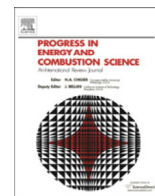




ELSEVIER

Contents lists available at ScienceDirect

Progress in Energy and Combustion Science

journal homepage: www.elsevier.com/locate/peccs

Ash-related issues during biomass combustion: Alkali-induced slagging, silicate melt-induced slagging (ash fusion), agglomeration, corrosion, ash utilization, and related countermeasures

Yanqing Niu ^{a,b,c,*}, Houzhang Tan ^{a,c}, Shi'en Hui ^{b,c}

^a Key Laboratory of Thermo-Fluid Science and Engineering of MOE, School of Energy and Power Engineering, Xi'an Jiaotong University, Xi'an, Shaanxi, 710049, China

^b State Key Laboratory of Multiphase Flow in Power Engineering, Xi'an Jiaotong University, Xi'an, Shaanxi, 710049, China

^c Department of Thermal Engineering, School of Energy and Power Engineering, Xi'an Jiaotong University, Xi'an, Shaanxi, 710049, China

ARTICLE INFO

Article history:

Received 22 August 2015

Accepted 10 September 2015

Available online 20 October 2015

Keywords:

Biomass ash

Slagging

Agglomeration

Corrosion

Additives

Leaching

Co-firing

ABSTRACT

Biomass is available from many sources or can be mass-produced. Moreover, biomass has a high energy-generation potential, produces less toxic emissions than some other fuels, is mostly carbon neutrality, and burns easily. Biomass has been widely utilized as a raw material in thermal chemical conversion, replacing coal and oil, including power generation. Biomass firing and co-firing in pulverized coal boilers, fluidized bed boilers, and grate furnaces or stoker-fired boilers have been developed around the world because of the worsening environmental problems and developing energy crisis. However, many issues hinder the efficient and clean utilization of biomass in energy applications. They include preparation, firing and co-firing, and ash-related issues during and after combustion. In particular, ash-related issues, including alkali-induced slagging, silicate melt-induced slagging (ash fusion), agglomeration, corrosion, and ash utilization, are among the most challenging problems. The current review provides a summary of knowledge and research developments concerning these ash-related issues. It also gives an in-depth analysis and discussion on the formation mechanisms, urgent requirements, and potential countermeasures including the use of additives, co-firing, leaching, and alloying.

Alkali species, particularly alkali chlorides and sulfates, cause alkali-induced slagging during biomass combustion. Thus, the mechanisms of generation, transformation, and sequestration of alkali species and the formation and growth of alkali-induced slagging, formed as an alternating overlapping multi-layered structure, are discussed in detail. For silicate melt-induced slagging (ash fusion), the evolutions of chemical composition of both the elements and minerals in the ash during combustion and existing problems in testing are overviewed. Pseudo-4D phase diagrams of $(\text{M}_2\text{O})\text{-MaeO-P}_2\text{O}_5\text{-Al}_2\text{O}_3$ and $(\text{M}_2\text{O})\text{-MaeO-SiO}_2\text{-Al}_2\text{O}_3$ are proposed as effective tools to predict ash fusion characteristics and the properties of melt-induced slagging. Concerning agglomeration that typically occurs in fluidized bed furnaces, melt-induced and coating-induced agglomeration and coating-forming mechanisms are highlighted. Concerning corrosion, seven corrosion mechanisms associated with Cl_2 , gaseous, solid/deposited, and molten alkali chlorides, molten alkali sulfates and carbonates, and the sulfation/silication of alkali chlorides are comprehensively reviewed. The effects of alloying, salt state (solid, molten, or gaseous), combustion atmosphere, and temperature are also discussed systematically. For ash utilization, potential approaches to the use of fly ash, bottom ash, and biomass/coal co-fired ash as construction and agricultural materials are explored.

Several criteria or evaluation indexes are introduced for alkali-induced slagging and agglomeration, and chemical equilibrium calculation and multicomponent phase diagrams of silicate melt-induced slagging and agglomeration. Meanwhile, remedies, including the use of additives, co-firing, leaching, alloying, and the establishment of regulations, are discussed.

It is suggested that considerable attention should be focused on an understanding of the kinetics of alkali chemistry, which is essential for the transformation and sequestration of alkali species. A combination of heterogeneous chemical kinetics and multiphase equilibrium modeling is critical to estimating the speciation, saturation levels, and the presence of melt of the ash-forming matter. Further practical

* Corresponding author. Key Laboratory of Thermo-Fluid Science and Engineering of MOE, School of Energy and Power Engineering, Xi'an Jiaotong University, Xi'an, Shaanxi, 710049, China. Tel.: +86 137 09181734; Fax: +86 029 82668703.

E-mail address: yqniu85@mail.xjtu.edu.cn (Y. Niu).

evaluation and improvement of the existing criterion numbers of alkali-induced slagging and agglomeration should be improved. The pseudo-4D phase diagrams of $(\text{M}_2\text{O})\text{-MaeO-P}_2\text{O}_5\text{-Al}_2\text{O}_3$ and $(\text{M}_2\text{O})\text{-MaeO-SiO}_2\text{-Al}_2\text{O}_3$ should be constructed from the data derived from real biomass ashes rather than those of simulated ashes in order to provide the capability to predict the properties of silicate melt-induced slagging. Apart from Cr, research should be conducted to understand the effects of Si, Al, and Co, which exhibit high corrosion resistance, and heavy metals such as Zn and Pb, which may form low-melting chlorides that accelerate corrosion. Regulations, cooperation among biomass-fired power plants and other industries, potential technical research, and logistics should be strengthened to enable the extensive utilization of biomass ash. Finally, alkali-induced slagging, silicate melt-induced slagging, agglomeration, and corrosion occur concurrently, and thus, these issues should be investigated jointly rather than separately.

© 2015 Elsevier Ltd. All rights reserved.

Contents

1.	Introduction	3
2.	Part I. Main ash-related issues during combustion: alkali-induced slagging, silicate melt-induced slagging (ash fusion), agglomeration, and customized countermeasures including additives, co-firing, and leaching	4
2.1.	Alkali-induced slagging	6
2.1.1.	Mechanisms of the generation, transformation, and sequestration of alkali species	6
2.1.2.	Mechanisms of the formation and growth of alkali-induced slagging	8
2.1.3.	Criterion numbers or evaluation indexes	10
2.2.	Silicate melt-induced slagging (ash fusion)	10
2.2.1.	Ash fusion test	13
2.2.2.	Effects of chemical compositions on AFC	13
2.2.3.	Evolution of chemical compositions in ash during combustion	15
2.2.4.	Chemical equilibrium calculation	16
2.2.5.	Multi-component phase diagram	17
2.3.	Agglomeration	19
2.3.1.	Effects of bed materials and fuels	19
2.3.2.	Agglomeration formation mechanisms	19
2.3.3.	Coating forming mechanisms	20
2.3.4.	Agglomeration indicator	22
2.4.	Countermeasures for the main ash-related issues: additives	23
2.4.1.	Effects of single oxide or element additives	23
2.4.2.	Effects of mineral additives	25
2.5.	Countermeasures for main ash-related issues: co-firing	28
2.5.1.	Co-firing benefits and classifications	28
2.5.2.	Co-firing in CFB	30
2.5.3.	Co-milling co-firing in PC furnace	31
2.5.4.	Injection co-firing in PC furnace	31
2.6.	Countermeasures for main ash-related issues: leaching	32
2.6.1.	Technical water leaching (batch leaching)	33
2.6.2.	Technical semi-continuous leaching	33
2.6.3.	Natural water leaching by rain and snow	35
2.6.4.	Effect of leaching intensity: amount of water and/or time	35
3.	Part II. Corrosion	37
3.1.	Corrosion mechanisms	37
3.1.1.	Corrosion associated with Cl_2	37
3.1.2.	Corrosion associated with gaseous alkali chlorides	38
3.1.3.	Corrosion associated with solid/deposited alkali chlorides	39
3.1.4.	Corrosion associated with sulfation/silication of alkali chlorides	40
3.1.5.	Corrosion associated with molten alkali chlorides	40
3.1.6.	Corrosion associated with molten alkali sulfates	41
3.1.7.	Corrosion associated with molten alkali carbonates	42
3.2.	Corrosion countermeasures or influence factors	43
3.2.1.	Alloying and salts	43
3.2.2.	Atmosphere and temperature	46
4.	Part III. Ash utilization	46
4.1.	Physico-chemical properties of biomass ash	49
4.2.	Utilization for construction materials	51
4.2.1.	Relative standard on ash utilization in cement	51
4.2.2.	BFA	53
4.2.3.	BBA	53
4.2.4.	Biomass/coal co-fired ash	54
4.3.	Utilization in agriculture and other fields	55
4.4.	Barriers and counterplans for the utilization of biomass ash	55
5.	Conclusions	55
	Acknowledgements	57
	References	57

Download English Version:

<https://daneshyari.com/en/article/241619>

Download Persian Version:

<https://daneshyari.com/article/241619>

[Daneshyari.com](https://daneshyari.com)