A. ČIKIĆ, A. PINTARIĆ, I. SAMARDŽIĆ

ISSN 0543-5846
METABK 52(1) 111-114 (2013)
UDC – UDK 620.95:662.96:621-73 =111

THE INFLUENCE OF BIOMASS QUALITY ON THE PURIFICATION OF FLUE GASES AND MULTICYCLONE ASSEMBLY MATERIAL

Received – Prispjelo: 2012-05-08
Accepted – Prihvaćeno: 2012-08-20
Preliminary Note – Prethodno priopćenje

Various types, forms and states affect the heating value of biomass and its conversion into exploitable energy forms. As a result of biomass quality investigations, the share of solid particles in flue gases purified in a multicyclone was measured and analyzed at various heating loads of a boiler, the maximum power of which amounts to 2,2 MW. This paper presents the influence of flue gases on the roughness and corrosiveness of multicyclone material inner wall. A corrective dimensional parameter of the multicyclone was suggested for the purpose of maximum purification of flue gases at unfavorable incineration conditions and biomass characteristics.

Key words: biomass, multicyclone, flue gases, purification, roughness, corrosiveness

UVOD

Biomass is a traditional energy source and the most complex form of renewable energy sources. For the most part it involves forest and agricultural biomass, waste and residual material from wood-working and similar industries, non-wood biomass, animal waste and residues as well as selected municipal and public waste [1, 2]. Each of the biomass forms has a different energy value. Depending on the moisture content, density, type and variety, the lower heating value of renewable wood ranges between 7,5 kJ/kg and 20 kJ/kg [2]. At the immobile boiler grid the combustion of sawdust and woodchips of various moisture and quality is enabled. With fuel being homogenously distributed on the whole grid surface and the inlet of the primary air that is blown below the grid being even, the combustion process is carried out. Depending on the state, type, form and moisture of biomass and by means of varied air excess ratio control, complete fuel combustion with the highest heating efficiency is aimed at. Grids with the fuel inlet from below are used in plants of lower power and for the combustion of biomass containing smaller amounts of ashes [3]. In the course of biomass combustion at such plants, the emission limit values of solid particles after the purification of flue gases amount to 150 mg/m^3 [4]. The removal of solid particles and ashes from flue gases is mostly carried out by using cyclone separators by means of combined actions of centrifugal and gravity force [5-7]. The separation of solid particles larger than 5 μm with the efficiency of up to 97 % is performed by using a multicyclone composed of several cyclone separators in parallel arrangement that are suitably sized [7-9]. While driving plants of lower heating efficiency, emissions of solid particles in flue gases are measured discontinuously or occasionally, mostly at convenient biomass characteristics and maximum heat load. There are limited analyses related to emissions of solid particles in purified flue gases depending on the type, state and moisture of biomass. Research related to the effects of solid particles on the roughness of multicyclone assembly walls while they are being separated from flue gases during the combustion of biomass of variable quality is scarce. The fact that tiny solid particles "stick" to inner walls in certain multicyclone assembly zones is more or less neglected. Research into solid particles content in purified flue gases during the combustion of various types and moisture levels of biomass was conducted. The research also involved the influence of solid particles on the roughness and "sticking" on to the multicyclone inner walls with the purpose of assessing fuel quality and emissions of solid particles.

OBJECT, MATERIAL AND EXPERIMENT

The research was conducted at a new thermal power plant, the maximum heat efficiency of which amounts to Q = 2,2 MW, during the biomass combustion on a grid with fuel inlet from below. The purification of flue gases was carried out by means of a multicyclone composed of 20 cyclone units, each with inner diameter d = 150 mm and total height h = 1500 mm (Figure 1). The produced thermal energy was used for district heating of agrotechnological objects during two heating seasons. Examinations were carried out during the combustion of various biomass: sawdust (Sd), woodchips (Wc) sized 10 mm – 80 mm and crushed indigo bush (Ib) (*Amorpha fructicosa*) stem sized 30 mm – 100 mm.

A. Čikić, Technical College in Bjelovar, Bjelovar, Croatia.
A. Pintarić, University of Applied Sciencies, Vukovar, Croatia
I. Samardžić, Faculty of Mechanical Engineering in Slavonski Brod University of Osijek, Croatia.

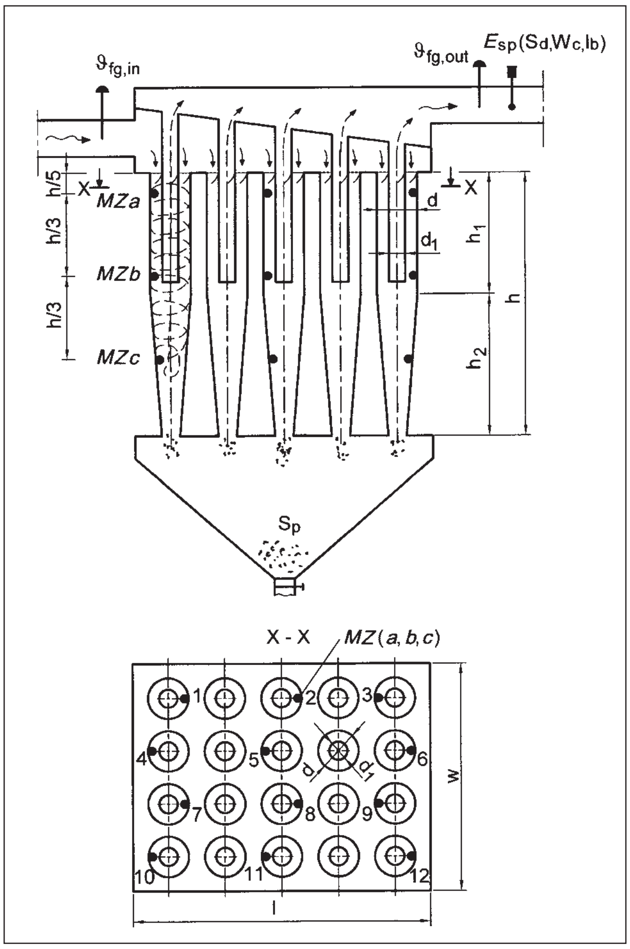

Figure 1 Multicyclone (measurement points)

Sawdust incineration in the boiler combustion chamber was carried out in three intervals, each lasting for 30 days, with the moisture amounting to ≈ 20 %, ≈ 30 % and ≥ 50 %. In the following intervals, each lasting for 40 days, woodchips with the moisture amounting to ≈ 20 %, ≈ 35 % and ≥ 50 %, and finally crushed indigo bush (*Amorpha fructicosa*) stem with the moisture amounting to ≈ 18 %, ≈ 25 % and ≥ 45 % were used as fuel.

By means of varied control of the fuel and air inlet the combustion process was controlled according to the changes of the plant's thermal load. A digital instrument of the D – RX 250 type was used for measuring emissions of solid particles E_{sp} in flue gases after they had been purified by a multicyclone. At the input speed equaling between 15 m/s and 18 m/s and the output speed equaling between 14 m/s and 16 m/s flue gas temperatures were measured in all biomass combustion intervals. The values amounted to $\vartheta_{fg,in}$ = 180 °C – 215 °C in front of and $\vartheta_{fg,out}$ = 175 °C – 211 °C behind the multicyclone. The solid particles emission E_{sp} in purified flue gases was measured and recorded every 10 minutes within a 24-hour interval *t* during the combustion of each biomass category. The average value of solid particles emission $E_{sp,av}$ during each interval *t* was determined as the arithmetic average of the $E_{sp,i}$ measurement result, by means of the equation (1) [10]:

$$E_{sp,av} = \frac{E_{sp,1} + E_{sp,2} + ... + E_{sp,N}}{N} = \frac{\sum_{i=1}^{N} E_{sp,i}}{N} \quad (1)$$

$$N = 144.$$

During the combustion of sawdust of diverse moisture (≈ 20 %, ≈ 30 % and ≥ 50 %) 40 average values of the solid particles emission $E_{sp,av}$ were determined per group in purified flue gases within 30 measurement intervals *t*, i.e. 40 average values of the solid particles emission $E_{sp,av}$ per group during the combustion of woodchips (moisture ≈ 20 %, ≈ 35 % and ≥ 50 %) and crushed indigo bush (*Amorpha fructicosa*) stem (moisture ≈ 18 %, ≈ 25 % and ≥ 45 %) within 30 measurement intervals *t*. With the multicyclone being technically adapted, surface roughness measurements *Ra* of the inner cyclone separators' wall were carried out along the height *h* in measurement test zones *MZa*, *MZb* and *MZc*, whereat there are various values of tangential and radial velocity of flue gases stream [6, 7]. In each multicyclone test zone measurements were carried out on *N* = 12 cyclone separators, i.e. at the total of 36 characteristic measurement points (Figure 1). Surface roughness *Ra* of the inner steel wall and the thickness of "stuck" solid particles on inner multicyclone walls δ_{sp} during the purification of flue gases were measured after each combustion cycle of a certain biomass type, granulation and moisture. Surface roughness of the steel wall was measured by a digital instrument with a corresponding probe of the M112/3522 SURTRONIC 25 type, and the thickness of "stuck" solid particles on the wall with a mobile digital instrument of the PCE – PT – FN – S1 type. The average value of surface roughness Ra_{av} of the inner wall in the measurement test zones *MZa*, *MZb* and *MZc* was determined as the arithmetic average of the Ra_i measurement results, by means of the equation (2) [10]:

$$Ra_{av}(MZa,b,c) = \frac{\sum_{i=1}^{N(a,b,c)} Ra_i}{N(a,b,c)}; \quad (2)$$

N(a) = 12, *N(b)* = 12 and *N(c)* = 12.

The relation (3) [10] was used for determining the average thickness value of "stuck" solid particles $\delta_{sp,av}$ on inner walls in zones *MZa*, *MZb* and *MZc* of the multicyclone cyclone separators;

$$\delta_{sp,av}(MZa,b,c) = \frac{\sum_{i=1}^{N(a,b,c)} \delta_{sp,i}}{N(a,b,c)}; \quad (3)$$

N(a) = 12, *N(b)* = 12 and *N(c)* = 12.

RESULTS AND DISCUSSION

Quantified average values of solid particles emission $E_{sp,av}$ of purified flue gases during the combustion of diverse biomass quality in a combustion chamber, the thermal efficiency of which amounts to 2,2 MW, are

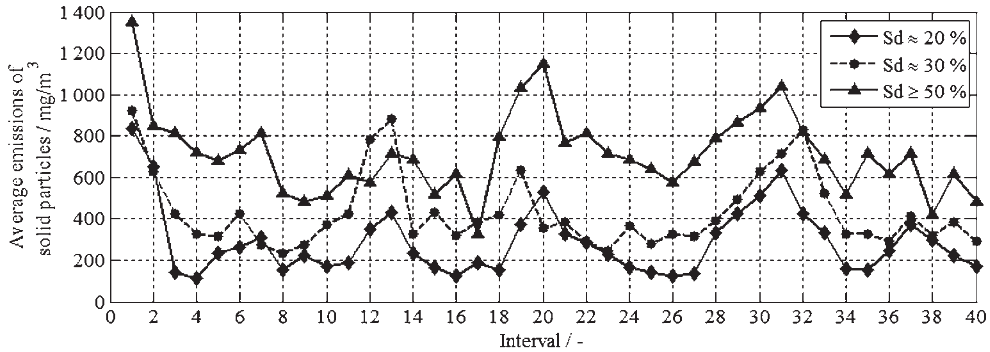

Figure 2 Average emissions of solid particles $E_{sp,av}$ – sawdust (Sd)

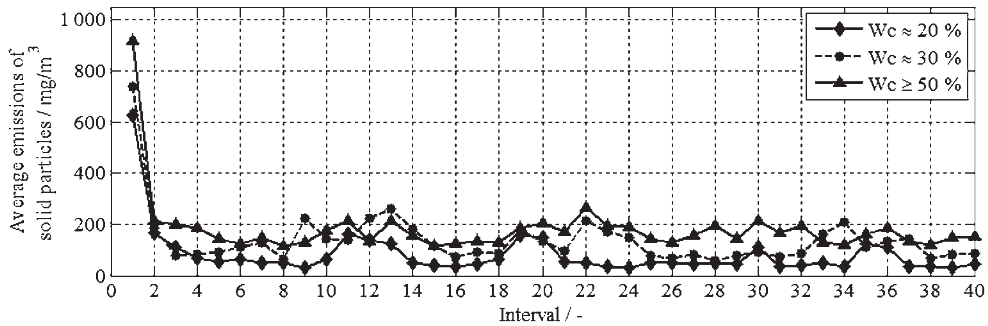

Figure 3 Average emissions of solid particles $E_{sp,av}$ – woodchips (Wc)

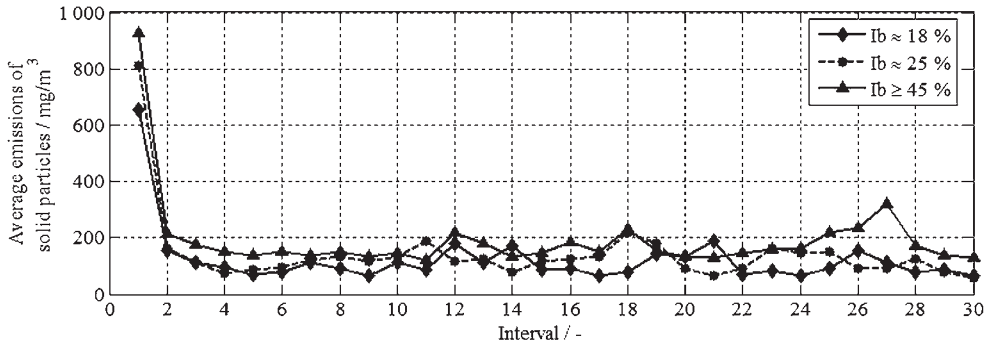

Figure 4 Average emissions of solid particles $E_{sp,av}$ – indigo bush (Ib) (*Amorpha fructicosa*)

shown in Figures 2, 3 and 4. Average values of solid particles emission $E_{sp,av}$ are four to six times higher than the limit allowed at plant commissioning. As the combustion of various types and granulation of wood biomass, the moisture of which amounts to more than 30%, takes place, the average emission of solid particles in purified flue gases increases, especially when the plant's thermal load decreases. There are oscillations and the values of solid particles emissions in purified flue gases during the combustion of sawdust of diverse moisture are 3 − 5 times higher. Only in shorter intervals the emissions of solid particles equal ≤ 150 mg/m^3 during the combustion of sawdust, the moisture of which amounts to approximately 20 %. There are significantly less oscillations in values of average emissions of solid particles in purified flue gases during the combustion of woodchips and crushed indigo bush stem (*Amorpha fructicosa*) of various moisture levels at variable thermal load of the plant. The average emission of solid particles $E_{sp,av}$ increases by about 25 % to 60 % as the moisture content increases above 20 % in woodchips and above 18 % in indigo bush.

Figure 5 shows a diagraph of the average surface wall roughness Ra_{av} by following the combustion of a certain biomass type, granulation and moisture.

In the *MZa* zone of high tangential speeds of flue gases and collisions of solid particles and cyclone separator walls, the average surface roughness of the steel wall Ra_{av} is decreased for about 20 % − 25 % compared to the initial value, and then it becomes approximately constant regardless of the biomass quality and moisture.

In the *MZb* and *MZc* zones the average wall roughness Ra_{av} increases compared to the *MZa* zone by approximately 15 % – 50 %, which is more apparent during the combustion of biomass with the moisture content amounting to ≥ 50 %. The quantified average values of the "stuck" solid particles layer $\delta_{sp,av}$ on cyclone separator walls of the multicyclone assembly are shown in Figure 6. During the separation solid particles do not "stick" in the *MZa* zone, whereas cumulative "sticking" of a part of solid particles, the layer thickness of which ranges between 40 μm and 540 μm, was determined in the *MZb* and *MZc* zones, where at the average surface

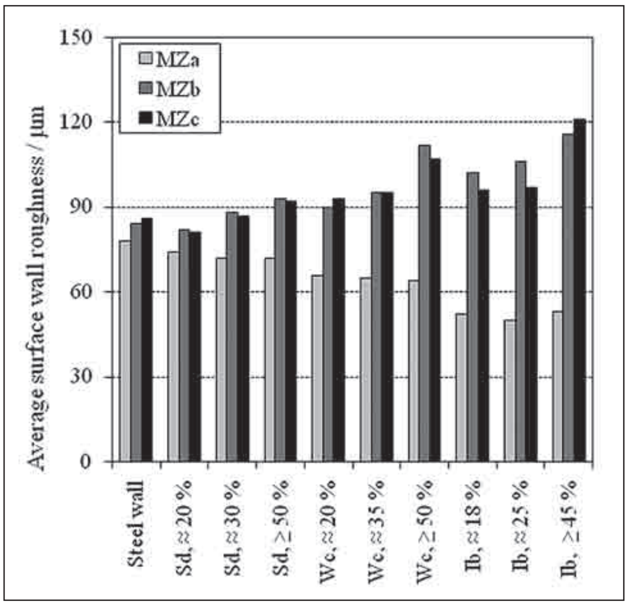

Figure 5 Average surface wall roughness Ra_{av} (*MZa, MZb, MZc*)

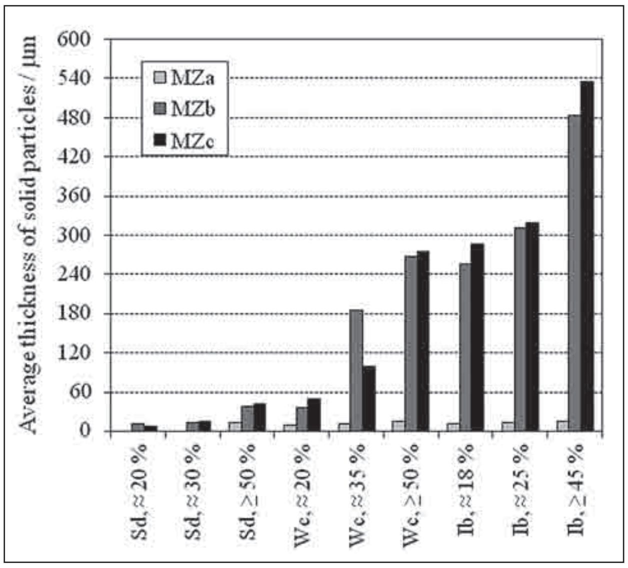

Figure 6 Average thickness of solid particles layer $\delta_{sp,av}$ (*MZa, MZb, MZc*)

wall roughness Ra_{av} increases. The moisture of woodchips > 35 % and crushed indigo bush > 25 % contributes to faster "sticking" of smaller solid particles of flue gases on to the cyclone separator walls.

At lower thermal load and during the combustion of biomass, the moisture of which amounts to ≥ 50 %, tiny particles partially get detached from the surface layer δ_{sp}, which increases solid particles emissions in purified flue gases. A corrosive effect of flue gases on the multicyclone assembly was not recorded.

CONCLUSION

During the combustion of examined biomass in a combustion chamber with maximum thermal efficiency amounting to 2,2 MW and the purification of flue gases by means of a multicyclone, the average surface roughness Ra_{av} is altered and the layer of "stuck" solid particles $\delta_{sp,av}$ cumulatively grows in certain cyclone separator zones. Ra_{av} and $\delta_{sp,av}$ directly contribute to higher average solid particles emission $E_{sp,av}$ in output flue gases.

Multicyclone application correction parameter f_m for a continuous emission of solid particles in output flue gases ≤ 150 mg/m^3 due to biomass combustion equals:

- woodchips with moisture content ≤ 35 %,
- crushed indigo bush (with moisture content ≤ 25 %,
- independent sawdust combustion is not recommendable,
- $Ra_{av} \leq 100$ µm, $\delta_{sp,av} \leq 320$ µm.

LITERATURE

[1] R. Marutzky; K. Seeger: Energie aus Holz und underer Biomasse, DRW Verlag, Weinbreener, Linfelden-Echtlingen, Njemačka, 1999.

[2] A. Čikić; Ž. Kondić: Research of the waste biomass technical and economic valve as one of the technological and energy development criteria wood processing plants, Technical Gazzete, 17(2010)1, 53-59.

[3] J. Kinni: Solutions of bioenergy – Fluidized bed boilers, http://www.greennetfinland.fi/en/clusters/energy/current-activites/biomass-seminar-12-sep-2005.html

[4] Uredba o graničnim vrijednostima emisija…. NN 21/07. i 10/08., NN RH, Zagreb, 2007. i 2008.

[5] C. J. Wijsman; R. Tol: Cyclone calculation, April, 1982.

[6] F. Boysan; H. W. Ayers: J. Swithenbank: A Fundamental Mathematical Modeling Approach to Cyclone Design, Trans. 1 Chem E, Vol 60, 1982.

[7] G. R. Dorman: Dust control and air cleaning, Pergaman Press, Oxford, 1974.

[8] J. A. Ter Linden: Cyclon Dust Collectors for Boilers, Transactions of the ASME, April, 1953.

[9] H. Brover; G. B. Y. Varma: Air Pollution Control Equipment, Springer-Verlag, Berlin, Heidelberg, New York, 1981.

[10] I. Šošić; V. Serdar: Uvod u statistiku, Školska knjiga, Zagreb, 1997.

Proofreading: prof. Ivana Jurković, Technical College in Bjelovar, Croatia