Journal of Advances in Science and Technology
Vol. 13, Issue No. 1, (Special Issue) March-2017, ISSN 2230-9659

Comprehensive Study on Additives to Reduce Ash Related Issues in Biomass Combustion

Mohammed Junaid[1]*, N. V. Sali[2]

[1]PG Scholar, Government College of Engineering, Karad

[2]Associate Professor, Government College of Engineering, Karad

Abstract – Biomass is used as fuel in power plant because of its high potential towards energy generation in a sustainable way. Exhaust of biomass fuels are less toxic substances as compared to other fuels. But some biomass fuels contain potassium which on reacting with couple of ash forming elements creates ash related problems such as slagging of heating surfaces, corrosion, agglomeration and fusion that causes some serious operational problems. In this paper, operational problems related to ash are discussed and the additives that can be used to reduce these operational problems are summarized. Additives that can be used are sulphur based, calcium based, phosphorus based and aluminium silicate based additives. These additives can reduce the effect of potassium, slagging ash deposition and ash fusion problems.

Keywords — Ash Related Problems, Biomass, Slagging, Combustion, Additives.

----------♦----------

INTRODUCTION

There is continuous increase of concern related to biomass to use as energy source because of the environmental problems. Biomass is the third largest after coal and natural gas for electricity generation. Biomass can be obtained from various sources and available in many forms. [1,2]. the net CO_2 emission can be reduced up to 93% if coal is replaced with biomass fuel and in case of natural gas if replaced with biomass, 84% CO_2 emission can be reduced. Biomass is defined as any solid organic material that can be used as a fuel. Despite of its various advantages like carbon dioxide neutrality and potential towards high energy generation, biomass combustion remains challenging for various reasons. This is because some biomass fuels contain serious amount of potassium (K) and other inorganic elements. During combustion process, these inorganic elements get released and create some serious ash related problems [1-3]. This ash related problems not only reduce efficiency of combustion but also increase cost for maintenance and cleaning the surfaces of boiler. Ash related problems that appear during and after combustion include, slagging of heating surfaces, agglomeration, corrosion, ash utilization, ash fusion [4].

Several techniques can be used to reduce various ash related issues during combustion of biomass such as use of alkali based additives to remove out problematic elements from fuels before combustion and fuel mixing [5-8]. Out of these methods, use of additives found out to be the most favourable method to reduce ash related problems. Till now, different materials and chemicals as additives have been tried and tested in various biomass combustion reactors and plants, with large amount of experimental data generated and reported [6-9]. The aim of this review paper is to briefly compile ash related problems and to check whether addition of additives can reduce these problems.

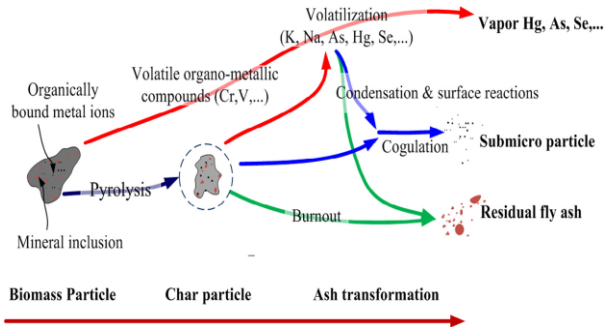


Fig: 1 Schematic diagram of ash formation and transformation mechanisms in biomass combustion [16]

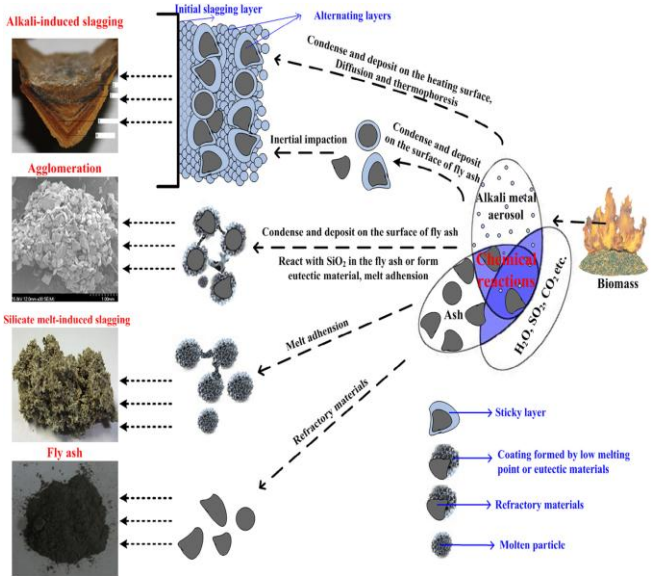


Fig: 2 Schematic of the formation processes of the main ash-related issues in biomass combustion [5]

Fig.1. shows a formation of ash particles and their transformation mechanism in biomass combustion. During this process ash forming particles formed and then released and which results in formation of slagging and agglomeration. Fig.2 shows formation mechanism of silicate induced slagging, fly ash and agglomeration. Potassium chloride is considered as the most responsible substance that influences the slagging process. [4]

Ash forming elements can be grouped into four types such as a) minerals included in the fuel structure b) water soluble salts c)matters associated with inorganic materials d) inorganic material added from extraneous sources. During combustion process, release and transformation of ash forming elements is generated which can create various ash related problems. One of the elements is Potassium that results in generation of some dangerous species on the heating surfaces at elevated combustion temperatures. The various species involving,

a) Generation of potassium salts like K_2SO_4, K_2CO_3 and KCL having melting temperature as low as 770°C [1,2].

b) Formation of various potassium silicates due to reaction between potassium salts and silicon in the elements. These salts are present when combustion temperature ranges from 700 to 1000°c in the form of viscous liquids which cause ash sintering and bed agglomeration [3].

c) Fly ash may melt on the heating surfaces, if the SiO_2 content is high. The silicate having melting temperature 700°C may melt at biomass combustion temperature and cause sintering.

d) Generation of potassium phosphates with high content of potassium ratio or potassium. These may melt during combustion results in slagging. [9,10]

Release and generation of various ash species, different operational problems may occur these are:

a) Slagging and fouling deposits on the heat transfer surfaces due to condensation of alkali salts and sticking of ash particles which carried by flue gas [1,2].

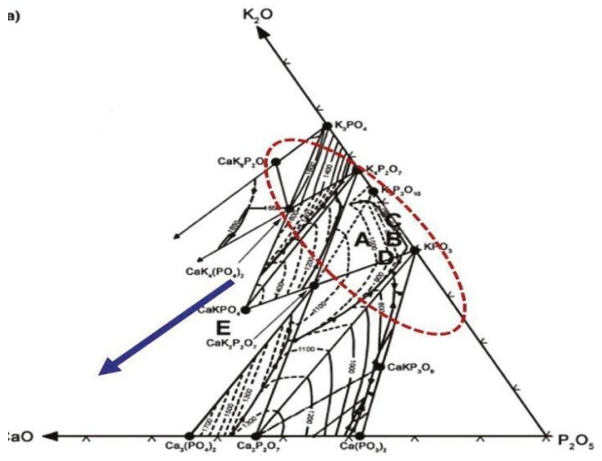
b) Formation of slag due to fused ash at high combustion temperature [2].

c) Gas and deposits that cause fireside corrosion on boiler components [1, 2]

d) Formation of aerosols and fine particles Reduce performance of gas cleaning equipment [10].

USE OF ADDITIVES TO AVOID OR REDUCE ASH RELATED PROBLEMS

Additives are nothing but a group of chemicals or minerals that can reduce performance of problematic species, diverse the ash chemistry and can raise the melting temperature of ash during combustion process. Studies showed that additives can be used in different forms such as feed as powder into combustor or blending with fuel before combustion. Different techniques can be applied to monitor the formation of ash forming matters like KCL. Listed are the different types of additives used.



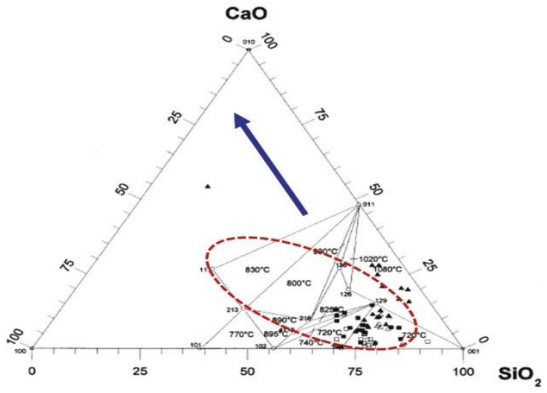


Fig: 3 Formation of potassium containing silicates and phosphates [14]

Sulphur Based Additives:

The measurable effect of this additive is to convert KCL formed during combustion into K_2SO_4. The sulphation of potassium chloride form chlorine atom which gets released and discharged with flue gas. This will reduce sufficient amount of Chlorine in the deposits also reduce the high temperature corrosion. Generally these additives are added in the form of solution [11].

Calcium Based Additive:

Calcium as an alkali earth metal can be diffused into potassium silicate melts, releasing potassium with the flow of flue gas. This will cause more silicon atom to react with calcium to form calcium silicate which has more melting temperature than potassium silicate. Enhancement of calcium in potassium phosphate rises the melting temperature of phosphate. Calcium based additives such as lime, marble sludge and limestone are convenient in minimizing ash related problems like slagging and ash sintering because liquid-solid reaction occurs at very high temperature. [7, 12]

Aluminium Silicate Based Additives:

Reaction between KCL and aluminium silicate based additive cause the formation of potassium aluminium silicate releasing CL atom. Kaolin can be used as an aluminum Silicate additive on reaction with KCL form Leucite and Kalsite. These products have melting temperature of about 1500°C and 1600°C respectively. Generally Kaolin, emathlite, bentonite and zeolites can be used as Aluminium Silicate additives. Sewage sludge can also be used as Aluminium Silicate additive. Presence of alumina and silica increases ash sintering temperature reducing fouling and deposition. [5-7]

Phosphorus based additives:

Phosphoric acid can be used as an additive to minimize ash sintering and slagging problems.

This type of additive used when Si and K found to be in higher proportions. By introducing Phosphorus based additive in the ash residue, potassium reacts with phosphorus to form potassium rich phosphates [9, 14]

CONCLUDING REMARKS:

There are various additives that can be used to reduce ash related problems as reported in literature. But there are many types of difficulties that arise during selection of particular additive are:

1) Reaction between biomass ash and additives is complicated and tough to control.

2) It is tough to anticipate changes in property of additives along with reaction time and temperature [8,9].

Recent literature shows more experiments performed to understand the behaviour of additives at higher temperature and reaction of them on ash deposition. The properties of an ideal additive are supposed to be as follows-

1) Higher stability at elevated temperatures.

2) High melting point without creating any operational issues.

3) Additive should not require any pre-treatment before adding them into the combustion process. Otherwise this will increase cost. [10]

4) Highly reactive to abate ash related issues.

5) Use of additive should not create problem during ash handling.

In this paper, ash related problems are discussed and also various additives to reduce these problems are summarized. More research is required to understand the reaction between biomass ash and additives.

New additives should be tasted and for high reactivity and stability towards high combustion temperature and the additive should be cost effective.

REFERENCES

[1] Larry L. Baxter, Thomas R. Miles, Bryan M. Jenkins, Thomas Milne, David Dayton,

Richard W. Bryers, and Larry L. Oden. "The behavior of inorganic material in biomass-fired power boilers: field and laboratory experiences." *Fuel processing technology* 54, no. 1 (1998): 47-78.

[2] FJ Frandsen, "Utilizing biomass and waste for power production—a decade of contributing to the understanding, interpretation and analysis of deposits and corrosion products." *Fuel* 84, no. 10 (2005): 1277-1294.

[3] J. Werther, M. Saenger, E-U. Hartge, T. Ogada. "Combustion of agricultural residues." *Progress in energy and combustion science* 26, no. 1 (2000): 1-27.

[4] Yanqing Niu, Houzhang Tan, and Shi'en Hui. "Ash-related issues during biomass combustion: Alkali-induced slagging, silicate melt-induced slagging (ash fusion), agglomeration, corrosion, ash utilization, and related countermeasures." *Progress in Energy and Combustion Science* 52 (2016): 1-61.

[5] L. Wang, G. Skjevrak, Johan E. Hustad, and Morten G. Grønli. "Effects of sewage sludge and marble sludge addition on slag characteristics during wood waste pellets combustion." *Energy & Fuels* 25, no. 12 (2011): 5775-5785.

[6] B.M. Steenari, A. Lundberg, H. Pettersson, M.Wilewska-Bien, and D. Andersson. "Investigation of ash sintering during combustion of agricultural residues and the effect of additives." *Energy & Fuels* 23, no. 11 (2009): 5655-5662.

[7] BM. Steenari, and O. Lindqvist. "High-temperature reactions of straw ash and the anti-sintering additives kaolin and dolomite." *Biomass and Bioenergy* 14, no. 1 (1998): 67-76.

[8] C. Gilbe, M. Ohman, E. Lindström, Dan Boström, Rainer Backman, R. Samuelsson, and Jan Burvall. "Slagging characteristics during residential combustion of biomass pellets." *Energy & Fuels* 22, no. 5 (2008): 3536-3543.

[9] E. Lindström, M. Sandström, D. Boström, and M. Öhman. "Slagging characteristics during combustion of cereal grains rich in phosphorus." *Energy & Fuels* 21, no. 2 (2007): 710-717.

[10] L. Tobiasen, R. Skytte, L. Storm Pedersen, S. Thaaning Pedersen, and Martin A. Lindberg. "Deposit characteristic after injection of additives to a Danish straw-fired suspension boiler." *Fuel Processing Technology* 88, no. 11 (2007): 1108-1117.

[11] M. Broström, H. Kassman, A. Helgesson, Magnus Berg, Christer Andersson, Rainer Backman, and Anders Nordin. "Sulfation of corrosive alkali chlorides by ammonium sulfate in a biomass fired CFB boiler." *Fuel Processing Technology* 88, no. 11 (2007): 1171-1177.

[12] Thy, P., C. E. Lesher, and B. M. Jenkins. "Experimental determination of high-temperature elemental losses from biomass slag." *Fuel* 79, no. 6 (2000): 693-700.

[13] L. Wang, J.E. Hustad, Ø. Skreiberg, Geir Skjevrak, and Morten Grønli. "A critical review on additives to reduce ash related operation problems in biomass combustion applications." *Energy Procedia* 20 (2012): 20-29.

[14] A. Grimm, N. Skoglund, D. Boström, and Marcus Ohman. "Bed agglomeration characteristics in fluidized quartz bed combustion of phosphorus-rich biomass fuels." *Energy & Fuels* 25, no. 3 (2011): 937-947.

[15] Y. Jia, and J. S. Lighty. "Ash particulate formation from pulverized coal under oxy-fuel combustion conditions." *Environmental science & technology* 46, no. 9 (2012): 5214-5221.

Corresponding Author

Mohammed Junaid*

PG Scholar, Government College of Engineering, Karad

E-Mail – junaidhpe@gmail.com