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PULSE COMBUSTION BURNER AS CLEANING DEVICE OF BOILER HEATING SURFACES – Experimental Investigation –

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ABSTRACT
Energy conversion from fossil fuels usually begins with combustion processes accompanied by series of technical and technological problems and very often produces significant amount of pollution. Problems are often encountered in cases of combustion of low ranking, low-reactive and deposition tending coals, like some of those exploited in Bosnia and Herzegovina. Because of these reasons, it is necessary to develop new and improve existing technologies of low pollution combustion, not enough investigated so far, especially in cases when low ranking coals are used. In this regard, the pulse combustion offers good possibilities. Additionally, the pulse combustion could be applied as auxiliary method in existing large-scale boilers as a cleaning device of outer heating surfaces. In this paper, the most recent results obtained from experimental work at Mechanical Engineering Faculty in Sarajevo are presented.
Key words: pulse combustion, boiler heating surfaces, deposition cleaning

1. INTRODUCTION, [3]
About 80 % of primary energy spent in the world is obtained from fossil fuels. Such situation, where energy needs are dominantly met by conversion of primary energy from fossil fuels, will continue also in the future. Bosnia and Herzegovina (BIH) is not a exception. It is well known that coals are most used fossil fuel. About 75 % of all worlds fossil fuel reserves are coals (Figure 1). It is estimated that with today's level of energy consumption the coal reserves are sufficient for next 200 years. Additionally, the coal reserves are more uniformly situated then the petrol reserves. Because of the rapid decrease of the petrol natural gas reserves, importance of the coal as energy source will probably rise in the future. On the other side, reserves of high quality coal are also decreasing and need to exploit low quality coals is more pronounced. In the process of conversion of the primary energy from fossil fuels combustion is the most important part with a variety of technical and technological problems and it is always potential source of pollution. Probability that problems will occur during a combustion process depends on a series of variables, but these problem occur more often during combustion of low ranking, low-reactive and deposition tending coals, like some of those exploited in BIH. There are very important deposits of lignite and brown coals in BIH, but there is no any stone coal. Due to last estimations, there are about $4 \cdot 10^9$ tones of coal, where 40 % are brown coals and 60 % is lignite. The quality of coals in BIH is very low and varies from one basin to another. Basic characteristics of these coals are low calorific value, high mineral and moisture mass fractions, low reactivity and tendency to making deposition (Figure 2). From the environmental aspect, the thermal power plants firing coal dust are the most unfavorable because of theirs CO_2, SO_x, NO_x and especially flying solid particle emissions. Specified facts gave a strong impulse to investigation of more efficient coal combustion technologies with reduced environmental impacts compared with conventional technologies (Clean Coal Technology). Beside the

technical aspects, the economical aspects of power plants are also very important because they influence the future use and environmental impact of plants.

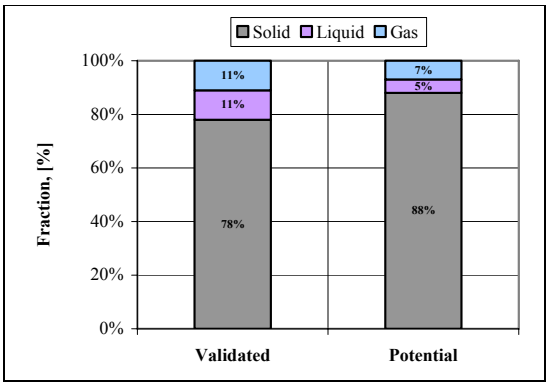

Figure 1. Validated and potential reserves of fossil fuels in the world (percent) [43]

Figure 2. Example of dirty boiler heating surfaces, TPP Kakanj, BiH

One of known combustion processes that, because of its nature, offer a series of advantages, but is not sufficiently wide used is the pulsating combustion. Basic reasons for the reduced use are intensive noise generated during the pulse combustion process, insufficiently known values and character of basic effects associated with the process and their changes during time. However, present results published around the world, show that the pulse combustion process could be applied as auxiliary equipment in existing large scale boilers [1-3]. Recommendation is that pulse combustion burners have to be applied as cleaning devices of dirty heating surfaces and as auxiliary burners in large scale boilers with the aim to raise the level of turbulence inside the atmosphere of the firebox and so to stimulate mixing of reactants and to improve efficiency of the combustion. In the following text, the results and some recommendations from experimental investigation of pulse combustion burner with defined geometry applied on a boiler model performed at Mechanical Engineering Faculty Sarajevo are given.

2. EXPERIMENTAL RIG, SETUP AND OBJECTIVES OF THE INVESTIGATION

Some of the objectives of the experimental investigation of various geometries of the modular pulse combustion burner were as follows: A) to determine characteristics and performances of the pulse combustion burner (values of pulsating pressure, level and spectrum of the generated sound on specified measuring positions) depending on the position of the burner itself to its ambience: i) burner is mounted in the laboratory room with resonant pipe end staying freely in the air, ii) burner is connected to a exhaust channel duct through a conic extension; B) to obtain results on the bases of which the application of the pulsating combustion burner on large scale boilers could be assessed, i) use of the burner as auxiliary device with the aim to raise the level of turbulence inside the atmosphere of the firebox and so to stimulate mixing of reactants and to improve efficiency of the combustion, ii) use of the burner as a device for preventing depositions and for cleaning of already formed depositions on the outer heating surfaces of the boilers, especially in its convective zone, [1], [3]. On the revitalized experimental boiler model, the pulsating combustion burner was mounted through two different positioned and directed connections: i) side connection, application of the burner in the firebox zone, ii) upper connection, application of the burner in the convective zone (Figure 3).

Together with changing three general mounting positions of the burner (freely mounted in the laboratory room and two different connections to the boiler), the geometry of the burner is also varied. For all these variations and changing thermal load regimes, following parameters are measured: i) wakening of total pressure oscillations along the propagation axes of the freely generated pressure wave and the level and spectrum of the generated sound energy [1-2], ii) intensity of wakening of the generated pulsating pressure in the boundary zone between the end of resonant pipe of the burner and the connection on the boiler, iii) weakening of the pulsating pressure in the interior of the boiler model, and before and after the pipe bundles, iv) influence of the pulsating flow of exhaust gases and sound energy on the revetment of the boiler, [3].

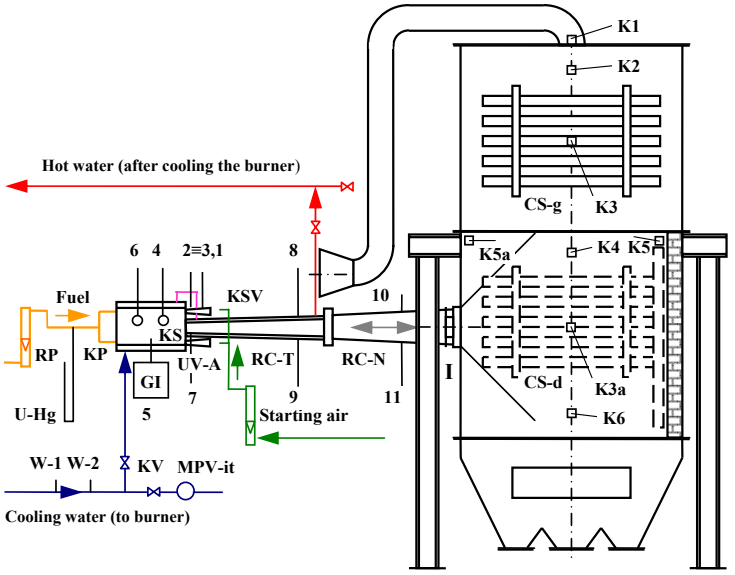

Figure 3. Application of the pulse combustion burner on the boiler model: Position I – firebox, Position II – convective zone, Measuring positions: 1÷11 burner, K1÷K6 interior of the boiler, CS-g and CS-d pipe bundle position: (up and down respectively), [3]

3. RESULTS OF THE INVESTIGATION - SUMMARY

Characteristics of the pressure wave freely generated in the atmosphere of the room: after analysis of this part of the investigation it is concluded that the weakening of the pulsations along the axis of the propagation of the pressure wave is evident, especially in the beginning part, but the pressure pulsations are registered on distances of several meters from the "source" with total amplitudes of 1,5 to 2,0 kPa (Figure 4). Therefore, it could be expected that such pulsation intensity with relatively high frequency, is sufficient for creation of additional turbulence inside the firebox of even large scale industrial and power plant boilers, [1].

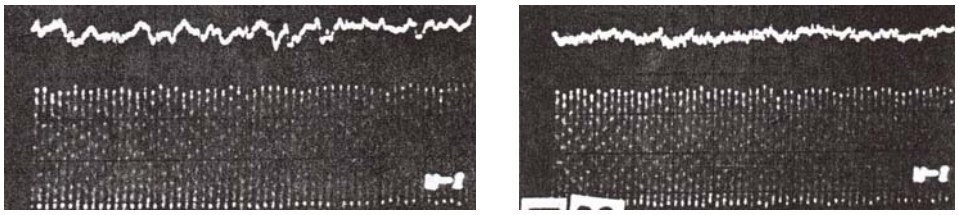

Figure 4. Pressure pulsations inside the combustion chamber (lower signal) and pulsations on the propagation axes (upper signal) at distances of 0,4 m (left picture) and 1,83 m (right picture) from the resonant pipe end, [1]

Burner as a cleaning device – flow along the bundle of pipes and crosswise flow through the bundle of pipes: at the Figure 5 results of measuring when the flow of pulsating exhaust gases was along the bundle of pipes inside the boiler model are given (position I, pipe bundle in position down, Cs-d). After analysis of the whole measuring results, some characteristics are observed: i) lower values of total pressure variations in measuring positions K5, K5a and K2 compared to values measured when the pipe bundle is in upper position. This could be explained with reasonable weakening of the intensity of pressure pulsations through the pipe bundle; ii) highest values of the pressure variations inside the boiler model occurred in the middle of the pipe bundle (measuring position K3a) and it is

worth to say that the pressure transducer at this position is on the axes of the resonant pipe of the burner and is at the distance of about 1,2 m from its end, [3].

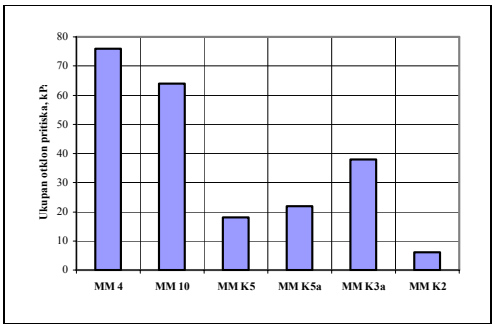

Figure 5. Values of pressure pulsations in function of the measuring position; geometry No: 43; fuel consumption: 5,15 m_n^3/h gas, [3]

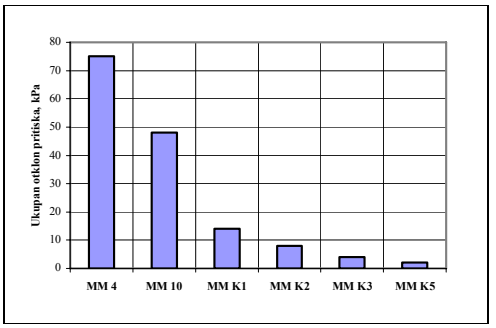

Figure 6. Values of pressure pulsations in function of measuring position; geometry No: 42; fuel consumption: 5,15 m_n^3/h gas; [3]

Relatively high values of total pressure pulsations inside pipe bundles of the boiler model is just the wanted result because of the intention to apply the pulse combustion burner as a cleaning device for heating surfaces of the boiler.

Dependence of the weakening of pressure pulsations of the exhaust gases on the position of the measuring place when the crosswise flow through the pipe bundle is taking place (position II, pipe bundle in upper position, SC-g) is shown at Figure 6. In this case, there is noticeable weakening of the intensity of pressure pulsations at the inlet in the boiler and later in its interior, compared to previous case (Figure 5 and 6). This is because of the energy dissipation of exhaust gases on the pipe connection.

The results of the measurements show that the pulse combustion burner promotes pulsating pressure in the whole volume of the boiler model. Amplitudes of the pulsation generally decrease with increasing the distance of the measuring position from the intake place of the pulsating flow into the boiler model but also the amplitudes depend on other factors like the thermal load of the burner, the way the exhaust gases enter the interior of the boiler model, volume of the free space, layout of the tubes in the bundles, etc, [3].

4. CONCLUSIONS

Values of high frequency pressure pulsations in the environment of the boiler elements inside the boiler model are significant. In regard to this, together with multiple reflections of pulsating flow and generated sound energy, it is recommended to test the pulse combustion burner under real operational conditions as a device for cleaning of depositions forming on convective heating surfaces of large scale boilers, especially in plants where low quality fuels are used.

5. REFERENCES

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