

**INERTIZATION OF COMBUSTION OF HYDROGEN-AIR MIXTURES IN A
CLOSED VESSEL BY SUPERHEATED WATER AEROSOL**

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ABSTRACT

An experimental investigation of influence of superheated water aerosol on flammability limits of hydrogen in air has been carried out. It was found that the value of inertization concentration of the superheated water aerosol is equal to near 60 kg/m^3 at temperature of water $t_i=150-180 \text{ }^\circ\text{C}$ and of walls of a reaction vessel $t_w=75-100 \text{ }^\circ\text{C}$. A minimum inertization concentration decreases with an elevation of t_i and t_w . The value of the minimum inertization concentration for hydrogen-air mixtures is approximately two times higher, than for mixtures of methane and methanol vapour with air. It was found that inertization effectiveness of the superheated water aerosol is stipulated mainly due to steam produced during formation of the aerosol.

INTRODUCTION

Aerosol produced at a rapid evaporation of superheated water is now considered as an effective fire extinguishing agent [1]. The main advantage of this agent in comparison with mechanically dispersed water is the possibility of obtaining fine water droplets, which fire extinguishing efficiency in relation to diffusion flames is very high. It is interesting to investigate a possibility of application of the superheated water aerosol not only for extinguishing of diffusion flames but also for inertization of premixed flames. It is known [2-4] that influence of dispersed water with relatively large droplets (mean droplet diameter near 1 mm) on premixed flames causes at some conditions of combustion intensification due to turbulization of a gaseous mixture. In was

mentioned [5] that for the effective inertization of premixed flames the mean droplet diameter should not exceed 10 μm . Though the distribution function of the droplet diameter for the superheated water aerosol is now not found, it is reasonable to propose an availability in it rather small particles which are able to prevent a flame propagation across the gas-air-aerosol mixture.

In [6, 7] the inertization efficiency of the superheated water aerosol produced by water of temperature 150 $^{\circ}\text{C}$ in relation to mixtures of methane and ethanol vapour with air was investigated. This efficiency occurs to be low enough probably due to rather low temperature of water. This low temperature causes two undesirable effects: first, mass concentration of steam produced due to evaporation of the superheated water is small enough, and second, the mean droplet diameter is rather high for evaporation of the droplets in a narrow flame front of the premixed flames. In this study the inertization effectiveness of the superheated water aerosol is determined in relation to hydrogen-air mixtures for higher water temperatures and for the case of heated walls of a reaction vessel.

EXPERIMENTAL

Experiments were carried out on the experimental set-up "Variant" having a reaction vessel of volume 4.2 l (Fig.1). This reaction vessel gives a possibility to make experiments in the ranges of initial pressure from 0.1 to 4.0 MPa and initial temperature from 20 to 250 $^{\circ}\text{C}$.

The set-up has the following parts: the reaction vessel, pressure detector with time constant $3 \cdot 10^{-3}$ s, ignition source, cavity for producing of the superheated water, tubes and valves for supplying of gases and the superheated water, storing oscilloscope. A fused nichrom wire located in the center of the reaction vessel was used as an ignition source. Ignition energy was near 10 J. The superheated water was introduced into the reaction vessel from the heated cavity equipped with a thermocouple for measuring of temperature of water and a pressure detector for measuring of pressure of steam in this cavity.

The experiments were executed in a following way. A required mass of liquid was introduced into the cavity for preparing of the superheated water, which initially had room temperature. Then the cavity was closed and heated up to required temperature. Combustible gaseous mixture was prepared by partial pressures immediately in the preliminary evacuated up to residual pressure

0.1 kPa reaction vessel. The mixing time was not less than 30 minutes. Then the heated cavity was for a short time (not less than 1 s) connected with the reaction vessel, and some quantity of the superheated water was supplied into the reaction vessel. This superheated water was partially evaporated producing mixture of steam and fine aerosol particles with the initial combustible gaseous composition. After a time interval of 5 s the ignition source was initiated.

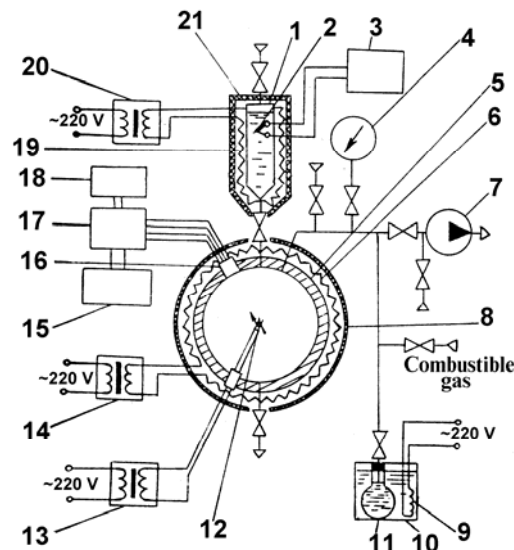


Fig. 1. Diagram of the experimental set-up.

1 – cavity for preparing of the superheated water; 2 – thermocouple; 3 – temperature regulator; 4 – vacuumeter; 5 – reaction vessel; 6, 9, 19 – electrical heaters; 7 – vacuum pump; 8, 21 – thermal isolation; 10 – vessel with hot water; 11 – vessel with flammable liquid; 12 – ignition source; 13, 14, 20 – transformers; 15 – oscilloscope; 16 – pressure detector; 17 – amplifier; 18 – source of direct current.

Pressure inside the reaction vessel was registered during the whole experiment (from the time moment of beginning of supplying of the superheated water to pressure drop after cooling of combustion products).

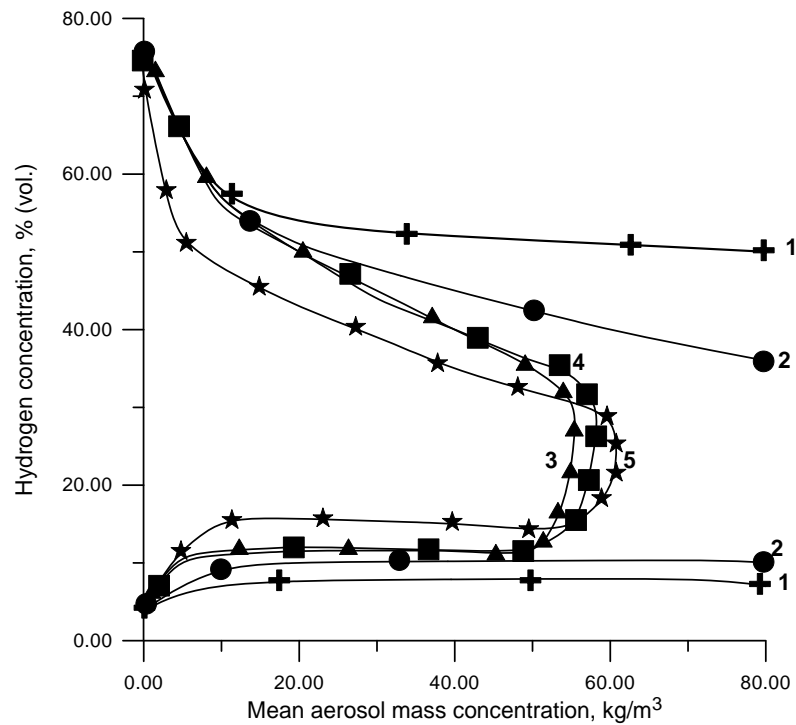


Fig. 2. Dependence of flammability limits of hydrogen in air on the mean aerosol mass concentration.

1 – temperature of the superheated water $t_l=150\text{ }^{\circ}\text{C}$, temperature of the walls of the reaction vessel $t_w=75\text{ }^{\circ}\text{C}$; 2 - $t_l=170\text{ }^{\circ}\text{C}$, $t_w=75\text{ }^{\circ}\text{C}$; 3 - $t_l=180\text{ }^{\circ}\text{C}$, $t_w=75\text{ }^{\circ}\text{C}$; 4 - $t_l=150\text{ }^{\circ}\text{C}$, $t_w=100\text{ }^{\circ}\text{C}$; 5 - $t_l=180\text{ }^{\circ}\text{C}$, $t_w=100\text{ }^{\circ}\text{C}$.

In Fig. 2 a dependence of flammability limits of hydrogen in air on mean mass concentration of the superheated water aerosol is presented. It can be seen that the values of inertization concentrations (peak concentrations) are close to 60 kg/m^3 . From this fact a conclusion can be made on a low inertization effectiveness of the superheated water aerosol in comparison with steam, for which the mass inertization concentration is near 0.2 kg/m^3 . For our opinion this effect is caused by formation of relatively large water droplets, which are not evaporated significantly in a narrow front of a premixed hydrogen-air flame. This phenomenon is not very important at extinguishing of diffusion flames (for example for pool fires), because even large droplets are evaporated quite totally in a diffusion flame (including preflame zone and combustion products) having sufficiently larger thickness in comparison with premixed flame. This is a qualitative explanation

of the difference in influence of the superheated water aerosol on premixed and diffusion flames. Such result is in a qualitative agreement with data [6, 7].

In Fig. 2 it can be seen that the inertization effectiveness of the superheated water aerosol is increased with an elevation of temperatures of the superheated water and the reaction vessel walls. At $t_i=150\text{ }^{\circ}\text{C}$ and $t_w=75\text{ }^{\circ}\text{C}$ we could not reach the peak point of the inertization curve (curve 1), but at the same time at $t_i=180\text{ }^{\circ}\text{C}$ and $t_w=75\text{ }^{\circ}\text{C}$ the peak concentration of the superheated water aerosol is near 60 kg/m^3 (curve 3). The same effect is observed for the curves 1 ($t_i=150\text{ }^{\circ}\text{C}$, $t_w=75\text{ }^{\circ}\text{C}$) and 4 ($t_i=150\text{ }^{\circ}\text{C}$, $t_w=100\text{ }^{\circ}\text{C}$). These phenomena can be qualitatively explained by elevation of the mass concentration of steam inside the reaction vessel at increase of the t_i and t_w values.

As it follows from data in Fig. 2, the inertization concentration of the superheated water aerosol in relation to hydrogen-air mixture is near 60 kg/m^3 , but at the same time this values for methane-air and ethanol-air mixtures are close to 30 kg/m^3 . This difference is probably caused by higher laminar burning velocity of hydrogen in comparison with methane and ethanol vapour. It should be noted that the inertization concentration of various gaseous agents is also 1.5-2 times higher for hydrogen-air mixtures than for hydrocarbon-air mixtures.

CONCLUSIONS

In this study the experimental investigation of the influence of the superheated water aerosol on flammability limits of hydrogen in air was carried out. It was found that the value of the inertization concentration of the superheated water aerosol is close to 60 kg/m^3 at the temperatures of the superheated water $t_i=150\text{-}180\text{ }^{\circ}\text{C}$ and the walls of the reaction vessel $t_w=75\text{-}100\text{ }^{\circ}\text{C}$. An increase of an inertization effectiveness of the superheated water aerosol with an elevation of t_i and t_w was observed. The value of the inertization concentration for hydrogen-air mixture is twice higher than for methane-air and ethanol-air mixtures. The obtained results can be qualitatively explained by the concept on the main role of steam in inertization of gaseous mixtures with the superheated water aerosol.

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