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# Multispark initiation of propane combustion in an enclosed volume

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# Multispark initiation of propane combustion in an enclosed volume

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**Abstract.** The initiation and combustion of propane-oxygen ($P_0$ = 1 atm) are experimentally studied by using multispark discharges (ranging from 1 to 9 in number), which are differently located in the cylindrical chamber 72 mm in diameter and 4 mm high. The methods of synchronous recording and measurements of parameters of force pulses with 26 μs resolution piezodynamometer were used in the studies. It was shown that for identical gas charges, the duration of generation of force pulses decreases by 30 % as the number of initiation sparks rises in comparison to one-spark initiation in the center of the chamber.

## 1. Introduction

Nowadays, basing on the principles of ecological safety, there is a tendency for a wider use of natural gas in automobile and water transport [1, 2] and mostly in producing electrical energy. We observe a competition for the parameters of energy efficiency for different methods of gas combustion in energy-generating plants, turbine generators, thermal power plants, and engines of internal combustion. In the solution of the problems under consideration, two approaches are developed: 1) subsequent initiation, 2) multispark initiation. In the first variant, by subsequent initiation, we mean the supply of group (~10) of high-voltage pulses per one spark. In the second variant, by multispark initiation, we mean the initiation of fuel mixture in a cylinder at multiple points on the cross-section of the cylinder. The first approach is developed technically as a reliable variant of initiation of fuel mixture [3]. The second approach is under theoretical development [4]. However, it is to be noted that nowadays in Korean motorcycles two ignition sparks are fixed in the cylinder and the late models of Volkswagen cars also have two ignition sparks per cylinder owing to reliability of ignition.

In this work, we consider one of the methods to improve fuel efficiency for the devices of the type of internal-combustion engine (ICE) and water movers as the example of propane combustion.

## 2. Experimental set-up

Figure 1 presents the principal scheme of experimental set-up. We made a device in the form of steel cylinder (1) of internal diameter 72 mm mounted on a massive base (2). Inside the cylinder, there was a movable piston (3) made of caprolon with rubber seal ring. By using rod (4), piston (3) was connected to piezodynamometer (5). The end of the cylinder was hermetically closed with glass block (6). Working chamber (7) was filled with gas through the aperture with a flame filter. For each series of experiment, spark gaps were arranged directly on the end of the piston with subsequent connection. Electrical ignition of spark gaps was performed synchronously with high-voltage block (8), pulses of 50 ns duration of total energy up to 2 J. The electrical signal of dynamometer (5) was detected by digital oscillograph TDS-210 (9). The initiation of ignition and gas combustion were recorded by using digital camera MotionXtra HG-LE (10). We controlled the system with remote panel (11) and registered synchronously the results on computer (12).

In all the experiments, we used a stoichiometric propane-oxygen mixture. These experiments were performed in the combustor of height h=4 mm for the stoichiometric propane-oxygen mixture ($C_3H_8+5\cdot O_2$) prepared in advance. From the oscillograms of registered force pulses (Figure 2), we took into account the following data: 1) the periods of combustion induction as the delay of visible

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combustion and start of generation of force pulse after initiation (t), 2) the periods of generating the maximal values of force pulse amplitude (T), 3) the integral of force pulse from the initiation moment to the maximal amplitude over period T.

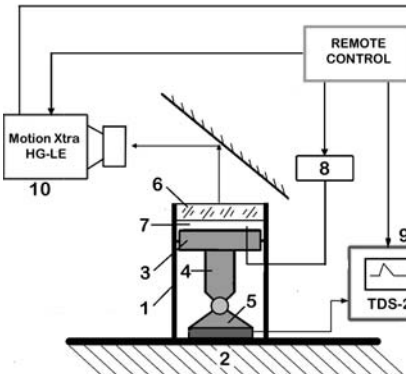
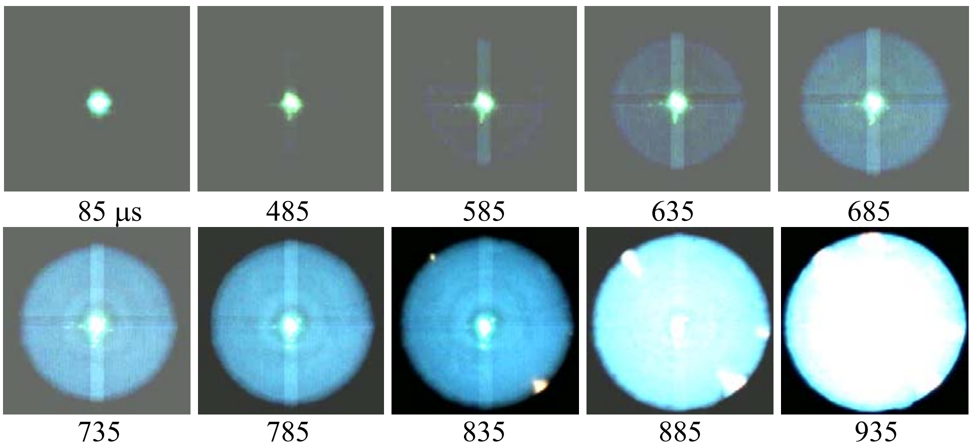


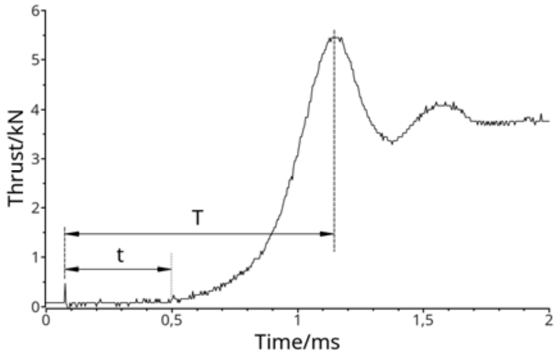

**Figure 1**. Experimental set-up

## 3. The results of experiments

Figure 2a illustrates the example of mixture combustion initiated by one spark in the center of the combustor and the oscillogram of force pulses corresponding to this experiment (Figure 2b).



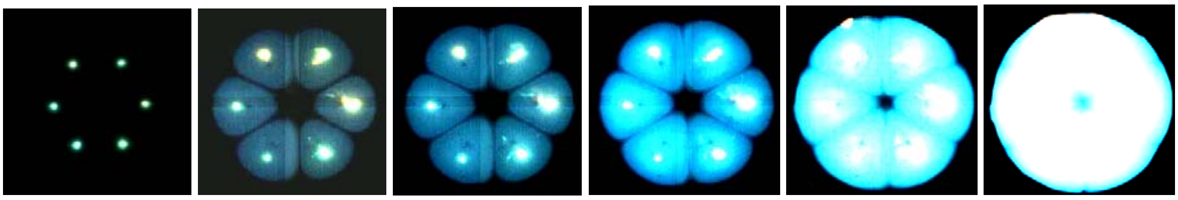

(a)




(b)

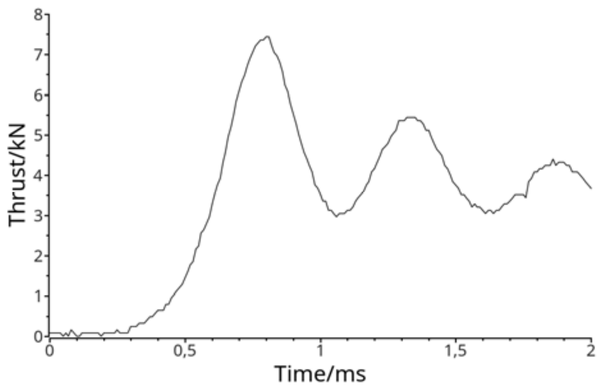
**Figure 2.** Ignition and combustion of propane-oxygen mixture by one spark

Figure 3 shows the record (a) and corresponding oscillogram of force pulses (b) for the case of 6-spark initiation of the same gas charge with spark initiators arranged in a circle 36 mm in diameter.



77 μs 377 427 477 527 627

(a)




(b)

**Figure 3.** Ignition and combustion of propane-oxygen mixture by six sparks

Figure 4 illustrates the results of measurements of combustion induction periods: the delays of the start of force pulse generation (t) and generation periods up to the maximal values of force pulse amplitude (T).

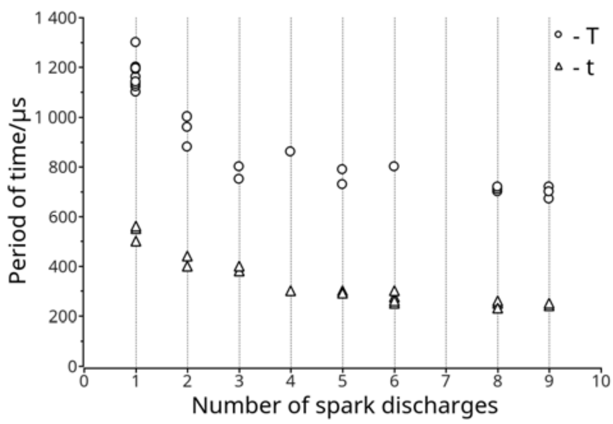



**Figure 4**

Figure 5 shows the dependence of maximal thrust on the number of spark discharges. The spread in values for the 1st, 2nd and 4th discharges is observed when the phenomena illustrated in Figure 6 arise in combustion. Without these phenomena, the repeatability of values of force pulses is about 5%.

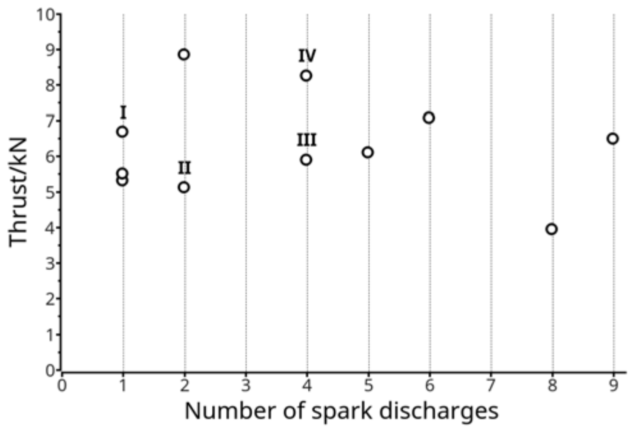



**Figure 5**. Force pulse vs the number of discharge gaps and the character of processes occurring in combustion

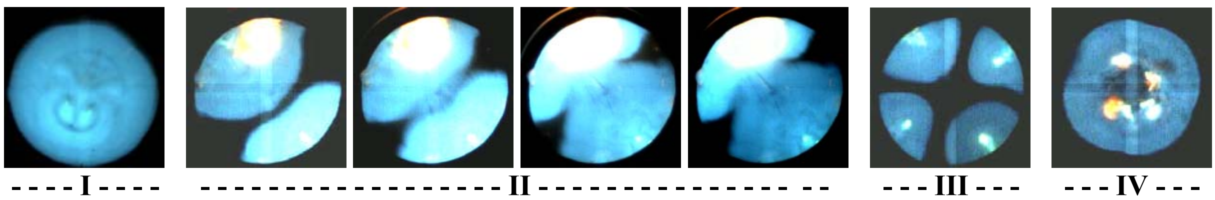



**Figure 6**. Processes affecting thrust characteristics. I – vortex flow of gas; II – changing direction of propagation of combustion fronts; initiation of combustion near the edge of combustor (III) and in the center (IV)

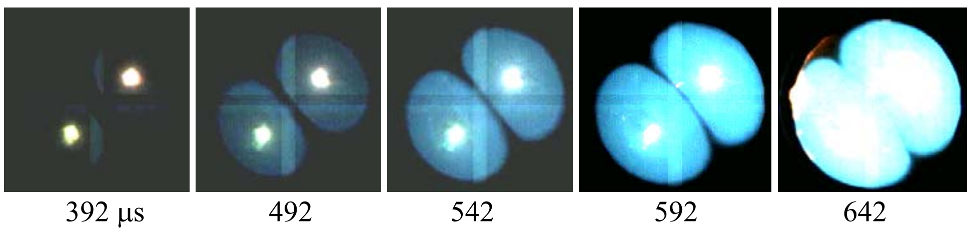



**Figure 7**. Dynamics of propagation of combustion fronts without change of direction

## 4. The analysis of results

From the above experimental results, it follows that the time of generation of force pulses decreases by 20÷30% as the number of initiation sparks rises. Here the electrical energy of initiation was about 2 J for all the electrodes.

From the experimental results partially presented in Figures 5 and 6, we can conclude that the change of direction of combustion fronts causes the reduction of maximal thrust and, on the contrary, the presence of vortex flow of gas stimulates the increase of force pulse. Moreover, the change of regimes of flame propagation results in increasing the amplitude of force pulse by 1.3 (for single-spark discharge) to 2 times (for two- and four-spark discharges). We can suppose that the vortex gas flow in combustion is based on the mechanism found in [5]. The authors of this work succeeded to obtain a spin front of flame in a diverging wave of combustion propagating in propane-oxygen mixture.

As an example, in Figure 7, we present the dynamics of propagation of combustion fronts in the initiation by two spark discharges without the change of direction. It is to be noted that mean velocity $\boldsymbol{v_a}$ of fronts propagating from the opposite direction along a straight line connecting discharges is less than velocity $\boldsymbol{v_p}$ of fronts propagating in the direction perpendicular to this straight line. Their relation is $\boldsymbol{v_p}/\boldsymbol{v_a} \approx 3.7$. Such a difference in velocities of propagation of combustion fronts is also observed for another number of initiating discharges.

Thus, the obtained results show that spatially-distributed spark sources of initiation of fuel in ICE will make it possible to increase the mean power due to increasing the cycling of fuel combustion in engines without affecting the environment, i.e., the engine speed can be increased without CO emission increase.

## 5. Conclusions

It is shown that for identical gas charges, the time of force pulse generation decreases by 30% as the number of initiation sparks rises (up to 6) in comparison to a single-spark initiation in the center of the combustor. This result predetermines complete fuel combustion in less time for each cycle without development of detonation regimes on the valves with increasing the speed of rotation in internal combustion engines.

Moreover, it is shown that specific regimes of combustion development have an essential influence on the amplitude characteristics of force pulse in the combustor. When controlling the change of regimes of flame propagation in the combustor, we can control thrust characteristics of the mover.

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## References

[1] Karpenko A and Koptseva E *Trans. Business Russ.* 2017 **130** (3) 63–6 (in Russian)
[2] Teslenko V S, Drozhzhin A P and Medvedev R N *Thermophys. Aeromech.* 2019 **26** (4) 611–7
[3] Abramchuk F, Kabanov O and Schvydkyi D *Avtomobil. Trans.* 2014 **34** 28–31 (in Russian)
[4] Kociszewski A, Jamrozik A, Sosnowski M and Tutak W *J. KONES* 2006 **13** (3) 123–30
[5] Samsonov V P, Alexeev M M and Smirnova I V *Usp. Fiz. Nauk* 2011 **181** (9) 965–72