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WATER-COOLED PULSE COMBUSTOR PERFORMANCES

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ABSTRACT

In this paper a part of the results obtained during experimental investigation of pulse combustion in water-cooled combustor are presented. The combustor consists of non-moving mechanical parts. The presented results show correlation between basic operational and constructional parameters of the combustor as a ground for optimization of its construction and operation. It is shown that parameters of the pulse combustion process depend not only on the geometry and heat load of the combustor, but also on the cooling intensity, that is on the combustor walls temperatures. High frequency low temperature oscillating combustion process is generated. Because the burner is constructed in a way which makes possible geometry changes of the combustion chamber, aero-valves and resonant pipe the frequency could be changed between 70 Hz and 170 Hz. Pressure oscillations inside the combustion chamber reach values over 90 kPa and the mean temperature of the combustion inside the chamber does not exceed 1450 K. It is also shown that the operation flexibility of this type in the stable operation regime regarding to geometry is up to 5:1. The results are compared with data obtained during previous investigations of pulse combustion burner with air-cooling system.

Key words: water-cooled burner, pulse combustion, pulse pressure

1. INTRODUCTION

Experimental setup of the pulse combustion burner is placed in laboratory at Mechanical Engineering Faculty Sarajevo – Energy Department. In this paper a part of the results obtained during experimental investigation are presented. Experimental results obtained from investigation of water-cooled combustor are compared with data obtained during previous investigations of air-cooled pulse combustor.

Pulse combustion burner is a Helmholtz-type water-cooled pulse combustor consisting of a combustion chamber, a resonant pipe and aero-dynamic intake valves supplying air needed for combustion. With continual supply of the fuel (LPG) and starting air into the combustion chamber, generated mixture is ignited 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 exhaust duct. Such a setup allows measurements on several geometries of the burner, enables finding the optimum one regarding to projected burner performances. Forced water-cooling of the burner is made possible by a shell around the combustion chamber and the root of the resonant pipe. By regulating the cooling-water flow rate it is possible to vary the temperature of the walls (intensity of the heat transfer) and so to vary the process performances: average temperature, total pressure amplitude and frequency. Other parts of the experimental setup are following: fuel supply line with measurement and safety equipment, starting air line and spark generation unit. Detailed schematic of the test-rig of the water-cooled pulse combustion burner and measurement equipment with selected measurement positions are given in Figure 1.

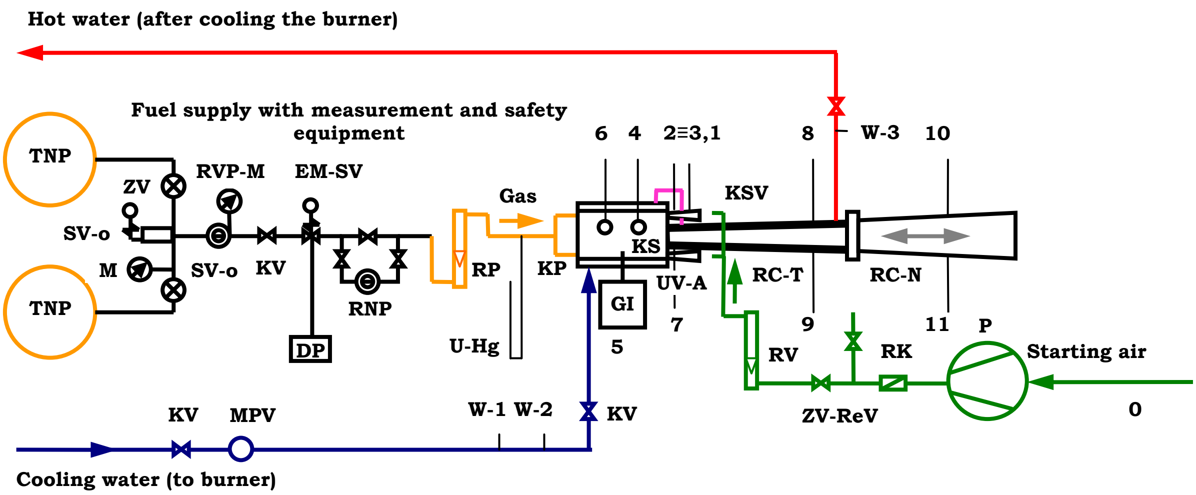

Figure 1. Water-cooled pulse combustion burner; parts of the test rig with measurement positions

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) – device for continual gas analysis produced by Hartmann & Braun. Data acquisition from the whole experimental setup is made by a personal computer with DEWESoft® software-package installed on it.

2. SOME RESULTS OBTANED FROM THE INVESTIGATION

After analysis of the results obtained from investigation it is concluded that with increasing the temperatures of the walls of the burner also the frequency of the pulsating pressure (f) significantly increases (Figure 2), while the total oscillations of the pulsating pressure generated inside the combustion chamber (p_{4uk}) decreases. During that both the positive (p_4^+) and the negative (p_4^-) pressure changes decrease and whit increased temperature the difference between their absolute values is lower (Figure 3). Such a change of monitored parameters is a logical implication of the fact that with increased temperature of the wall the temperature of oscillating combustion products is also increased. In other words, the mass of oscillating medium is decreased.

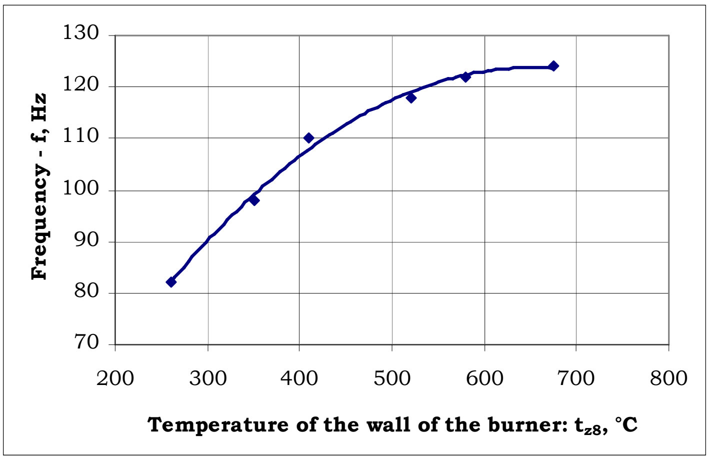

Figure 2. Influence of the wall temperature on the process frequency; geometry: code 41,fuel consumption: 5,15 Nm^3/h gas, resonant pipe: free end

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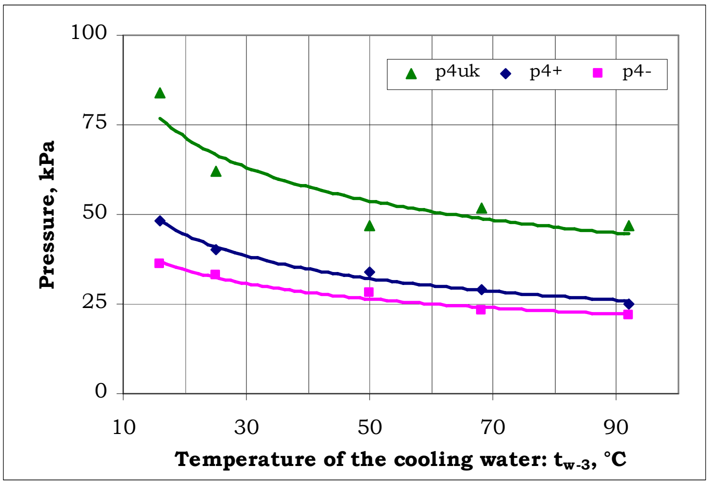


Figure 3. Changes of the pressure inside the combustion chamber depending on the cooling intensity: p_{4uk} – total change, p_4^+ – positive, p_4^- – negative; geometry: code 44, fuel consumption: 4,42 Nm^3/h, resonant pipe: free end

Frequency of the process is an invariant property with respect to position of the measurement place on the burner. Figure 4 shows changes of the frequency of the process depending on the load of the burner.

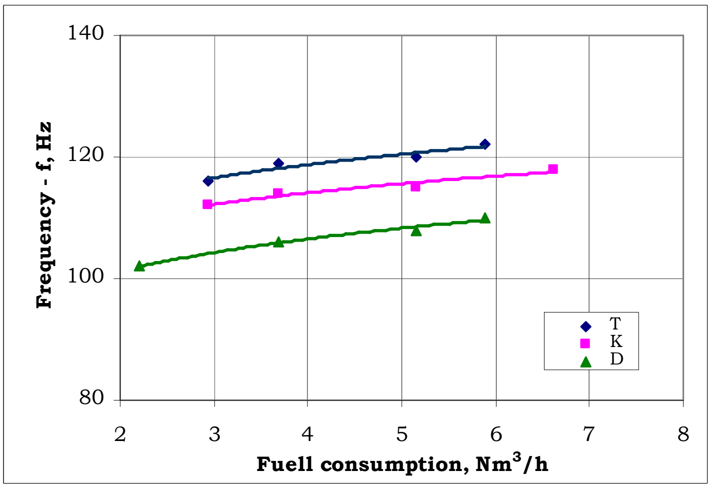


Figure 4. Frequency of the pulsating combustion process in a water-cooled burner; geometry: code 21, 22 and 24, (MK~);resonant pipe – position "d" inside the exhaust duct

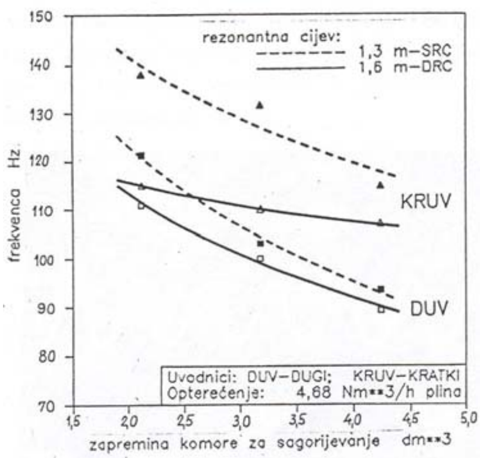
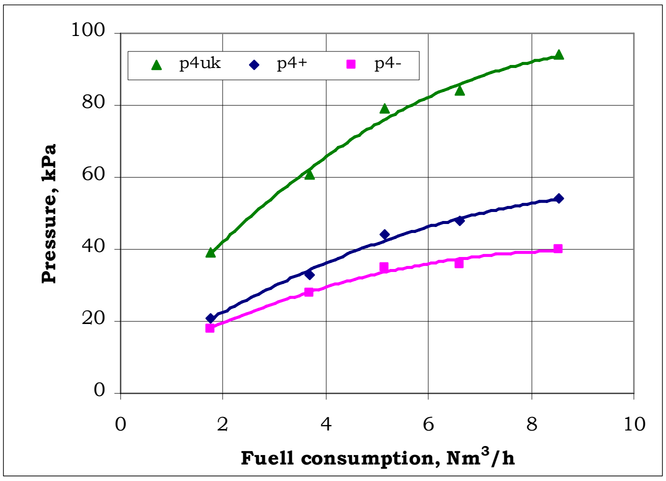


Figure 5. Change of the pulsation frequency depending on the geometry of the air-cooled burner; fuel consumption: 4,68 Nm^3/h

Frequency of the pulsating combustion process decreases whit the increase of the resonant pipe. This could be explained with the increased volume of the burner, in other words with the increase of the total mass inside that volume. Comparing results given in the Figure 4 (water-cooling) and Figure 5 (air-cooling), it is shown that the process frequency of the water-cooled burner is lower by about 3 Hz. More intensive cooling of the burner results to increased oscillating mass and so the process is more inert. With the increase of the load of the burner total pressure oscillations inside the combustion chamber increase significantly - p_{4uk} in Figure 6. These oscillations are formed from the pressure increase in the overpressure zone (p_4^+) and from the depression inside the combustion chamber (p_4^-), while the oscillations in the overpressure zone are always higher. This difference between underpressure and overpressure oscillations is increased with the increased burner load. Changes of the pulsating pressure also occur with the change in burner geometry, e.g. the resonant pipe length, while the operational flexibility of the burner changes also (upper and lower off limits).



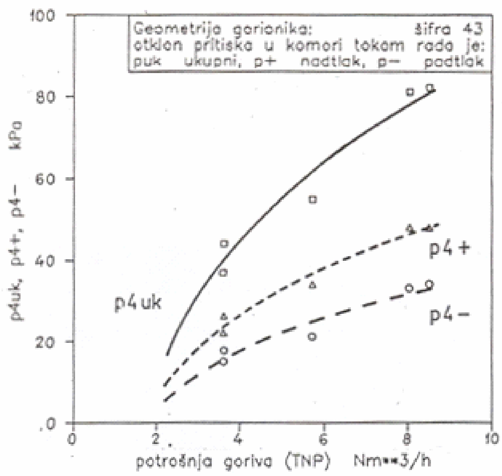
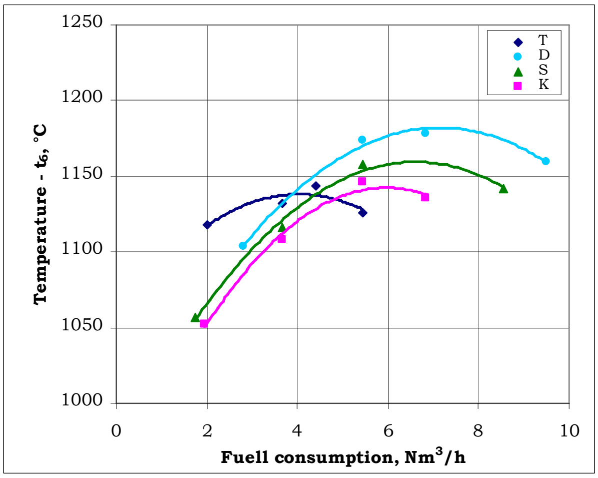


Figure 6. Form of the pulsating pressure inside the combustion chamber and the oscillating intensity changes whit varying burner load (water-cooled burner); geometry: code 43, burner off limits 1,75 and 8,55 Nm^3/h

Figure 7. Form of the pulsating pressure inside the combustion chamber and the oscillating intensity changes whit varying burner load (air- cooled burner); geometry: code 43, burner off limits 1,74 ÷ 8,6 Nm^3/h



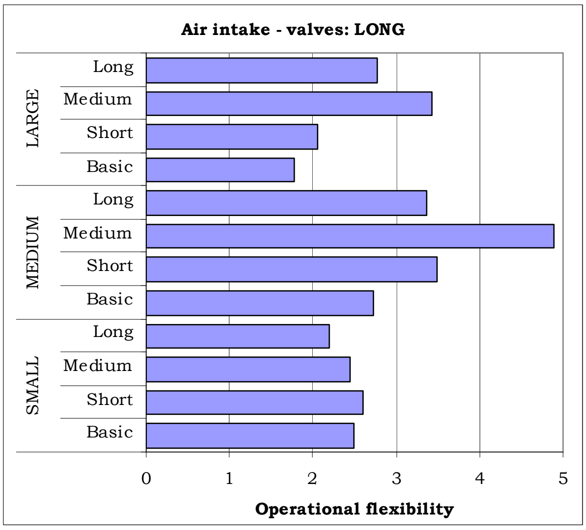


Figure 8. Average temperature of the combustion chamber depending on the fuel consumption and geometry changes; geometry: code 41, 42, 43, 44

Figure 9. Operational flexibility of the water-cooled burner with long air intake-valves

3. CONCLUSION

From the experimental results following is to be concluded: with the increase of the cooling intensity of the burner the frequency of the pressure changes decrease while the amplitude of the pulsating pressure oscillations increases; the mean chamber temperature of the process is relatively low and, depending on the geometry of the burner and thermal load, was measured to be max. *1450 K* (1177 °C); noise intensity, as a unavoidable side effect during the operation of the burner, was sometimes over 130 dB, while the sound-spectrum was very wide.

4. REFERENCES

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