Convergent (cumulative) shock waves generation by surface gliding discharges. Physics and applications.

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Possibilities of gliding surface discharges adoption for generation of different kinds of convergent (cumulative) shock waves in a gas medium are considered. Peculiarities and advantages of electric discharges application compared to adopted methods (localized charges explosion, explosion of diaphragm, for example) are as following:

1. Electric-discharge method enables to perform repeated generation of shock waves (even in form of sequence of realizations with the definite frequency) without chamber opening up and restoring gas-dynamic disturbance source.
2. System of multielectrode gliding discharges on a flexible base permits easily realize complicated geometries of shock waves including cylindrical and spherical ones.
3. Electric-discharge system based on the gliding surface discharges is source of intense ultraviolet and infrared radiation that exerts some action on a gas in a volume spanning by discharger (ionization, dissociation, excitation of vibrational and electron states of molecules). Activation of gas medium has to effect on a shock wave characteristics strengthening it and transforming into a detonation wave near the axis.

The main object of this paper is investigation of combustion processes in flammable gas mixtures under action of complicated geometry gliding surface discharges generating cumulatively converging shock waves.

In [1,2] experimental and theoretical investigation of methane-oxygen gas mixture ignition by gliding surface discharge forming annular plasma layer [3] and generating toroidal (annular) shock wave has been performed. Scheme of possible application of such a discharger for ignition of flammable gas stream is shown on the Fig. 1.

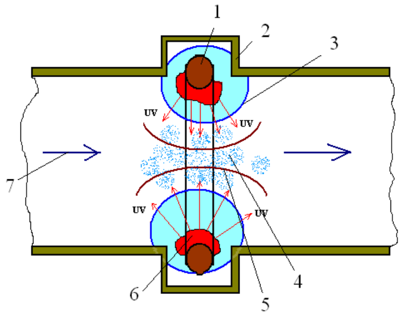

Fig. 1. Scheme of annular gliding surface discharge action on a combustible gas stream.1- annular electric discharger; 2 – combustion chamber; 3 – periphery combustion wave; 4 – activated by UV and IR radiation gas; 5 – cumulative shock wave; 6 – ring gliding surface discharge plasma; 7 – combustible gas flow.

Toroidal (non-one-dimensional) shock wave cumulatively converging to the axis of annular discharger is capable to heat gas in a focal region up to very high temperature. Thus in experiments [1,2] with annular discharger having radial size Rd ≅ 5 cm and at energy release in annular air plasma layer W ≅ 200 J temperature as high as 6000 K has been achieved near the discharger axis (see Fig. 2).

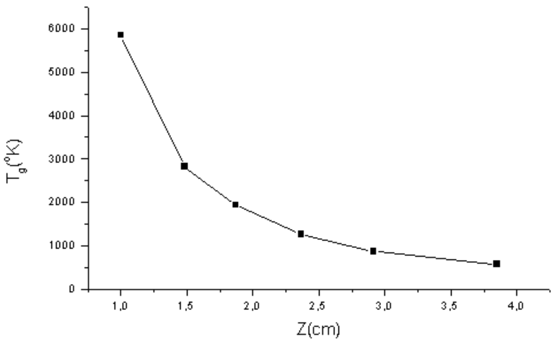

Fig. 2. Peak values of temperature attainable at the front of the Mach wave at different points at the Z-axis; calculations with W= 200 J.

Experiments on the ignition of CH_4:O_2 through the annular gliding surface discharge have been carried out. It has been shown that at the same energy release induction time of combustion for annular discharger is significantly smaller (by the factor 2-3) than for linear one.

Characteristic high speed photograph of luminescence from reactor chamber (see for example Fig.3) allows us to make conclusions that ignition of CH_4:O_2 mixture with subsequent propagation on the whole volume of reactor starts near the axis of ring shape discharger. Flame propagates with such a high velocity that we can identify it with the detonation wave

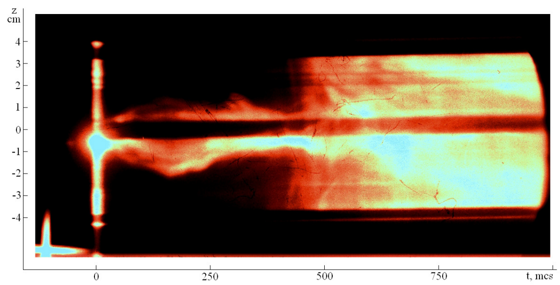

Fig. 3.

Typical streak images of glow in the reactor. The slit of the streak camera is oriented along the Z axis.

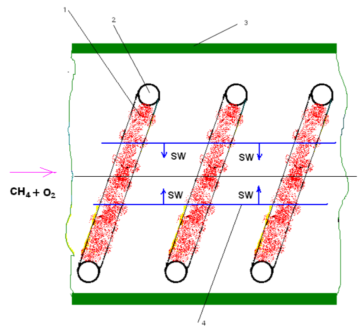

Fig. 4.

Scheme of cylindrical cumulative wave generation. 1-gliding surface discharge; 2-coils of spiral discharger; 3-chamber of reactor; 4-cylindrical cumulative shock wave.

In could be suggested that such a shape of electric discharge system has to be realized that one-dimensional shock waves (spherical and cylindrical) could be generated in the reactor volume. These dischargers have to be placed on periphery of ignited gas mixture. The region near the focal place having high gas temperature for one-dimensional shock wave has to be significantly higher than for toroidal one (see [4-6]).

Scheme of helical electric discharge system (based on the developed in the GPI flexible dischargers) that could result in cumulative cylindrical shock wave generation is shown on the Fig. 4.

For generation of spherical shock wave in the reactor volume it is reasonable to refer to the [7] in which spherical shock wave was generated under the conditions shown on the Fig. 5. Here annular electric discharger is placed in front of a flat surface (wall). Reflection from it of shock wave generated by annular discharger leads to the formation quasi-spherical shock wave near the wall.

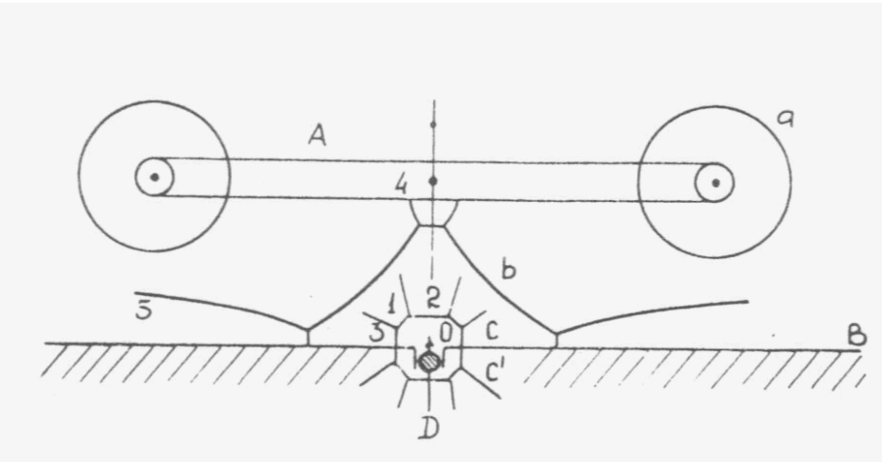

Fig. 5.

Scheme of experiment on quasi-spherical shock wave excitation.

It is easy to show that system presented on the Fig. 5 is similar from gasdynamic point of view to the system presented on the Fig. 6 where the role of reflector wall plays the second annular discharger in front of the first one. Quasi-spherical cumulative shock wave has to be appear between these two dischargers as it is possible to see on the Fig. 6.

Experiments and theory have to be developed for determination of possibility of spherical and cylindrical shock wave realization on the base of gliding surface discharges.

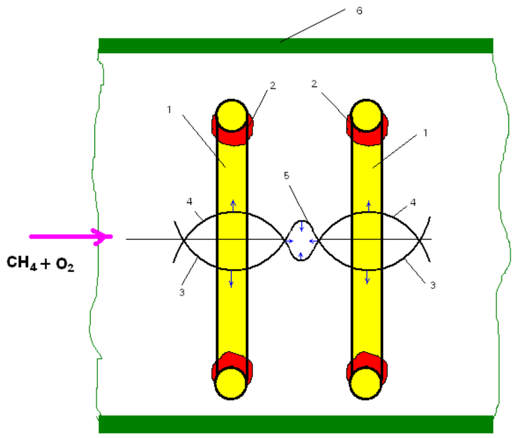

Fig. 6.

Scheme of quasi-spherical shock wave generation.

1-annular discharger; 2-annular gliding surface discharge; 3,4 –reflected from axis toroidal shock wave; 5-quasi-spherical shock wave; 6-chamber of reactor .

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