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PULSATING COMBUSTION BURNER ON THE BOILER MODEL: AN EXPERIMENT SUPPORTED BY NUMERICAL INVESTIGATION

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ABSTRACT
In this work a part of the results from experimental investigation of pulsating combustion with application on boiler model are presented. The Helmholtz-type water-cooled pulse combustor consists of a combustion chamber, a resonant pipe and aero-dynamic intake valves supplying air needed for combustion. Inside the boiler model a bundle of tubes is mounted representing one of the convective parts of the boiler. In case when the tube bundle is in upper position, the bottom of the boiler model represents the fire-place. Application of the pulse combustion burner on the boiler model refers basically to two zones: the fire-place and the convective part of the boiler. The laboratory experiments showed: weakening of the generated pressure pulsations of the exhaust gases on the boundary between burner and the interior of the boiler model; weakening of pressure pulsations in the free space of the boiler model; weakening of pressure pulsations during propagation through the tube bundle; impacts of the pulsating flow of the exhaust gases and generated sound energy on the walls of the boiler model .The experimental work is supported with numerical investigation of the pulsating combustion process. Combustion models included in FLUENT program package are used for calculations. It is shown that results from simulation are in good agreement with experiment.
Key words: burner, pulse combustion, boiler model, sound energy

1. EXPERIMENTAL SETUP
Pulse combustion setup mounted on the boiler model is placed in the laboratory at Mechanical Engineering Faculty Sarajevo – Energy Department. In this work a part of the results from experimental and numerical investigation are presented.
The burner is of Helmholtz-type consisting of a combustion chamber, aero-dynamic intake valves for air-supply and a resonant pipe. With continual supply of the fuel (propane-butane) and starting air into the combustion chamber, generated mixture is fired by a spark-plug combustion generation. After a stable regime of pulse combustion is established the spark-plug combustion generation and the forced air supply are stopped - "selfpumping" mode. The burner is constructed in a way which makes possible geometry changes of the combustion chamber, aero-valves and resonant pipe, as well as enables different positions in regard to boiler model which is a part of the experimental setup. Such a setup allows measurements on several geometries of the burner, enables finding the optimum one and enables investigation of parameters while applying the burner in different zones of the boiler model. A schematic of the pulse combustion burner connected to the exhaust duct is given in Figure 1.
The boiler model is a part of the experimental setup. Two different connection points are made on it to enable mounting of the burner in two different ways and bringing the generated pulsating flow of the combustion products inside the boiler model from side and from above (I and II in Figure 2). The combustion products flow is feasible in two different directions to the tube bundle inside the boiler model: along and across the tubes, and it possible to fix the tube bundle on different heights.

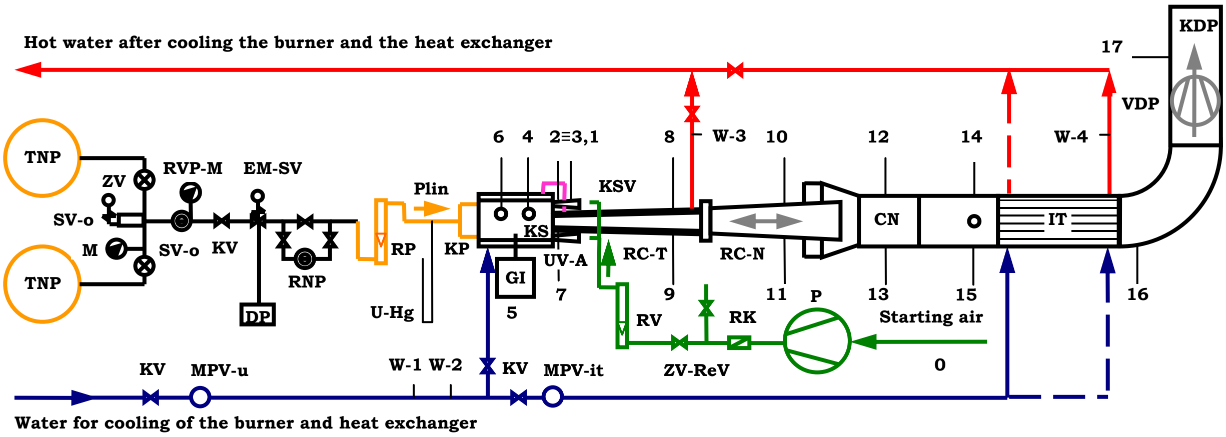

Figure 1. Pulsating combustion boiler connected to the exhaust duct

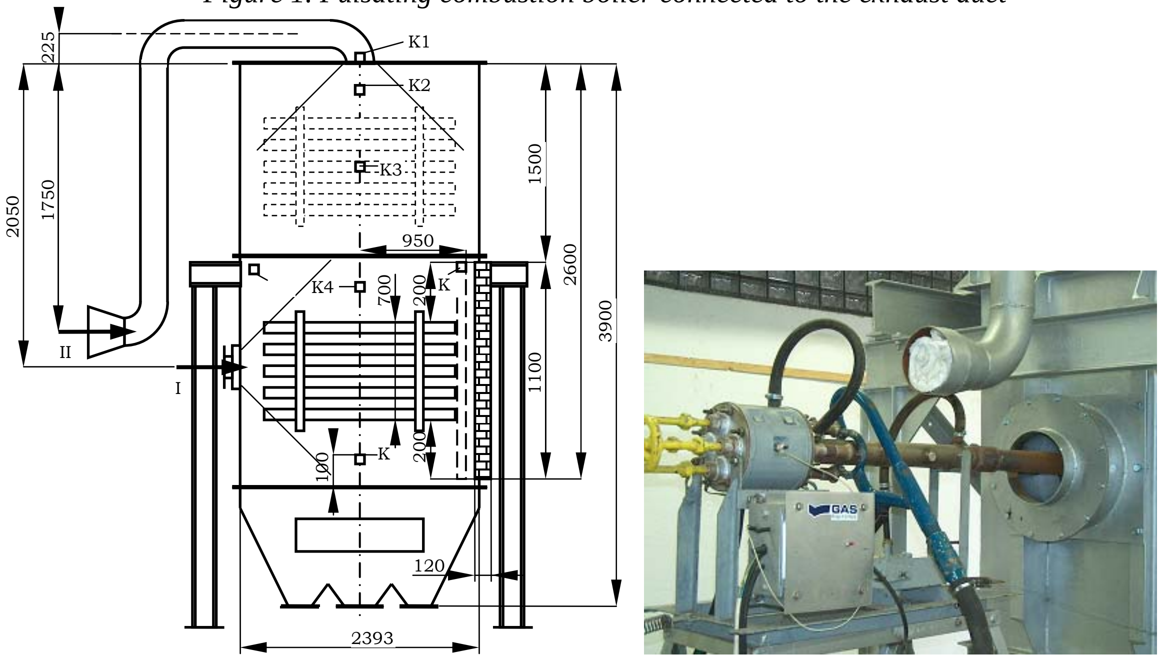

Figure 2. Left - Basic dimensions of the boiler model; burner connections (I and II), measurement places (K1 - K6); Right – photo of the burner mounted at the connection I

When the tube bundle is in the upper position and the burner is mounted from the side (position I), the situation is similar to the application of the burner to the fire-place. When the burner is mounted from above (position II), the situation is similar to the application of the burner to the convective part of the boiler. In that way, it is possible to monitor parameters inside the model for two basically different applications of the burner: a) In fire-place, as auxiliary burner to be turned on from time to time and when needed, for additional turbulization and intensification of the mixing of the reactants, and so to improve the combustion; b) In convective parts of the boiler, for cleaning of the ash depositions of the outer side of the heating surfaces of the boiler.

Monitored parameters and measurement equipment. During the investigation following parameters are measured: Temperatures of the air, gas, combustion products, cooling water (thermocouples of type K); pressure of the gas, water, pulsating medium inside the aero-valves, pressure inside the combustion chamber, resonant pipe and inside the boiler model (manometers with Burdon pipe and pressure transducers: type 601A, 6511 SP and SEN-8700 produced by Kistler); gas flow rate (rotameter, Aalborg instrument); cooling water flow rate (flow meter, AMS); noise (microphone type 2671); exhaust gases analysis (CO_2, CO and O_2). Data acquisition from the whole experimental setup is made by a personal computer with DEWESoft® software-package installed on it.

2. SOME INVESTIGATION RESULTS

In the Figure 3 results from the measurements when applying the burner from the side of the boiler model are shown (position I in the Figure 2). The tube bundle is in the upper position. Weakening of the pulsations of the exhaust gases dependent on the position of the measurement place is obvious.

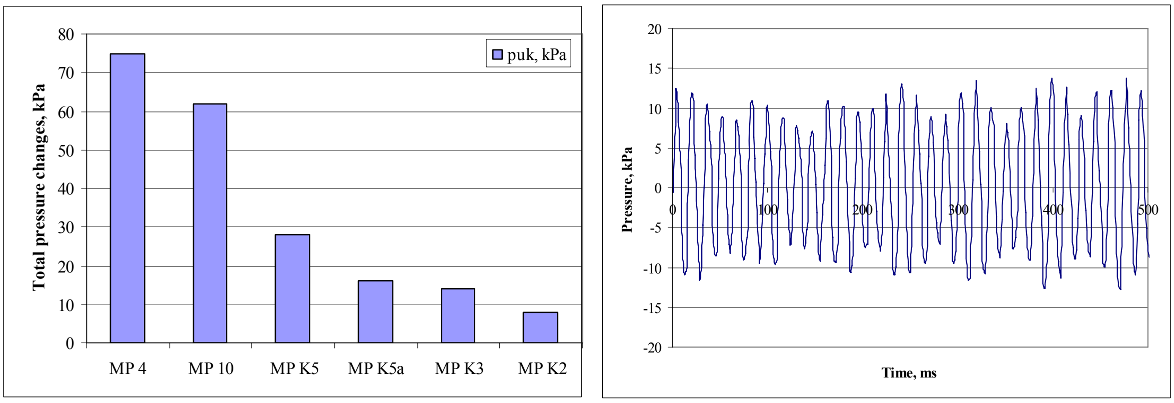

Figure 3. Left-Total pressure pulsations dependent on the position of the measurement place; Right–pressure pulsations of the exhaust gases (measurement place K5); Burner -position I, Bundle-upper

From the obtained results it could be concluded that pulsations of the exhaust gases generated inside the pulse combustion burner (installed as auxiliary burner) could additionally turbulize the atmosphere inside the fire-place and stopping in that way the appearance of the so called of dead pockets (zones with decreased reactant mixing), which occur when low-quality coal is used. The effect of increased turbulization is very important for increasing the energy efficiency and for protecting environment.

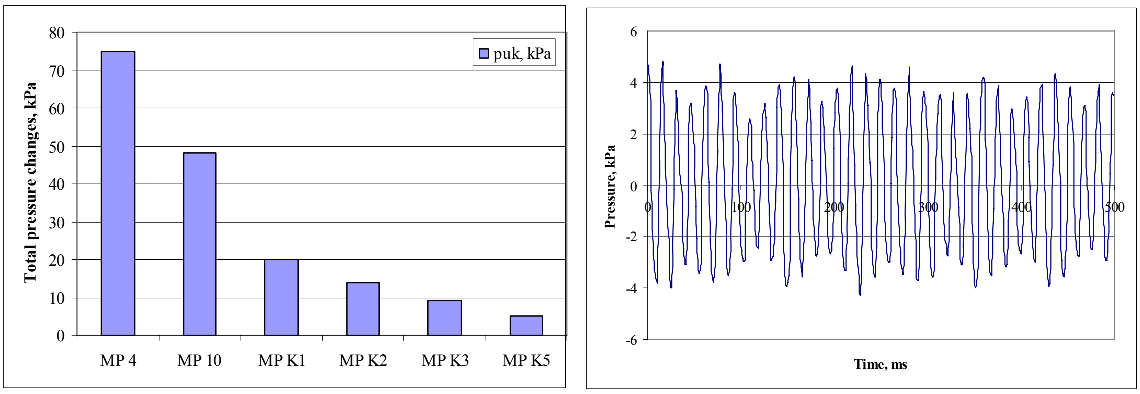

Figure 4. Left-Total pressure pulsations dependent on the position of the measurement place; Right–Pressure pulsations of the exhaust gases (measurement place K3); Burner-position II, Bundle-upper

It is to suppose that the pulsating pressure energy and accompanying sound energy with a spectrum containing waves of different frequencies could destroy and carry out deposits formed on heating surfaces of boilers. By varying the geometry of the burner sound spectrum varies too and in that way response of the tubes with different characteristics is assured (resonance).

3. NUMERICAL INVESTIGATION

Using FLUENT Program package numerical simulations of the pulsating combustion are made. Simulation of the combustion of the burner connected to the exhaust duct with a length of about 6 m is made. The second part of the numerical investigation was to simulate the pulse combustion of the

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burner mounted on the boiler model in the position I shown in the Figure 2. In the Figure 5 the numerical mesh of the pulse combustion burner and the exhaust duct connected to are shown. In the Figure 6 pressure changes in three points are shown, p_4- inside the combustion chamber, p_8 – inside the resonant pipe and p_{12} – inside the exhaust duct. In the Figure 7 temperature changes inside the combustion chamber are shown and in the Figure 8 mass fractions of exhaust gases are presented.

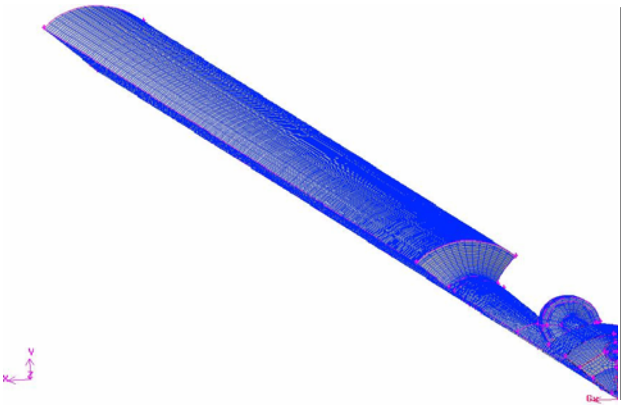

Figure 5. Numerical mesh of the burner and the exhaust duct connected to

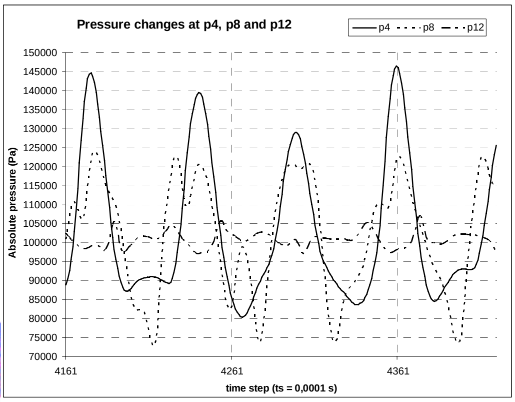

Figure 6. Pressure changes along the burner and the exhaust duct, points 4, 8 and 12 – Figure 1

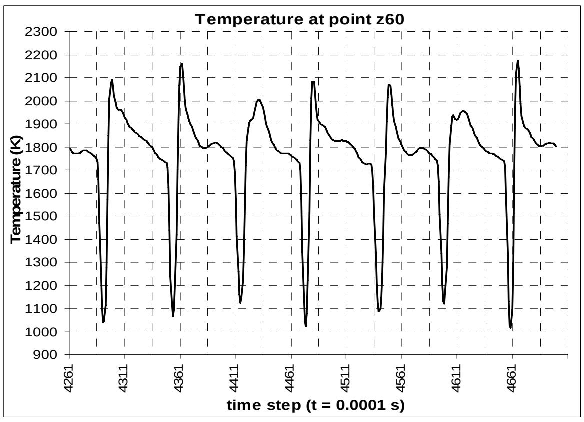

Figure 7. Temperature changes inside the combustion chamber

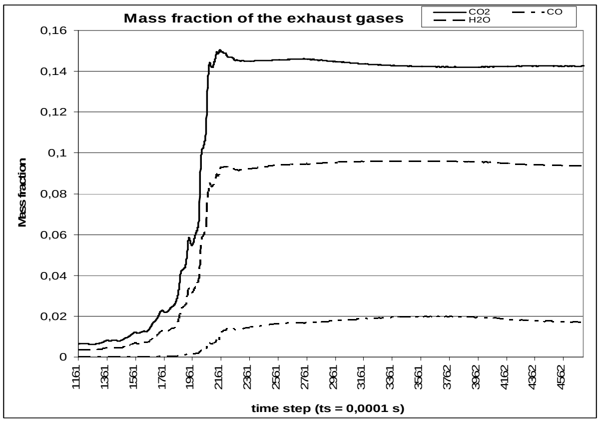

Figure 8. Mass fraction of exhaust gases

4. CONCLUSIONS

According to the results of the experimental investigation high frequency pressure pulsations of the exhaust gases generated inside the pulse combustion burner it is estimated that the burner could be suitable for turbulization of the interior of the fire-places of boilers and furnaces. Also, the burner could be applied for cleaning of the heating surfaces of boilers – particularly for cleaning of the convective heating surfaces of boilers using solid fuels with tendency to form depositions. Numerical simulation of the burner mounted on the boiler model will be deeply analyzed.

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