

Successful Straw Combustion Technology in Zluticka Heating Plant

P. Volakova, M. Mika, V. Verner, B. Klapste, O. Jankovsky

Abstract—We successfully developed and tested a new separation layer solving problems with unmanageable deposits inside the boilers of Zluticka Heating Plant. The deposits are mainly created by glass-forming melts. We plotted straw ash compositions in K_2O - CaO - SiO_2 phase diagram and illustrated that they are in the area of low-melting eutectic points. To prevent the melting of ash and the formation of deposits, we modified ash compositions by injecting additives into biomass fuel, and thus effectively suppressed deposits in a burner.

Keywords—Biomass, straw, combustion, deposit, heat, additives

I. INTRODUCTION

CURRENTLY, biomass is the most often renewable source of energy in the Czech Republic. The potential of wood fuel is at its limit because of steeply increasing number of new biomass heating and power plants that brings a huge demand and a steep increase of wood prices. Hence, crop residues and the agriculture production of energy plants represent a very reasonable alternative. This energy production strategy has several positive effects, like the decentralization of energy production and significant energy independence of a region as well as the creation of new jobs. The crop residues, such as straw, are ideal for a combustion process generating heat in local heating plants. Currently, the building of new heating plants burning straw is obstructed by a significant draw back in this technology caused by the formation of hardly manageable glassy deposits inside boilers reducing its efficiency. This problem can be overcome by applying our new technology of straw combustion. This technology was successfully tested in Zluticka Heating Plant where they burn 1 000 tons of wheat, rye, barley, or rape straw every year. When using the new technology, they have not encountered significant problems.

Authors thank for the support of the Ministry of Industry and Trade "New biomass combustion technology with continuous removal of ash with controlled chemical composition" FRTII/497.

P. Volakova is with the company Zluticka Heating Plant, Inc., Velke namesti 131, Zlutice 36452, Czech Republic (phone: +420 353 227 407 e-mail: zlutickateplarenska@ztzlutice.cz).

M. Mika is with the Institute of Chemical Technology, Technicka 5, Prague 6, 166 28, Czech Republic (phone: +420 220 444 102; fax: +420 220 350; e-mail: Martin.Mika@vscht.cz).

V. Verner is with the company VERNER, Inc., Sokolska 321, Cerveny Kostelec, 54941, Czech Republic (phone: +420 491 465 024; e-mail: sef@verner.cz).

II. APPLIED RESEARCH

Our goal was to apply a new technology eliminating problems with the melting of ash and the formation of glass deposits, which is closely connected to low melting eutectics of straw ashes. These low melting ashes caused the formation of glass deposits strongly bonded to the walls of refractory ceramics inside the flamer part of boilers. The glassy deposits are formed by melted ash particles carried by flue gasses in a flamer at temperatures around 1100°C.

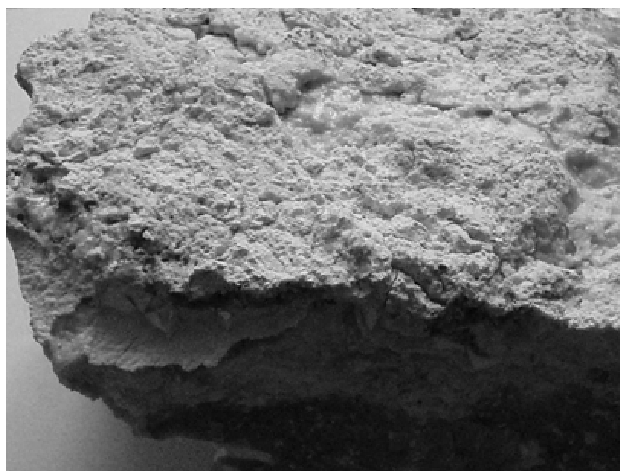


Fig. 1 Glass deposit removed with a layer of refractory ceramics

The formation of the glass deposits was a serious problem. Usually, after each three months, the efficiency of the boilers decreased so much, that it was necessary to shut them down for cleaning. Then workers have to perform very laborious and time-consuming removal of the deposits because the glass melt deposits were very strongly stuck to refractory ceramics. The process of removing the deposits with a pneumatic hammer seriously damaged the refractory ceramics and the deposits were very often taken out with the layers of the ceramics (Figure 1). Even though the workers were removing the deposits very carefully, at least 5 mm of the ceramics was removed with each piece of the deposit. Without any technology improvement, the ceramics walls will be dangerously thinner down shortly and the whole ceramic segments would have to be replaced. It would seriously increase the cost of repairs and consequently heat energy prices for costumers. This problem was very serious when certain types of straw were fired, mostly barley.

Additionally, the low eutectic temperature of some straw ash caused problems with agglomeration and clogging in a burner.

The manager of the heating plant started to solve these problems in her PhD thesis in 2007; she successfully defended this research in 2008. This interesting and useful research has been continuing since then in a close collaboration with the Department of Glass and Ceramics at the Institute of Chemical Technology in Prague. Currently, this ongoing research has been funded by the Ministry of Industry and Trade of the Czech Republic.

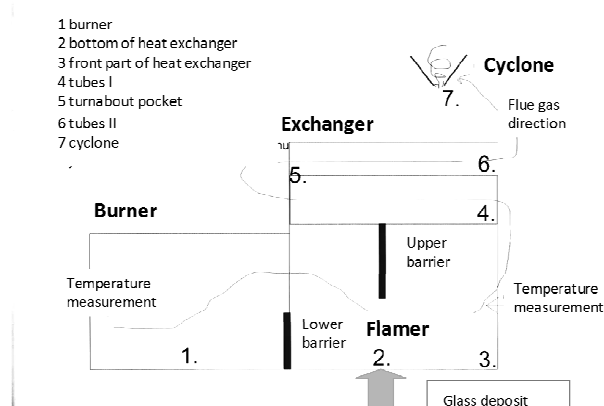


Fig. 2 Locations in a boiler from where samples were collected

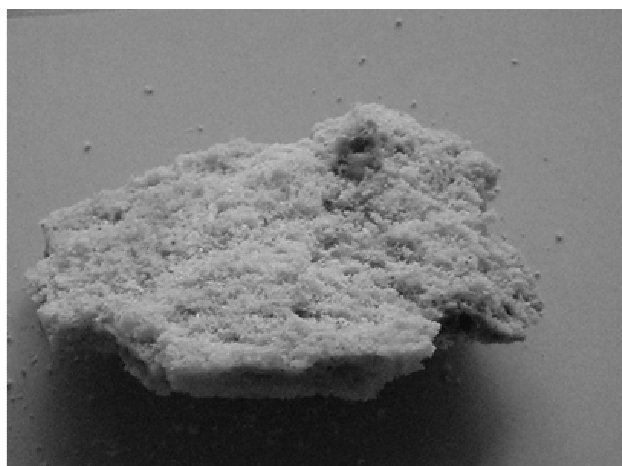


Fig. 3 Glass deposit with a separation layer on top

III. NEW STRAW COMBUSTION IMPLEMENTATION

The new technology of straw combustion was mainly focused on fast and highly efficient solving of problems with unmanageable glass deposits in boilers firing various types of straw.

A. Contribution of Zluticka Heating Plant

The operators in the heating plant monitored and recorded all important parameters of the boilers during the whole operation cycle in which the new technology was tested. They also collected samples from several locations in a boiler that were important for assessing the results of the tests (Figure 2).

The samples were collected from a burner, the bottom of a heat exchanger, the front part of the heat exchanger, tubes I, tubes II, and a cyclone.

B. Contribution of the Institute of Chemical Technology

All the collected samples of straws, straw ashes and boiler deposits were examined at the Department of Glass and Ceramics. The fuels were burned in an electric furnace to obtain ash. Then the selected and pretreated samples were analyzed and their chemical composition was determined by the x-ray fluorescence (XRF). Using the measurement of ash impedance, the ash eutectic temperature was determined. The chemical composition of samples and their properties are the inputs for a comprehensive database with more than 150 records. Using the existing database, we can predict ash composition modification to increase its eutectic temperature, and thus prevent it from melting. Based on the collected data, we are able to adjust the straw combustion technology to a specific type of straw fuel; hence, efficiently reducing deposits problems in the boilers. This approach helps to very significantly suppress the growing of deposits.

C. Contribution of the producer of biomass boilers

Company VERNER, Inc., is a producer of biomass boilers and a supplier of biomass combustion technology. His original technology has been installed in Zluticka Heating Plant. Since its beginning, the plant has also been used as a testing facility for the development and improvement of biomass combustion technologies, which were optimized during our research. In a close collaboration with the plant manager, it has been testing there a new equipment of the boilers as well.

IV. NEW TECHNOLOGY VERIFIED IN INDUSTRY

In our approach, we put a strong emphasis on immediate testing of newly developed combustion technologies in Zluticka Heating Plant and in the company VERNER.

A. Separation layer

Based on straw ash analysis and extensive laboratory experiment, we developed a new separation layer. The layer is formed from a special mixture of silicate materials [1] which are environment friendly and cost-effective as well [2]. The layer stays inert even at high temperatures and does not melt; hence, it is able to separate melted glass deposits from refractory ceramics during the whole operation cycle of the boilers. For the purpose of cleaning, the boilers are shut down and the deposits can be very easily removed from the top of the separation layer.

The layer was verified by long-term testing in Zluticka Heating Plant during the normal heat generation cycle. At the beginning of the test, the ceramics of the walls and the bottom of a flamer were cleaned and painted with the separation layer of final thickness about 40 mm. Then the boiler went through a normal three months cycle of firing various types of straw. After the shutdown of the boiler, the separation layer with deposits was examined. It was found that the separation layer formed a brittle solid layer completely preventing melted

deposits to flow through and stick to the walls of refractory ceramics. The deposit with the separation layer on top is shown in Figure 3. Following these positive tests, the separation layer has been successfully applied during the normal operating of the boilers in Zluticka Heating Plant. Glass deposits have been regularly removed from the boilers very easily and only significantly shorter shutdowns have been necessary.

B. Suppression of ash melting

Our approach to the suppressing of straw ash melting in a burner is based on our systematic monitoring and studying of ash composition and its relation to the ash eutectic temperature utilizing K_2O - CaO - SiO_2 phase diagram [1, 2]. To avoid ash melting, the eutectic temperature must be increased by changing the composition of ash. Such change can be made either by mixing biomass fuels of sufficiently different composition or by injecting additives.

We did the laboratory combustion tests of straw with the additives rich in CaO or Al_2O_3 and SiO_2 . When we compared these ashes with the ash without the additive, we could conclude that the additives significantly suppressed the formation of glass-forming melts.

The technology of straw combustion with predicted minimal amounts of additives were tested in the biomass boilers of Zluticka Heating Plant. For five months the additives were injected into various types of straw in the amount of few mass% of the fuel. We observed very positive effects of the additives that increased the eutectic temperature, and thus strongly suppressed the formation of glass melts in a burner.

V. CONCLUSION

Our research team found the mutual collaboration between the research institute, the heating plant, and the producer of boilers, as very fruitful. The main advantages of our team belong efficiently targeted applied research with immediate feedback from industry as well as very beneficial economic effects for the industry partners. They successfully implemented new technologies of treating unmanageable deposits and the straw combustion technology with minimal amount of additives.

ACKNOWLEDGMENT

Authors thank M. Netusilova for measuring eutectic temperatures

REFERENCES

- [1] V.I. Babushkin, G.M. Matveyev, and O.P. Mchedlov-Petrosyan, *Thermodynamics of Silicates*. Berlin: Springer-Verlag, 2002, ch. II.
- [2] P. Atkins and J. de Paula, *Physical Chemistry*. Oxford: Oxford University Press, 2002, pp. 230–240.
- [3] P.W. Atkins, T.L. Overton, J.P. Rourke, M.T. Weller, and F.A. Armstrong, *Inorganic Chemistry*. Oxford: Oxford University Press, 2010, Part 2.

Pavlina Volakova was born in Plana, Czech Republic, on June 9, 1970. She graduated at the Institute of Chemical Technology Prague (ICT) in “Chemistry and technology of fuels and water” in 1994. In 2008, she obtained PhD in “Technology of fuels” at the same institute. She is CEO of Zluticka Heating Plant, a.s. She has been involved in a straw combustion optimization project funded by the Ministry of Industry and Trade of the Czech Republic. Since 2001 she has been managing the local biomass heating plant supplying heat to about 1000 households in the town of Zlutice. During this period, she has gained extensive experience in biomass combustion, boilers operation, ash deposits management, heat generation, and hot water distribution. Recently, Pavlina has also focused on the growing of dedicated energy crops, namely *Miscanthus Giganteus*; and she has worked as a consultant for the Ministry of the Environment of the Czech Republic. She also worked in a water treatment plant and as a chemistry teacher.