) emissions from conventional energy sources. Among these options, biomass is unique in that it is carbon-based and provides fuels comparable to fossil fuels. The use of biomass resources for energy production has already become very significant: currently biomass provides approximately 13% of world primary energy supply and more than 75% of global renewable energy. Indeed it is estimated that bio-energy could contribute 25–33% of global energy supply by 2050. A recent report of the World Energy Council anticipates that the current expansion will continue for several decades. Continued adoption of biomass will require efficient conversion routes and avoidance of competition with food and fiber.

Pyrolysis can convert biomass from a variety of sources– including agricultural and forestry residues–into liquid, solid and gaseous forms. All three output fractions have potentials fuels (either directly or after up-gradation) in various types of prime mover for transport, power generation, combined heat and power (CHP) or combined cooling heat and power (CCHP).The pyrolysis liquid (PL) is promising for use in both internal and external combustion engines, especially in internal combustion (IC) engines of the compression ignition (CI) type. The solid char is useful for heating, co-firing in coal plant, and as soil fertilizer and conditioner where by It also provides some sequestration of atmospheric carbon. Char can also be used to produce syngas via gasification techni-ques. The pyrolysis gas (PG) can be used in gas-fired boilers, gas turbines, spark ignition(SI) engines or dual-fuel engines. Recent reports have highlighted the opportunities to produce sustainable IC engine fuels from biomass pyrolysis. Moreover, the UK's Carbon Trust has identified biomass pyrolysis as an interesting option to provide future transport fuels. Internal combustion engines, especially CI engines, are used extensively worldwide for a variety of energy services such as transport, shipping, fishing boats, irrigation, power generation, CHP and CCHP. Most likely, they will remain popular for decades due to their high efficiency (both at full and part load) and variations in scale (from very small to very large), high power to weight ratio, low capital investment and operating costs, and fuel flexibility. In 2005, the total estimated world GHG emission was 44153 MtCO2 eq. of which 66.5% was associated with energy services. The share of transportation, electricity and heat was 39.2% alone (of total emission) and 59% (of total energy-related emission), with mostly IC engines (including gas turbines) and steam turbines serving as prime movers. Therefore a very large reduction in GHG emissions is possible by substitution of fossil fuels destined for IC engines with renew- able alternatives such as fuels from biomass pyrolysis. Though there have been several reviews of pyrolysis conversion techniques, parameters and products variations, relatively few have been focused on the applications of pyrolysis fuels. Chiaramontia et al. reviewed the use of fast PL in both internal and external combustion engines for power generation, but did not cover the use of PG in IC engines. Biomass pyrolysis and its applications are still in the early stages of development. To accelerate progress, it is important to consolidate and disseminate the outcomes of cutting-edge research. The aim of this review is therefore to present the current status and future R&D prospects of PL and

PG as alternative fuels in IC engines, for the benefit of researchers involved in production and up-gradation of pyrolysis fuels. This study will also interest those involved in engine testing and development including engine and component manufacturers. The specific objectives are to (i) outline the main pyrolysis techni- ques and reactor types used to produce these fuels; (ii) review the properties of PL in comparison to standard fossil diesel; (iii) review the technical experience relating to CI engines running on crude and up-graded PL in comparison to standard diesel; (iv) review the technical feasibility of PG use in SI (and dual fuelled) engines; and (v) review the PL up-gradation techniques and assess the upgraded properties of the PL in comparison to crude PL. Modifications to the IC engines for use with pyrolysis fuels will also be discussed.

2 PYROLYSIS

For There are several ways to make use of the energy contained in the biomass from old direct burning to gasification, pyrolysis. The selection of the most profitable technique to recover the energy from a particular type biomass is and most important step towards a profitable investment. Direct Combustion is the old way of using biomass. The biomass is completely transformed into heat, but the efficiency is just about 10 percent. The gasification pushes to the maximum level the cracking of biomass by completely transforming it into a combustible gas before burning it. The charcoal production, the slow pyrolysis of wood at temperature 500 °C is a process that charcoal makers have exploited for thousands years. Charcoal is a smokeless fuel which is still used for heating purposes. It first technological use can be dated back to the iron age when charcoal was used in ore melting to produce iron. Production of wood vapor was usually related to the smocking which is one of the oldest food preservation method, probably applied since the development of cooking with fire. These vapors, which contain nature preservatives like formaldehyde and alcohol, were used as feedstocks. The main attraction is small and very simple plants could be made at a very low investment cost. The disadvantage is rather low energy yield and the air pollution. The biomass pyrolysis is attractive because solid biomass and wastes which are very difficult and costly to manage. can be readily converted into liquid products. These liquids, as crude bio-oil or slurry of charcoal of water or oil, have advantages in transport, storage, combustion, retrofitting and flexibility in production and marketing. The energy densities are summarized in Table 1. The crude pyrolysis oil is a blank fluid which often named as bio-oil, pyrolysis oil, or just oil. The other main product is a slurry which can be made from waste and charcoal with chemical added to stabilize the suspension. Stable and mobile concentration of up to 60% wt have been reported. Slurries can also be made from the oil and charcoal. In pilot plant, the gas is usually flared but in a commercial process it would be used to drive the process or use it as a fuel drying or power generation. In transport, the bulk density is important, and some estimated values are given in Table 1 Oil and slurry mixture have a clear advantage over wood chips and straw in transport bulk density and notable in energy density. For longer distance collection of biomass, this difference may be a decisive factor. Storage and handling may be important because of seasonal variations in production and demand of some storage will always be required. Apart from the bulk density and the energy consideration, it is important that raw biomass will deteriorate during storage due to biological degradation process. Char, however, is very stable and will not biologically degrade. Another important factor is handling, in which liquids have significant advantages over solids. Generally liquid products are easier to control in the combustion process and this is important in retrofitting existing equipment. Current oil fired burners can’t be fully directly with solid biomass without any modification of the unit, which may not be interested in uncertain fuel markets. However, Bio-oil, char-oil slurry and char-water slurries are likely to be required only relatively minor conversion of the equipment or even none in some case. Powered coal burners can relatively easily accept charcoal as a partial fuel replacement, as long as the violated content is compatible with the burner design. In power station, the gas turbines can readily fired with bio-oil and slurry fuels although there is needed with the alkali ash in the char content of the slurry. Some modified engines can be used to use the upgraded oil. In some countries there is a market for charcoal lumps and briquettes for leisure and industrial application.

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Feed	Bulk density Kg/M³)	Heating value dry basis (GJ/T)	Energy density (GJ/M³)
Straw	100	20	2
Woodchips	400	20	8
pyro-oil	1200	25	30
Charcoal	300	30	9
char-water slurry (50/50)	1000	15	15
char-oil slurry (20/80)	1150	23	26

Table 1: Energy and Density Characteristics

2.1 Pyrolysis principle

Pyrolysis is a thermochemical processing taking place under inert atmosphere. Pyrolysis reactions are endothermic. *Pyrolysis is thermal degr*adation either in the complete absence of oxidizing agent, or with such a limited supply that gasification does not occur to an appreciable extent or may be described as partial gasification. Relatively low temperature are employed of 500 to 800 °C, compared to 800 to 1000 °C in gasification. Three products are usually produced: gas, pyrolysis oil and charcoal, the relative proportions of which depend very much on the pyrolysis method, the characteristics of the biomass and the reaction parameters. Fast or flash pyrolysis is used to maximize either gas or liquid products according to the temperature employed. So far, there are many kinds of processes of biomass pyrolysis, such as conventional, flash or fast which depend on reaction parameters. However, the typical pyrolysis process can be described as follows:

The biomass are previously cut to size and dried to obtain a fully control of the process. The biomass is therefore feed to the reactor with just enough air to burn that part of biomass or heat carrier (sand or others) supplying the heat necessary to the process. A system of cyclones and condensers allows to recover the products. Generally speaking, the biomass pyrolysis system deals with many aspects: biomass planting, pretreatment, pyrolysis process, products utilization and upgrading, cost and economic evaluation. The following will review the latest technologies of biomass pyrolysis in European countries and U.S.A.

2.2 Pyrolysis Technologies

Pyrolysis has been practiced for centuries for production of charcoal. This requires relatively slow reaction at very low temperatures to maximize solid yield. More recently, studies into the mechanisms of pyrolysis have suggested ways of substantially changing the proportions of the gas, liquid and solid products by changing the rate of heating, temperature and residence time. High heating rates, of up to a claimed 1000 °C/s or even 10000 °C/s, at temperature below about 650 °C and with rapid quenching, causes the liquid intermediate products of pyrolysis to condense before further reaction breaks down higher molecular weight species into gaseous products. The high reaction rates also minimize char formation, and under some condition no char is apparently formed. At high maximum temperature, the major products is gas. Pyrolysis at these high heating rates is known as fast, or flash pyrolysis according to the heating rate and residence time, although the distinctions are blurred. Other work has attempted to exploit the a complex degradation mechanisms by carry out pyrolysis in unusual environment. The main pyrolysis variants are listed in Table 2 and the characteristics of the main models of pyrolysis are summarized into Table 3.

Tech.	**Residence time**	**Heating rate**	**Temperature °C**	**Products**
carbonation	Days	very low	400	charcoal
Conventional	5-30 min	Low	600	oil, gas, char
Fast	0.5-5s	very high	650	bio-oil
Flash-liquid	< 1 s	High	< 650	bio-oil
Flash-gas	< 1 s	High	< 650	chemicals, gas
Ultra	< 0.5	very high	1000	chemicals, gas
Vacuum	2-30s	Medium	400	bio-oil
Hydro-pyro.	< 10s	High	< 500	bio-oil
Methano-pyro.	< 10s	High	> 700	chemicals

Table 2: Pyrolysis Technology Variant

	Flash low T	**Flash high T**	**Slow**	**Carbonization**
Feedstocks				
Feedsize	small	small	moderate	Large
Moisture	v.low	v. low	low	Low
Parameters				
Temp °C	450-600	650-900	500-600	450-600
Pressure, bar	1	0.1- 1	1	1
Max. input, t/h	0.05	0.02	5	10
Product				
Gas, % wt dry	< 30	< 70	< 40	< 40
MJ/Nm3	10-20	10-20	5-10	2-4
Liquid %	< 80	< 20	< 30	< 20
MJ/Kg	23	23	23	10-20
Solid %	< 15	< 20	< 30	< 35
MJ/Kg	30	30	30	30

Table 3: Characteristics of Pyrolysis Technologies

2.2.1 Types of Pyrolysis Reactor

A. Fixed bed reactor:

Charcoal can be produced with a fixed bed reactor in which the biomass feedstock is partially gasified by air. The company Bio-Alternative SA operated a downdraft fixed bed gassier of 1 m diameter and 3 m height (Bridgwater and Bridgw, 1991). with a biomass throughput of 2000kg/h. Products of this process are gas, viscous tars and charcoal of which the yield is maximized. For fir and beech wood, charcoal yields of 300 weight percent on fed wood basis have been achieved. All products are used as energy carriers.

B. Fluid bed reactor

The well known fluid bed reactor technology has been applied by Kosstrin (1980), Gourtay et al (1987) and Scott et al (1988). Tar yields, produced by a medium scale (100kg/h) fluid bed reactor, are quite low due to cracking of the vapors in the large volumes of bed and freeboard. Fluid bed reactor technology offers good possibilities in gasifying biomass feedstocks with minimum tar formation. In that case, bed material should be selected on basis of optimum catalytic tar cracking behavior. If, however, tar is the product aimed at, a non-catalytic shallow fluid bed should be applied followed by immediate quenching of the gaseous products. The well known fluid bed reactor technology has been applied by Kosstrin (1980), Gourtay et al (1987) and Scott et al (1988). Tar yields, produced by a medium scale (100kg/h) fluid bed reactor, are quite low due to cracking of the vapors in the large volumes of bed and freeboard. Fluid bed reactor technology offers good possibilities in gasifying biomass feedstocks with minimum tar formation. In that case, bed material should be selected on basis of optimum catalytic tar cracking behavior. If, however, tar is the product aimed at, a non-catalytic shallow fluid bed should be applied followed by immediate quenching of the gaseous products.

2.2.2. Current Status of the Technologies:

There are plans for small commercial units to be derived from this technology in Italy, Spain and Greece as LEBEN projects. A 250 kg/h pilot plant based on the Waterloo processes has been constructed in Spain. Several plants are in operation at a demonstration level for sewage sludge and refuse/WSW in West Germany at capacities up to 2t/h, based on slow temperature pyrolysis. Elsewhere, a number of demonstration plants for flash pyrolysis are operation in North America at a scale of up to 25 kg/h with plans for several commercial developments ranging up to 40 kg/h, including a commercial installation planned for California based on the SERI ablative pyrolysis and sewage sludge pyrolysis in Canada and Australia. Examples of current research and development activities are listed in Table 4 Some properties that have been reported are summarized and compared in Table 5.

Technology	**Organization**	**Capacity (kg/h)**	**Desired Gas/Tar/char**		**T (°C)**
			product	**(Wt%)**	
Fixed bed	Bio-Alternative	2000	Char	55/15/30	500-800
Fluid bed	THEE	500	Gas	80/10/10	650-1000
Radiation Furnace	Univ. Zaragoza	100	Gas	90/8/2	1000-2000
Conventional	Alten (KTI+ Itaenergy)	500	Tar		
Circulation fluid bed	Ensyn Engineering	30	Tar	25/65/10	450-800
Fast entrained flow	Georgia Tech Research Ins.	50	Tar	30/60/10	400-550
Vacuum	Laval University	30	Tar	15/65/20	250-450
Vortex reactor	Solar Energy research Ins.	30	Tar	35/55/10	475-725
low temperature	Tubingen University	10			
Flash fluid bed	Waterloo University	3	Tar	20/70/10	425-625
Rotation cone reactor	Univ. Twente	10	Tar	20/70/10	500-700

Table 4: Comparison of Pyrolysis Process Technologies ranking according to the desired products

Technology	**GIT**	**Ensyn**	**laval**	**SERI**	**Twente**
Temperature [°C]	500	550	480	510	600
Pressure [bar a]	1.0	1.0	0.01	1.0	1.0
Flow rate [kg/h]	50	50	30	30	12
dp [mm]	0.5	0.2	10	5	0.5
t gas [s]	1.0	0.4	3	1	0.5
t solid [s]	1.0	0.4	100		0.5
gas yield [wt%]	30	25	14	35	20
tar yield [wt%]	60	65	65	55	70
Char yield [wt%]	10	10	21	10	10
Tar characteristics (on wet basis)					
Density	1.23	1.21	1.23	1.20	1.20
Viscosity [cp]	10 (60c)	90 (25c)	5 (40c)	90 (30c)	80 (20c)
C wt%	39.5	45.5	49.9	54.4	43.2
H wt%	7.5	7.0	7.0	5.7	8.2
0 wt%	52.6	45.4	43.0	39.8	48.6
HHV [MJ/Kg]	24	19.3	21	15	25
Water in tar [wt%]	29	16	18	15	25
Product yield					
% wt liquid	21		59	66	70
Water	26		26	10	10
Char	21		15	14	10
Gas	32		-	10	10

Table 5: Characteristics of Various Pyrolysis Technologies for Bio-oil

2.2.3. SPECIFIC TECHNOLOGIES FOR BIO-OIL PRODUCTION:

Bio-oil production is maximal at medium process temperatures (450-650) and short vapor residence times in the reactor. Useful criteria for selecting pyrolysis technologies for bio-oil production are: i) the bio-oil yield per unit of mass of wood which should be as high as possible, ii) the reactor capacity of the process should be as large enough to limit the number of scale-up steps to full plant capacity. Pyrolysis technologies include in the following survey are selected on the basis of these criteria. Accordingly, it was decided to consider only processes with bio-oil yield larger than 50 weight percent on dry wood basis and a plant capacity of more than 10kg/h.

i. ENTRAINED FLOW REACTOR:

Biomass pyrolysis in an entrained flow reactor has been studied by Gorton et al (1990) at the Georgia Institute of Technology, Atlanta, GA, U.S.A. A flow sheet of their process is given in Fig.1a. The vertical reactor tube has a length of 6.4m and an internal diameter of 0.15m. Air and propane are introduced stoichiometrically and combustion in the bottom section of their reactor. The produced hot flue gas flows upwards through the tube while passing the biomass fees point. In this way the thermal energy of the combustion gas is used to heat the biomass particles and, if necessary, provide the heat of the pyrolysis reaction. Typical operation condition are ratio of carrier-gas mass flow over the pyrolysis mass flow of about 4, a reactor inlet temperature of 900 °C, an atmospheric reactor pressure and a reactor throughput of 500 kg.h. The disadvantage is that it needs large amount of carrier gas (nitrogen).

ii. CIRCULATING FLUID BED REACTOR:

An upflow circulating fluid reactor has been operated by Ensyn in Ottawa, Canada (Graham, 1988). The biomass particles and pre-heated sand are fed together in the bottom section of the circulating fluid reactor. Unfortunately there is no literature available reporting the dimension and the flow rates of the preheated carrier gas and sand for this process. Typical operation of this reactor are a temperature 600 ° C and a biomass throughput of 100 kg/h. It is claimed 60% bio-oil can be achieved with poplar wood as the feed stocks. The use of the sand as a heat carrier offers the advantage of a compact construction because of the high heat transfer rate from the sand to biomass particles. Another advantage is the short residence time of gas, by which secondary tar cracking is suppressed. When this reactor becomes scales-up, special attention should be pay to the rapid mixing of biomass particles with solid heat carrier. Again the requirement of carrier gas is a disadvantage.

III. VACUUM FURNACE REACTOR:

The vacuum pyrolysis of aspen polar in a multiple hearth reactor has been studied by Roy et al (1992, 1993) at the University of Laval, Quebec, Canada. Six heated hearths with a diameter of 0.7 m are staked on top of a total height of 2 m. Wood is fed into the top compartment of reactor and transported downwards by gravity and by the action of scrapers which at present in each compartment. If the biomedicine is converted completely, the bottom compartment contains only charcoal which can be easily removed from the reactor. The temperature of top hearth is about 200 °C and increases towards the bottom the reactor where it reaches 400 ° *C* to achieve maximum bio-oil products. A vacuum pump is used to keep the reactor pressure at a value of 1 KPa. A difficulty in scaling -up the reactor is necessary installing a large capacity vacuum pump which is sensitive to fouling and also it is very expensive.

IV. VORTEX REACTOR:

A vortex reactor has been constructed by Diebold and Power (1988) at solar Energy Research Institute, Golden, Co. U.S.A. This reactor has a tube diameter of 0.13 m and a length of 0.7 m For proper operation the reactor, biomass particles should be entrained in a nitrogen flow with velocity of 400 m/s and enter the reactor tube tangentially. For such condition the biomass particles experience high centrifugal forces which induce high particle ablation rates on the heated reactor wall (625 °C). The ablating particles leave a liquid film of bio-oil on the wall which evaporates rapidly. If the wood particles are not converted completely they may be recycled with a special solids recycle loop. In their paper, Dieblod and Power (1988) estimate the number of cycles required to achieve completely conversion of the biomass particles to be about 15, which is considered to be quit high. However, 80 weight percent bio-oil (on dry wood basis) has been achieved up to now.

2.3 PYROLYSIS PRODUCTS AND THEIR CHARACTERISTICS:

The primary products can be gas, liquid and solid depending on the process employed. Most of the projects interest in the liquid products due to their high energy density and potential for oil substitution. The liquid, when formed, approximates to biomass in elemental composition with a slight higher heating value of 20-25 MJ/Kg, and is composed of a very complex mixture of oxygenated hydrocarbons. The complexity arise from the degradation of lignin, and the broad spectrum of phenolic compounds. The liquid is often called oil, but is more like tar. This also can be degraded to liquid hydrocarbon fuels. The crude pyrolysis liquid is a thick black tarry fluid with up to 20 % wt water and viscosity as heavy oil. The solid products from pyrolysis process is char, which has limited application in developed countries for metallurgical and leisure use. An alternative approach to liquid products lies in grinding the car and slurry it with water with a stabilizer. Stable and mobile concentration of up to 60 % wt has been reported. The slurry can also be made from the bio-oil and char, but the maximum solid concentration appears to be 30 %. The gas product from pyrolysis usually have a MHV fuel gas around 15 -22 MJ/NM^3. or a LHV fuel gas of around 4-8 MJ/Nm^3 from partial gasification depending on feed and processing parameters.

3 SOLAR THERMAL PYROLYSIS

Solar thermal pyrolysis is the pyrolysis process that deploys concentrated solar energy to drive at least part of the endothermic pyrolysis reactions. It produces solar energy carriers, effectively achieving the storage of concentrated solar energy into chemical energy carriers.

3.1 Control of Solar Thermal Energy:

The use of renewable energy, such as solar energy, experienced a great impulse during the second half of the seventies just after the first big oil crisis. At that time, economic issues were the most important factors and the interest in these types of processes decreased when oil prices fell. There is renewed interest in the use of renewable energies nowadays driven by the need of reducing the high environmental impact produced by the use of fossil energy systems. The most abundant, sustainable source of energy is the Sun, which provides over 150,000 terawatts of power to the Earth; about half of that energy reaches the Earth surface while the other half gets reflected to outer space by the atmosphere. Only a small fraction of the available solar energy reaching the Earth surface would be enough to satisfy the expected global energy demand. Although most renewable energies derive their energy from the Sun, by solar energy we refer to the direct use of solar radiation. One of the greatest scientific and technological opportunities we are facing is to develop efficient ways to collect, convert, store, and utilize solar energy at affordable costs. There are two main drawbacks to solar energy systems: (a) the resulting energy costs are not yet competitive and (b) solar energy is not always available when needed. Considerable research efforts are being devoted to techniques which may help to overcome these drawbacks; control is one of those techniques. While in other power generating processes, the main source of energy (the fuel) can be manipulated as it is used as the main control variable, in solar energy systems, the main source of power which is solar radiation cannot be manipulated and furthermore it changes in a seasonal and on a daily base acting as a disturbance when considered from a control point of view. Solar plants have all the characteristics needed for using advanced control strategies able to cope with changing dynamics (nonlinearities and uncertainties). As fixed PID controllers cannot cope with some of the mentioned problems, they have to be detuned with low gain, producing sluggish responses or, if they are tightly tuned, they may produce high oscillations when the dynamics of the process vary, due to environmental and/or operating condition changes. In some cases, especially with high solar radiation and scattered clouds, oscillations are so severe that the field may have to be defocused or shutdown. The use of more efficient control strategies resulting in better responses would increase the number of operational hours of the solar plants and thus reduce the cost per kW-h produced, not only because of low radiation levels, but of the oscillations due to disturbances produced by scattered clouds.

3.2. Solar energy harvesting:

Solar powered electrical generation can be done either directly, by the use of photovoltaic (PV) cells or indirectly by collecting and concentrating the solar power (CSP) to produced steam which is then used to drive a turbine to provide the electrical power. The direct generation of electricity from solar energy is based on the photovoltaic effect which refers to the fact photons of light knock electrons into a higher state of energy. Although the first application of photovoltaic was to power space crafts, there are many PV power generation systems for everyday life applications such as grid isolated houses, pumps for water extraction, electric cars, roadside emergency telephones and remote sensing. Concentrating solar thermal (CST) systems use optical devices (usually mirrors) and Sun tracking systems to concentrate a large area of sunlight onto a smaller receiving area. The concentrated solar energy is then used as a heat source for a conventional power plant. A wide range of concentrating technologies exist. The main concentrating concepts are: (a) parabolic troughs, (b) solar dishes, (c) linear Fresnels, and (d) solar power towers. The main purpose of concentrating solar energy is to produce high temperatures and, therefore, high thermodynamic efficiencies. Both technologies, PV and CSP, have their advantages and drawbacks.

They are summarized below:

Photovoltaic panels are able to collect both direct and diffuse radiation so that they can work even on cloudy days.
The electricity in CSP systems is produced by a power conversion system delivering alternating current (AC).
Photovoltaic panels produce direct current which must be converted to alternating current using a grid tie inverter in existing distribution grids that use AC.
This may lead to an energy loss of 4–12%. CSP possesses an inherent capacity for thermal storage.
Batteries for storing the electricity produced by PV are more expensive. The construction process and installation is simpler for PV than CSP systems.
PV systems require less maintenance than CSP technology. In a technical and economical comparison of photovoltaic and concentrating solar thermal power systems is performed.

3.3. Solar Thermal Pyrolysis Principle

$$\text{Biomass pyrolysis} \xrightarrow{\text{Solar energy}} \text{Syngas+Bio-oil+Char}$$

This approach is very attractive because the energy carrier products are of high energy density.

3.4 Solar Thermal Pyrolysis Advantages

(a) Takes advantages of the complementary features of both biomass and solar energy (b)Storage of solar energy into chemical energy carriers (c)The energy carriers are of high-energy density and readily transportable (d) Eliminating the need of dedicated storage of solar energy.

3.5 Solar Tracking Device

Asd Solar radiation can be converted into useful energy directly, using various technologies. It can be absorbed in solar collectors to heat water and can also be converted directly into electrical energy using photovoltaic solar cells. It allows the automatic measurement of direct solar radiation with a pyrheliometer. It operates automatically, guided by a closed loop servo system. A four-quadrant photo detector senses the position of the sun and two small DC motors move the instrument platform keeping the sun's image at the center of the four-quadrant photo detectors. Under cloudy conditions, when the sun is not visible, a computing program calculates the position of the sun and takes control of the movement, until the detector can sense the sun again. The presented tracker proves the effective work of a simple and cheap mechanism, which can be adapted to also work with larger following installations like solar cell panels, concentrators, etc.

3.6 solar thermal technologies for pyrolysis

Different type of solar technology was used to pyrolysed biomass. There are four basic technologies which are currently in use:

ƒ Dish Stirling
ƒ Central Receiver Plants
ƒ Fresnel's Reflector
ƒ Parabolic Trough

Different technologies produce different peak temperatures and have different efficiencies, due to differences in the way they track the sun and focus the the solar radiation.

4. FUTURE CHALLENGE

- Understand and analysis the limitations of the solar prylysis processes.
- Improvement of the reliability of solar thermal pyrolysis reactors and processe.
- Development of more efficient technologies for the production of chemicals and biofuels from pyrolysis oils
- Document environmental health and safety issues in handling, transport and usages;
- Improve the quality and consistency of bio-oil;
- Development of catalysts for bio-oil upgrading;
- Determine detailed characteristics of bio –oil and products.,

4. CONCLUSION

Due to some drawbacks of pyrolysis, solar thermal pyrolysis is getting interested now a days .

After studying the research papers and based on today's scenario we can say that solar thermal pyrolysis will be the future best technology. Because the amount of efficiency which we received from solar thermal pyrolysis is much better than pyrolysis .

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