Experimental and Theoretical Investigation of Torrefaction Process

Mr. Harshul Brahmbhatt[1] Mr. R.S.Khanna[2]
[1]ME Student [2]Assistant Professor
[1]Department of Thermal Engineering
[1,2]LJIET

Abstract— Biomass typically contains approx. 70 % volatile matter and 30 % fixed carbon on dry mass basis. During the torrefaction process, solid biomass is heated in the absence of oxygen at a temperature of approx. 200-350 °C, leading to a loss of moisture and partial loss of the volatile matter in the biomass. With the partial removal of the volatile matter (about 25%), the characteristics of the original biomass are drastically changed. Torrefaction is different from steam explosion, and results in different product characteristics.
Key words: Torrefaction Process, CAPEX, Gasification

I. INTRODUCTION

Biomass is a versatile energy resource that could be used as a sustainable energy resource in solid, liquid and gaseous form of energy sources. Torrefaction is an emerging thermal biomass pretreatment method that has an ability to reduce the major limitations of biomass such lower bulk density, lower energy density, hydrophobic behavior, and fibrous nature. Torrefaction, aiming to produce high quality solid biomass products, is carried out at 200-300 °C in an inert environment at an atmospheric pressure. The removal of volatiles through different decomposition reactions is the basic principle behind the torrefaction process. Torrefaction upgrades biomass quality and alters the combustion behavior, which can be efficiently used in the co-firing power plant. Despite of the number of disadvantages, torrefaction is motivated mainly for thermochemical conversion process because of its ability to increase hydrophobicity, grindability and energy density of biomass. In addition to this, torrefied biomass could be used to replace coal in the metallurgical process, and promoted as an alternative of charcoal.

Wood is one of the most traditional energy sources. However, due to the targets to increase the utilisation rate of renewable energy sources, development of more efficient ways for energy utilisation of wood is required. Torrefaction is a new technology for wood refinement, and the end product, i.e. the torrefied wood pellets, can be utilised in existing coal-fired power plants.

Over the last decade, torrefaction technology has been rapidly developed from pure R&D to the stage of market introduction and commercial operation. The first contracts for off-take to energy companies were recently signed and indications are that torrefaction has a potential to replace over time the wood pellets as a standard solid biomass fuel for co-firing in a pulverised coal fired power plant. The torrefied pellets have superior characteristics in terms of compatibility with coal (ie. Heating value, grindability, bulk energy density, density, hydrophobic aspects, etc) which potentially avoid costly power plant modifications. Particularly in the current investment climate with uncertainties in political support for biomass co-firing and increasing operating expenses (OPEX) while avoiding capital expenses (CAPEX) is often preferred.

II. TORREFACTION PROCESS

During the first stage the biomass is heated up. At this point the temperature rises, but no water evaporates yet. The stage ends when the temperature approaches 100 °C and water starts to escape. The second phase is pre-drying, when the temperature keeps constant, but the biomass gets dried due to water evaporation. When the biomass gets dry enough, so that temperature starts to rise again, the stage ends. During the phase of post-drying and intermediate heating, the temperature rises up to 200 °C. At this point the remaining water evaporates and therefore the moisture content gets close to zero. [4]

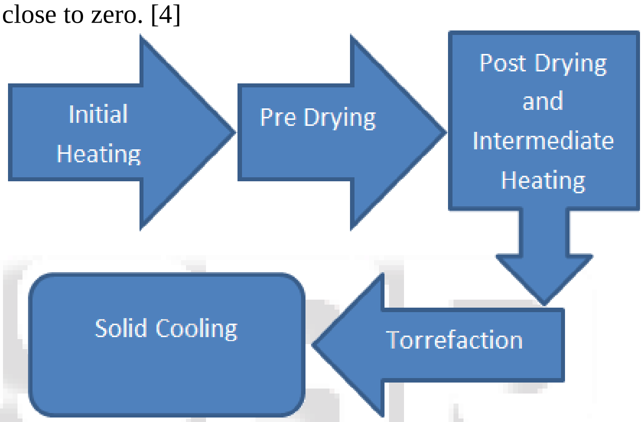

Fig. 1: Torrefaction Process

The density of torrefied material is approximately 10 - 20 % lower than that of dried raw material. At the end, the mass is cooled down. The torrefied material is partly dust-type and contains fine material, because of which the material is pelletized in order to enhance the handling properties. Biomass is dried completely in the torrefaction process, and afterwards the moisture uptake is very limited, approximately 1 - 6 % depending on the level of torrefaction and post-processing of torrefied biomass.

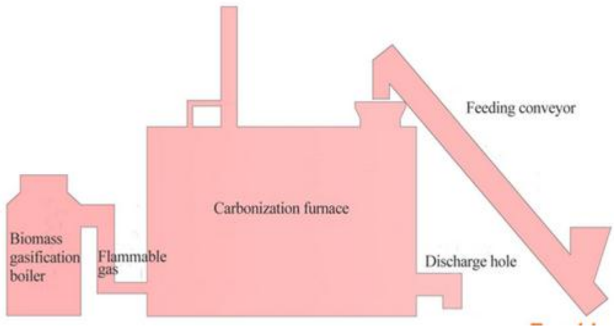

Fig. 2: Carbonization Furnace

The whole equipment is with biomass gasification boiler, flue-gas cleaner, gas burner and carbonization furnace. The equipment adopts the dry distillation carbonization technique. It makes full of the flammable Gas during the carbonization process and these gas go through the flue-gas cleaner system to get the pure flammable gas after separating the wood tar and wood vinegar. The pure gas goes into the burner for burning completely to heat the high-temperature carbonization pipes.

In the carbonization furnace, there are four layers of pipelines from top to bottom. The first and second layers are preheated drying pipelines, and the third is lower temperature carbonization pipeline and the forth is high temperature carbonization pipeline. In the first and second layers of pipelines, there are equipped with independent exhaust pipes used to exhaust the vapor, and the pipelines uses the waste heat existing in the furnace to dry the materials, then the vapor comes out from exhaust pipes. In the third and fourth layers of pipelines, there are installed with independent flammable gas recycling pipe, and the carbonization pipelines starts high temperature carbonization and flammable gas (CO, methane, hydrogen etc) produced is processed from recycling pipes, gas cleaner to gas burner and burns finally to provides heat to pipelines, to reach the effect and aim of to pipelines, to reach the effect and aim of reciprocating, circulat-ing heating carbonization. In the first time of carbonization, the gas source and heat is supplied by the biomass gasification boiler.

III. APPLICATION OF TORREFIED BIOMASS

Torrefied biomass can be used for various applications; the most likely ones being co-firing with coal in pulverised coal fired power plants and in cement kilns, dedicated combustion in small scale pellet burners and gasification in entrained flow gasifiers that normally operate on pulverized coal. For all of these applications however, several issues remain to be verified.[3]

A. Co-Firing In Pulverized In Coal Power Plants:

The advantages of torrefaction are particularly recognized for use in (older) and existing pulverized coal (PC) fired power plants. Since these installations have not been designed for biomass co-firing originally, significant capital expenditures can be saved for modification of the plant when torrefied product is co-fired instead of regular wood pellets. This is particularly the case for torrefied clean biomass resources such as clean wood, which usually meets the constraints of existing environmental permits of the PC fired plant.

The combustion of torrefied biomass classified as waste (e.g. waste wood, roadside grass, and SRF (solid refused fuel)) typically needs to comply with stricter environmental requirements than the normal regime for clean biomass as a result of the European Waste Incineration Directive. Burning torrefied biomass produced from waste material results in a more stringent environmental operational regime and additional emission monitoring obligations. In addition, burning such fuels that are classified as waste may increase operational problems, related to additional slagging, fouling or corrosion or negatively influence the quality of the ash resulting from the combustion. Energy companies are therefore somewhat hesitant to co-fire such fuels at present and generally prefer to use clean biomass feedstock for torrefaction. This might change in future in case torrefied wastes exhibit significant price benefits and have proven to result in acceptable operational plant performance.

New coal fired power plants that are currently in the planning or construction phase are designed for high co-firing ratios of lignocellulosic biomass, which makes the financial advantages of a torrefied biomass fuel with similar characteristics as the main fuel less obvious. Nonetheless, even in new PC boilers torrefaction might even lead to higher co-firing ratios than was originally envisaged for pure biomass co-firing, as it is a much better in replacement due to the similarity in terms of grindability and combustion. The financial drivers for co-firing torrefied biomass are therefore mainly determined by the replacement value of the coal and the market value of CO2.

B. Gasification:

The relatively low moisture content, good grindability and attractive C/H/O ratios make torrefaction an interesting pretreatment technology for gasification. For a gasifier using biomass, particle size and moisture contents are critical factors for good operation. This usually results in relatively expensive biomass feedstock. Torrefied and pelletised biomass is already uniform in particle size and has a very low moisture content, therefore the incremental fuel cost is less important for gasification as for an industrial combustor where cheaper biomass is normally used.

Gasification using torrefied biomass could potentially benefit from improved flow properties of the feedstock, increased levels of H and CO in the resulting syngas, and improved overall process efficiencies. The grindability could be considered positive aspect in the case of entrained flow gasifiers. As of yet, there is hardly any practical knowledge available on the options and limitations of torrefied biomass for gasification.

C. Blast Furnace:

There is a large potential for substituting coal in blast furnaces, given the lack of alternatives for CO reduction. The main issues with torrefied material in a blast furnace are related to the alkali content and composition as well as the high volatile matter content. The steel industry is mainly interested in carbonised biomass, and the application of torrefied biomass seems limited.

D. Standalone Combustion:

Standalone combustion installations are typically based on a grate furnace or fluidized bed furnace and lack the pulveriser which is present in PC plants. This makes them much more fuel flexible in terms of the fuel characteristics that are influenced through torrefaction (fuel particle size, physical appearance and grindability). As the range of fuels that can be used in dedicated plants is mostly limited by the chemical composition (which is not influenced by torrefaction), there is hardly any reason for combining torrefaction with dedicated combustion.

An exception may be the application of relatively small scale pellet boilers that are used for space heating. In this case, fuel logistics may be significantly improved due to the increase in bulk energy density which is particularly relevant in urban areas. One of the unknown issues here relates to public perception due to the change in colour and smell.

REFERENCES

[1] Richard B. Bates, Ahmed F. Ghoniem "Biomass torrefaction: Modeling of volatile and solid product evolution kinetics." Bioresource Technology, Volume 124, pp. 460-469, July 2012.
[2] A.A.Boateng, C.A.Mullen. "Fast pyrolysis of biomass thermally pretreated by torrefaction.", Journal of Analytical and Applied Pyrolysis, Volume 100 , pp. 95-102, December 2012.
[3] Environment Impact of Torrefied Wood Pellet Production, MIKTECH, November 2012.
[4] A.Dutta, "Pros and Cons of Torrefaction of Woody Biomass,school of enginnering, University of Gulf.
[5] Nicole Labbe, Amy Johnson,: "Bio energy Crop Production " , University of Tennesse, November 2013.
[6] Prabir Basu , Anup Kumar Sadhukhan , Parthapratim Gupt , Shailendra Rao , Bishnu Achary , Alok Dhungana. "An Experimental and Theoretical investigation on torrefaction of a large wet wood particles.", Bioresource Technology, Vol. 159, pp. 215-222, March 2014.