Propane and Air Mixture –Based Short-Barrel Detonation Gun

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1 Introduction

The pulsating detonation is widely used for the detonation spray coating technology [1]. At the present time the Praxair Company uses detonation guns with the frequency of up to 100 Hz. However, these guns operate using the fuel-oxygen mixture. Therefore, a variety of the sprayed materials is limited by the compositions that are not sensitive to the oxidation in the oxygen environment. In addition, the detonation technology provides the top coating quality in contrast to other gas–thermal spray coating technique [2]. Detonation guns operating on the fuel-air mixture provide an opportunity for the use of such coating material as, for example, titanium that is slightly sensitive to the oxidation in the air environment. It is known [3] that in the case of an increase in the gas mixture pressure the detonation sensitivity of a mixture is also increased. This allows us to use fuel –air mixtures for pulse detonation devices instead of fuel-oxygen mixtures. This method of an increase in the mixture sensitivity was realized in our experimental setup.

It is known [3] that the detonation combustion provides a maximum efficiency of the conversion of explosion energy into the kinetic energy of gas flow. Therefore, in order to compete with the known gas-thermal spray techniques (HVOF, HVAF), in terms of cost and efficiency we developed the short-barrel detonation gun that operates using the atmosphere air and propane mixture with the frequency of firing exceeding 20 Hz. A principle of operation and the performances of the developed gun are described in this research paper.

2 Short-barrel detonation gun parameter studies

The diagram of experimental short-barrel detonation gun is given in Fig. 1. The detonation tube *1* length was equal to 0.6 m. The inner tube diameter was 20 mm. The precombustion chamber *2* volume was within 150 cm^3. A periodic formation of the combustible gas mixture under a high pressure occurred in the mixing chamber *5*. The heater *6* provided a preliminary heating of the combustible mixture. The mixture was formed using the air *3* and the liquefied petroleum gas *4*. The mixture was ignited from the

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improved discharge energy unit using the spark plug *9*. The pressure was measured by pressure sensors *7*. A signal was registered by the oscillograph *8*.

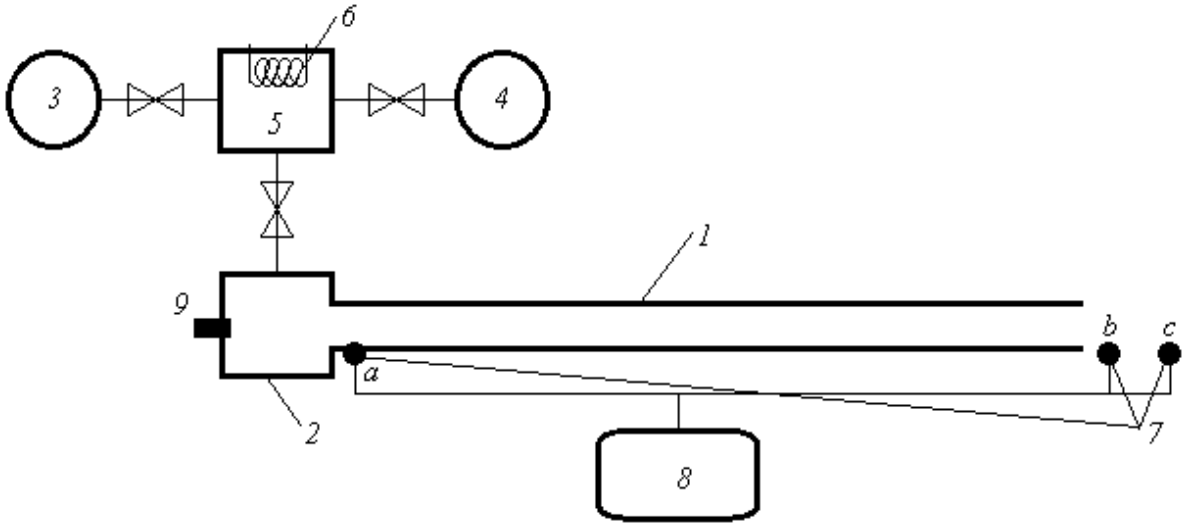

Figure 1. Short-barrel detonation gun diagram

A specific feature of this setup consists in its ultra-fast pressurized filling of the detonation tube with the combustion mixture. Due to such a filling the combustion mixture in the precombustion chamber *2* and in the certain portion of the detonation tube *1* is under the pressure that exceeds the atmospheric pressure by the time of detonation initiation. The option of such a distribution is shown in Fig. 2. The mixture supply time and the tube length are selected in the way that the combustion mixture fails to leave the detonation tube prior to the detonation initiation. Therefore, the combustion mixture is completely burnt in the setup due to the detonation combustion. The heater *6* and the spark ignition with increased discharge energy [4] allow for the stable initiation of the detonation using combustion mixtures with a considerable deviation from the stoichiometric composition.

Fig. 3 gives the pressure measurement data at a point *a* obtained using the ADZ-10 sensor. Since the detonation gun is intended for the coating, the coating cycle alternates with the blowing cycle. The amplitude excess gas pressure at a point *a* exceeded 0.3 MPa with no combustion and it increased more than 3 to 4 times due to the combustion. The pressure oscillogram shows the appropriate sequence of pressure waves that reflect given cycles. A more detailed investigation of a change in the pressure at an *a* point using the piezosensor showed availability of the explosive combustion. The duration of such combustion is equal to several hundred of microseconds. Prior to each explosive combustion cycle we have a spike caused by the inducing from the spark ignition unit. The oscillogram analysis showed that the delay time between the spark and the explosion is about 2 ms.

The pressure wave travelling time between the pressure piezosensors was measured at the points *b* and *c*. The sensor *b* was installed at a distance of 1 cm from the detonation tube end. The distance between the sensors *b* and *c* was equal to 5 cm (Fig. 4). The measurement data show a step-wise change in the pressure recorded by the sensors. According to the multiple measurement data the wave travelling time between the sensors was equal to 29 -30 μs. It corresponds to the wave velocity of 1667 – 1724 m/s. This is an explicit evidence of the available detonation. According to the experimental data the detonation velocity of the propane-air mixture is equal to 1800 m/s.

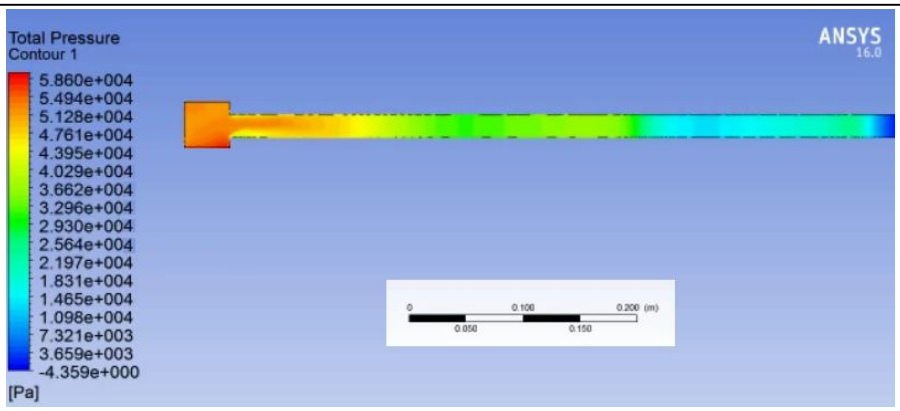

Figure 2. Example of the distribution of excess pressure inside the gun at the time prior to detonation initiation

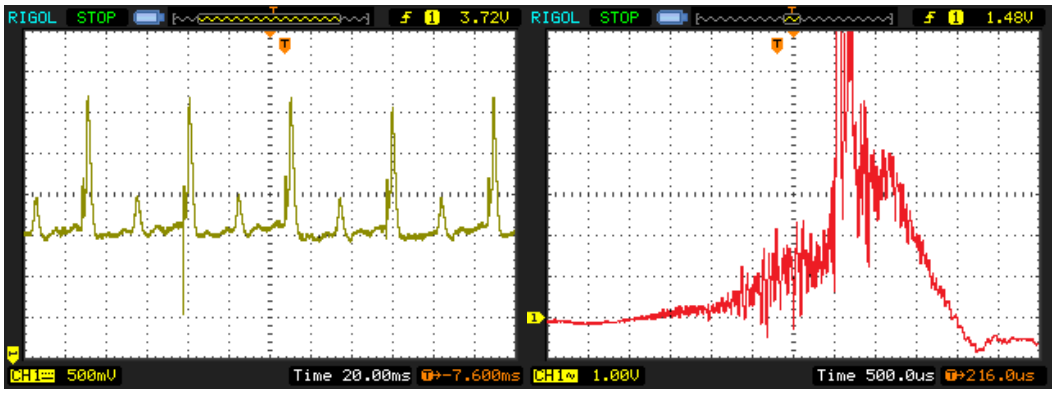

Figure 3. Left: Pressure at a point *a*; right: a change in the pressure during the explosive combustion at a point *a*

An overall estimate of the inputs for the heating and supply of compressed gas mixture per one detonation cycle was equal up to 500 J at an efficiency factor of the preparation system within 60%. A temperature of the combustion mixture supplied into the precombustion chamber was about 150 ºC. The gun spends about 0.6 l of the fuel mixture of atmospheric pressure per one detonation cycle. The frequency of detonation cycles exceeds 20 Hz. The estimated output power of the detonation gun is 50 kW.

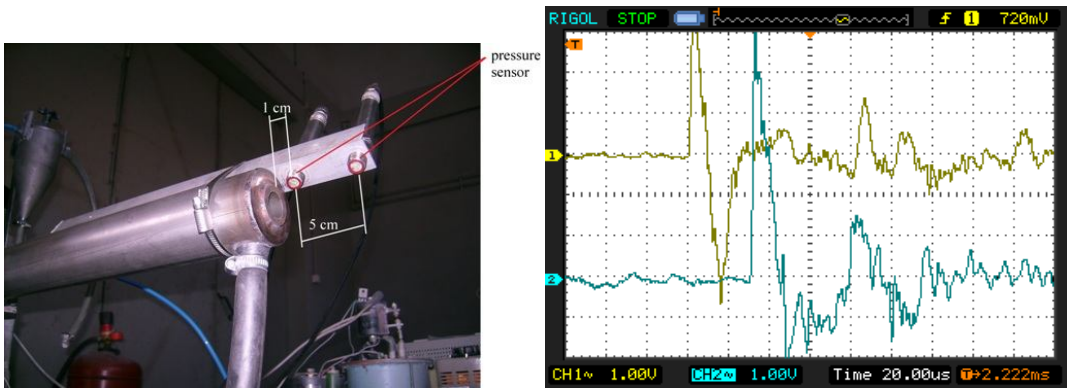

Figure 4. Left: Arrangement of sensors at the points *b*, *c*; right: the pressure measurement data at the points *b* and *c*

It is known [5] that the critical tube diameter at which the deflagration-to-detonation transition happens is equal to the detonation cell size λ. For the propane –air mixture $\lambda \approx 50$ mm. The internal diameter of the tube of detonation gun is equal to 20 mm, therefore the DDT occurred due to the fuel mixture heating and the compression of it.

3 Conclusion

The developed short-barrel detonation gun can be used as a detonation initiation source in the pulse detonation engines to replace fuel-air predetonators.

References

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