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Mechanism of spin flame front formation

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Contents

Abstract. **Possible physical mechanisms of the formation of the spin flame front in deflagrating gas mixtures are discussed. Conditions for the observation of a new physical phenomenon — the propagation of the spin flame front in a limiting propane–air mixture in an open narrow slot — are identified. Experimental techniques for investigating the spin mode of flame propagation in a gas mixture with low Reynolds numbers are suggested. The conditions where transport can affect the formation of a spin front in a gas–air mixture are formulated and prospects for future research are outlined.**

1. Introduction

The spin combustion wave is different from the laminar combustion wave in that its formation is followed by continuous rotation of the velocity vector component perpendicular to the chosen element of the front surface with either a uniform or variable angular velocity.

The propagation patterns of spin combustion were discussed in [1, 2]. The analog of spin detonation obtained during combustion wave propagation over the surface of a cylindrical sample of condensed fuel was considered in [3]. The authors of [4] provided experimental evidence of the possibility of spin flame front formation in a gas-phase chemical reaction above the surface of a liquid fuel. As is shown in [5, 6], a decrease in the speed of a continuously fed gas results in transition from the usual continuous cylindrical combustion wave to the focal flame propagation normally to the gas flow lines. The literature contains no reliable data on the formation of the spin flame front during deflagration propagation through a combustible gas mixture.

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Today, there is a consensus on the nature of spin combustion with excess enthalpy in the heated layer ahead of the combustion wave and on the formation of transverse waves in the thermal channel [7, 8]. Evidently, it is possible to construct individual models of the behavior of spin combustion waves under concrete conditions. The authors of [8, 9] sought to develop a general theory of the spin combustion regime in self-propagating high-temperature synthesis (SHS) systems based on a formal analysis of solutions of a phenomenological equation for the function giving the front position in the system of coordinates that moves with the mean burning rate.

However, there can be no universal description of physical mechanisms governing spin combustion in nonlinear kinetic systems (detonation in gases and SHS systems and deflagration in gases). The difficulty of developing the general theory ensues from a variety of mechanisms of chemical reactions and molecular and convective transfer, as well as the thermophysical properties of the system, scaling factors, and the geometric and hydrodynamic configuration of objects under study.

Deflagration propagation of the flame during gas combustion is due only to convective and molecular heat and mass transfer. The intensity and stability of heat and mass exchange strongly depend on the boundary conditions and scaling factors characterizing combustion systems. Therefore, we believe that special mechanisms of spin front formation during gas deflagration can be proposed based on the presently lacking experimental facts reflecting the influence of critical transfer phenomena on burning stability.

From the standpoint of basic science, the importance of investigating spin combustion regimes ensues from the need in new data for understanding the mechanisms and kinetics of frontal chemical reactions and the development of criteria for burning stability. During the last decade, researchers in developed countries have shown considerable interest in the creation of microcombustors and internal combustion microengines as the most promising choices for the further development of energy-conserving technologies. Technical applications of spin combustion include the creation of efficient ignition devices for fuel mixtures, methods for the control of the burning rate and stability, and estimation of fire risks in mineral industries.

2. The role of the leading point in spin flame front formation

The known spin fronts in gas detonation, SHS systems, and the gas-phase combustion of liquid fuels [1–4] have some common properties; specifically, they occur in spaces confined within solid surfaces. The direction of spin front propagation along the confining surfaces is determined by the spatial distribution of reactant temperatures and concentrations ahead of the leading point of the front. Therefore, the spin front propagation patterns to a large extent depend on the geometry of the surfaces confining the combustion zone and their orientation with respect to the gravitational acceleration vector.

The notion of the leading point as the forwardmost point of the front surface was introduced by the authors of [11]. The propagation velocity of a leading point in a laboratory reference frame is the sum of the combustible gas velocity and the normal flame propagation velocity through the gas, the former depending on the hydrodynamic situation at large and the latter on the combustible mixture composition and the local temperature of the flame front surface. Hence, the leading point trajectory is determined by nonstationary fields of velocities, pressures, concentrations, and temperatures in the flow of a combustible mixture. Instantaneous distributions of these physical parameters depend on the flow direction and stability of the reacting medium, diffusion streams of gas mixture components, and heat. The leading point trajectory is essential in terms of production of excess enthalpy in the heated layer ahead of the combustion wave. The behavior of the leading point is a most important characteristic in the description of mechanisms of formation and propagation of all kinds of spin combustion waves.

For example, a condition for the formation of a spin detonation front is ignition of the gas at the leading point that forms when a transverse compression wave merges with the shock front [1], which ensures the maximum temperature in accordance with four gas detonation mechanisms. The first is the mechanism of normal propagation with mixture ignition behind the shock wave. The second is the reflective mechanism underlying reflections of the shock wave from irregularities on the chamber walls. The third is the convective mechanism associated with the transition of the combustion zone in accordance with the velocity profile maximum and not with the ignition due to adiabatic gas compression; the maximum gas velocity added to the normal flame propagation velocity equals the shock wave velocity. The fourth is the spontaneous gradient mechanism arising from the spatial distribution of the gas ignition lag time.

Each of the governing mechanisms is realized depending on the concrete boundary conditions for combustion wave propagation, and the physical and kinetic properties of the combustible gas medium determined by the exponent E/RT, where E is the activation energy of the chemical reaction, T is the temperature behind the shock wave, and R is the universal gas constant. The aggregate action of the four gas detonation mechanisms is responsible for the four regimes of detonation wave propagation, one of which is spin detonation spiraling along circular tube walls [7].

Similarly, propagation of the combustion center in an SHS system depends on the position of the leading point in the hottest layer along the combustion wave front [3]. Recently elaborated mathematical models clearly demonstrate the dependence of spin wave propagation patterns in an SHS system on external conditions. The author of [12] used a numerical method to study the spin wave propagation with a single combustion center through a cylindrical sample with an axial internal channel. The thermal losses from the inner and outer surfaces of the sample were assumed to be absent. The characteristics of the spin wave (maximum temperature, longitudinal and circumferential speed, 'screw' pitch, and revolution time of the center around the sample axis) vary with the channel radius.

The authors of [13] proposed a three-dimensional mathematical model of filtration combustion whose front propagates through a cylindrical sample compacted from a solid powder reactant and embedded within an oxidizer. They investigated spin wave characteristics depending on the gas pressure around the sample. It was shown that the behavior of stationary and nonstationary spin waves is governed by the leading point, i.e., the point of maximum temperature. Specifically, stationary surface combustion waves propagate through the sample at low pressures, while spin waves propagate at higher pressures, their characteristics varying nonmonotonically with pressure.

It was shown in [14] that the spin regime of powder system burning may be due to the capillary redistribution of the low-melting component at the combustion wave scale, which ensures additional heat and mass transfer. The leading point trajectory and spin foci geometry are given by the shape of the melt filtration front under nonisothermal conditions.

The authors of [4] argue that in the case of a gas-phase reaction above the liquid fuel surface, the leading point is located where local burning conditions are optimal, as determined by the geometry of the metal supports that accumulate combustion heat.

The aforementioned studies [1–4, 7, 12] demonstrated the possibility of several leading points, which accounts for the formation of multi-head spin in both gas detonation and condensed fuel burning. Specific conditions for the formation of one or several leading points at the flame front are created for the slow burning of gas mixtures in narrow channels. The possibility of a simultaneous formation of two fronts of a chemical reaction was considered in a study of nonstationary burning of a gas in a straight tube and in the gap between two disks in the case of radial fuel feeding with a temperature gradient in the wall [15]. In either case, the characteristic transverse size of the channel was smaller than the critical diameter at ambient temperature, and the gas burned in the zone where the wall temperature was higher than the ambient temperature. One front corresponded to a normal flame propagating upward from the hot to cold part of the channel, while the other moved with the flow and died out as the fuel burnt away.

The authors of [16], in the framework of the diffusional-thermal two-component model, predicted — and thereafter proved in experiment — the existence of two fronts of a gas combustion reaction in a narrow channel with heated walls. They showed that the formation of flame leading points and the separation of combustion wave fronts may be complex processes, even in combustion chambers of the simplest geometric shape. The authors of [16] carried out experiments with the use of high-speed videofilming and demonstrated the possibility of three reaction peaks and two divisions of the combustion wave in a propane–air system within a single periodic ignition/extinction cycle. This finding suggests the formation of several leading points at the chemical reaction front.

An external feature of spin front formation emphasized in [1–6, 12–14] is that their trajectories coincide with the leading point trajectories. They are shaped as flat, crescent, or helical spirals with a constant or variable pitch at the surfaces bounding the combustion zone.

3. The formation of the spin flame front during propagation in a gas mixture with a low Reynolds number

The analysis of characteristic dimensions determining heat and diffusion fluxes, i.e., possible directions of the leading point of the flame front, allowed determining the geometry of the combustion chamber in which the spin regime of the limiting propane–air mixture is realized. The characteristic thermal width of the flame front l_1, the width of the diffusion zone of gas mixture components l_2, and the thickness of the boundary layer l_3 were estimated from the relations

$$l_1 \approx \frac{a}{u_n}, \quad l_2 \approx \frac{D}{u_n}, \quad l_3 \approx \sqrt{\frac{\nu L}{u_n}}, \tag{1}$$

where a is the thermal conductance coefficient of the gas, u_n is the normal flame propagation velocity, D is the diffusion coefficient, ν is the kinematic viscosity coefficient, and L is the largest characteristic size of the combustion chamber. Parameter dimensions in relations (1) define two dimensionless similarity criteria: the Lewis number $\mathrm{Le} = D/a$ and the Peclet number $\mathrm{Pe} = u_f l/a$, where u_f is the visible front propagation velocity and l is the slot width.

The order of magnitude of characteristic dimensions l_1, l_2, and l_3 depends on that of diffusion and kinematic viscosity coefficients and of the normal flame propagation velocity in hydrocarbon–air mixtures at atmospheric pressure. At $L \approx 1$ m, $l_1 = l_2 \approx 1 \times 10^{-3}$ m and $l_3 \approx 4 \times 10^{-3}$ m. If $l = (2-6) \times 10^{-3}$ m, the slot width is limiting for stationary flame propagation. At $l < 2.0 \times 10^{-3}$ m, the flame becomes extinct. The wall effect significantly decreases at $l > 6 \times 10^{-3}$ m. Thus, the orders of magnitude of characteristic dimensions l_1, l_2, l_3, and L indicate the simplest shape of the combustion chamber in which the choice of more than one leading point — and therefore of different trajectories of their motion — is possible. The half-width of the gap between the surfaces must not be much greater (in orders of magnitude) than the length of the gas heating zone ahead of the flame front (roughly 10^{-3} m). The order of magnitude of the minimal size of the combustion chamber gave rise to the term ‘combustion microchamber,’ widely used in the literature.

The heat-conducting walls of a ‘microslot’ affect the diffusional-thermal instability of the flame. Moreover, flame front stability depends on the stability of a radially expanding flow of combustion products. The loss of stability of the radial flow is one of the factors governing local distributions of temperature and concentration of the combustible gas. The location of zones with maximum temperature and a quasi-stoichiometric composition of the gas mixture makes one or several leading points shift toward them along the cylindrical flame front.

A natural cause of radial flow instability is the widening of streamlines. The requirement for fulfillment of the mass conservation law results in the appearance of a transverse component (with respect to the radius) of the flow velocity vector, hydrodynamic expansion of the flame front, and alteration of temperature in separate parts of the front surface.

The effects of the radial flow instability of a combustible gas between two flat disks on flame dynamics were studied in [19]. The authors analyzed the stability of solutions for energy and diffusion equations describing flame propagation in a cylindrical coordinate system. The results indicate that a radial gas flow is stable only at low or high velocities, regardless of the radius size. The range of velocities at which the radial flow is unstable increases as the Peclet number decreases. This means that in a narrow slot and at a minimal velocity of flame propagation, the gas begins to rotate in the channel plane. The authors of [19] demonstrated the possibility of obtaining a stable flame in a narrow velocity interval at the boundaries of the unstable gas flow region.

It was experimentally shown in [17, 18] that narrowing the slot to the critical width approximately equal to 2.5×10^{-3} m leads to the absolute diffusional-thermal instability of the symmetric cylindrical front. The flame front is unstable over the entire range of gas mixture concentrations, from the lower to the upper concentration limit of ignition. The ignition of the gas mixture is immediately followed by cell-like perturbations of the flame front. In a narrow range of low propagation velocities of the flame front corresponding to the limiting compositions of gas mixtures, only two of all the perturbations ‘survive’ to give rise to two combustion centers or spin nuclei propagating along symmetric spiral trajectories in the slot plane.

Figure 1 shows snippets of a video illustrating the typical picture of spin flame front formation and evolution in the case of combustion of a propane–air mixture in a horizontal slot under excess air conditions. It can be seen that arc-shaped ‘whiskers’ extend from the spin nuclei, apparently in association with instantaneous distributions of nonstationary temperature, concentration, and velocity fields and the geometric locus in which the flame front can propagate after ignition in the spin nucleus. Spin nuclei move along Archimedean spirals that turn into logarithmic spirals as the slot width increases, because the normal flame propagation velocity increases as heat release from the combustion zone into the chamber walls decreases.

Variations of external conditions for the formation of local distributions of the above physical parameters lead to a change in the trajectories and speeds of the leading points, the length and shape of the whiskers. An example of the gravity effect on the position of a leading point during flame front propagation in a horizontal tube is considered in [11]. We find the Froude number $\mathrm{Fr} = u_f^2/(gl)$ (g is the acceleration of gravity) to elucidate the role of gravitational forces in the formation of nonuniform velocity, temperature, and concentration distributions in a vertical slot. Measurements made in [17, 18] indicate that the mean flame front propagation velocity is $u_f \approx 10^{-1}$ m s^{-1}. Therefore, $\mathrm{Fr} \approx 1$, which suggests a marked gravity effect leading to free convection.

Figure 2 illustrates typical propagation of the spin flame front through a combustible gas mixture of the same composition in a vertical slot. Worth mentioning is the significant decrease in the size of the spin nucleus and the curvature radius of the leading point trajectory in the vertical slot. The decrease in the curvature radius of a whisker and the angular velocity of the spin nucleus results from a change in

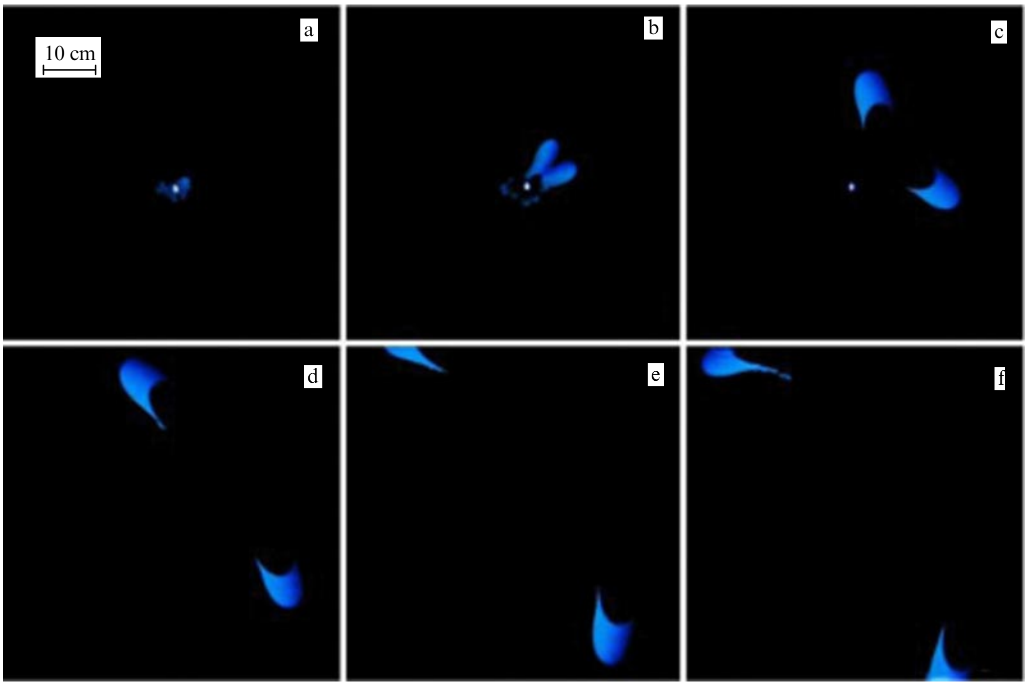

Figure 1. (a–f) Snippets of a video: photographs of the luminous flame front at different time instants illustrating the rotation of two spin nuclei and the formation of whiskers in a horizontal slot. A mixture of 3.0% C_3H_8 and 97.0% air.

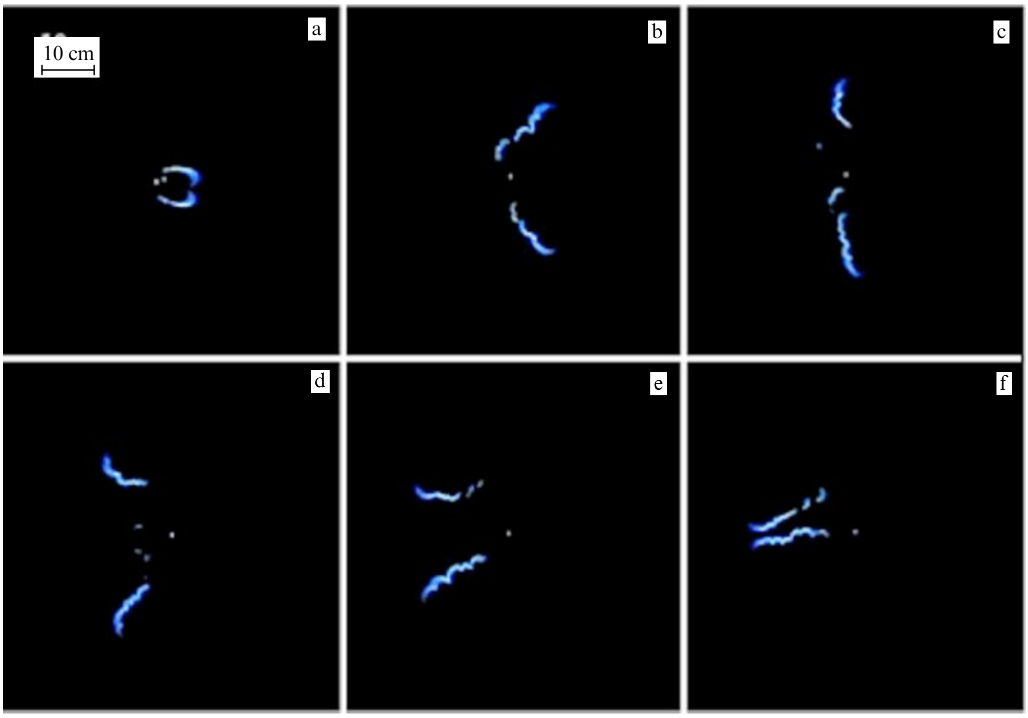

Figure 2. (a–f) Snippets of a video: photographs of the luminous flame front at different time instants illustrating the rotation of two spin nuclei and the formation of whiskers in a vertical slot. A mixture of 3.0% C_3H_8 and 97.0% air.

the shape of the spin nucleus and its position relative to the whisker.

The gas flow near the spin flame front is essentially inhomogeneous. It consists of vortex motion initiated by a temperature jump in the combustion zone and tangential motion due to the flame front curvature. Figure 3 presents a photograph magnified several times to show a whisker curled into a screw surface under the effect of vortical gas motion in the flame front. The screw pitch increases and the diameter decreases with the distance from the leading point in the spin nucleus. This can be accounted for by an increase in the hydrodynamic expansion rate of the flame front in conjunction with a decrease in the gas rotation speed attributable to the decreased flame temperature.

Figure 3. Screw structure of a whisker being drawn out of a spin nucleus.

4. The influence of critical conditions of diffusion and heat release

It follows from [17, 18] that the primary cause of spin nucleus formation in a slow gas–air flame is the absolute diffusional-thermal instability developing under the effect of closely positioned slot walls. The diffusional-thermal instability evolves in a narrow slot not only due to the difference between the diffusion and heat conduction coefficients of the missing component but also because the resulting directions of the heat and diffusion fluxes are not parallel to each other. The substance diffuses normally to the slot cross section, whereas the heat loss from the combustion zone is perpendicular to the slot walls. A decrease in the slot width affects the relation between the heat and diffusion fluxes, such that heat release from the flame zone increases while diffusion of the missing component of the gas mixture decreases. As is known from [20], the mean diffusion distance of a molecule in a symmetric problem is given by

$$\bar{r} = \sqrt{6Dt}\,, \tag{2}$$

where $t = l_1/u_n \approx 10^{-3} - 10^{-2}$ s is the chemical conversion time in the combustion zone. Substituting $D \approx 3 \times 10^{-4}$ m^2 s^{-1}s, we arrive at $\bar{r} \approx (1-4) \times 10^{-3}$ m. Evidently, the mean distance covered by a molecule traveling from the fresh combustible mixture to the combustion zone may be either smaller or greater than the critical slot width at which the spin nucleus begins to form, depending on the composition of the gas mixture. This means that the diffusion flux diverges near the curved flame front. In such a case, diffusion occurs under critical conditions; that is, the diffusion flux density may take an extreme value as the slot width changes.

We choose a coordinate system in which the x axis passes along the slot through its center and the y axis is perpendicular to the walls. The origin lies on the flame front surface. Assuming the source of diffusion to be pointlike, we express the diffusion flux density near the flame front as

$$\Phi = \frac{I}{r^2}\cos\alpha\,,$$

where I is the diffusion flux per unit solid angle, r is the distance from the source to the chosen element of the flame surface, and α is the angle between the direction of the diffusion flux and the normal to the surface element. We express the distance and the cosine of the angle in terms of the source coordinates x and y, whence

$$\Phi = \frac{Ix}{(x^2 + y^2/4)^{3/2}}\,.$$

In this expression, y ranges from 0 to l, while the mean diffusion distance $\bar{r}$ sets the scale for the coordinate x. We find the derivative of $\Phi(x)$ and equate it to zero. It follows that the diffusion flux density reaches a maximum value at $x = y/\sqrt{8}$. The critical condition for the diffusion flow density in scale units of length is $\bar{r} = l/\sqrt{8} \approx 10^{-3}$ m. Here, $l = 2.0 \times 10^{-3}$ m corresponds to the gap width used in [17, 18]. A comparison of this value with the estimates obtained from relation (2) shows that they coincide and correspond to the critical ones for the diffusion process.

We consider the critical conditions for heat release to elucidate their role in the formation of the leading point and spin nucleus during the propagation of the perturbed flame front in a narrow slot.

The estimate of an absolute change in the flame temperature follows from the solution of the heat balance equation for heat exchange between a gas layer and the slot walls:

$$\chi(T - T_w) = \frac{c_p \rho_b l}{2}\frac{dT}{dt}\,, \tag{3}$$

where χ is the heat release coefficient, T and T_w are the flame temperature at a given instant and the constant temperature of the combustion chamber walls, c_p is the specific heat capacity of combustion products at constant pressure, and ρ_b is the combustion product density. The initial condition for Eqn (3) is given by $T = T_{max}$ at $t = 0$, where T_{max} is the maximum flame temperature at the onset of heat transfer. The integration of (3) and calculation of the integration constant lead to

$$T - T_w = (T_{max} - T_w)\exp\left(-\frac{2\chi t}{c_p \rho_b l}\right). \tag{4}$$

The substitution of spin nucleus formation time $t \approx 0.15-0.20$ s experimentally found from frame-by-frame viewing the videofilm in (4) and the assumption $T_{max} \approx 1200$ K give the current flame temperature $T \approx 1100$ K. A drop in the flame temperature due to heat transfer onto the slot walls is $T - T_{max} \approx 100$ K. The heat transfer rate increases with increasing the contact area between the cellular flame front and the wall. Therefore, small cells disappear as a result of rapid gas cooling over a relatively large surface, and the spin nucleus forms from large-scale perturbations.

We derive an expression for the instability criterion at which the rate of heat transfer from the flame zone to the walls of a narrow infinite slot due to heat conduction is higher than the heat release rate. For this, following [20], we use the heat balance equation in the form

$$\lambda\frac{d^2T}{dx^2} + QW(T) = 0\,, \tag{5}$$

where λ is the heat transfer coefficient of the gas, Q is the thermal effect of the reaction, $W(T)$ is the combustion reaction rate, and x is the coordinate perpendicular to the slot wall. Using the Frank-Kamenetskii transformation, the chemical reaction rate can be represented as

$W(T)=W(T_b)\exp(\Delta T/\theta)$, where $\Delta T=T-T_b$, $\theta=RT_b^2/E$, and T and T_b are the respective current temperature and combustion temperature. Integration of Eqn (5) with the boundary conditions $T=T_w$ at $x=l/2$ and $T=T_b$ at $x=0$ gives the criterion for the appearance of thermal instability in the form

$$\frac{l^2 EQW(T_w)}{RT_b^2} = 4e^2\lambda\,, \tag{6}$$

where T_w is the temperature of the slot wall. It follows from (6) that thermal instability is largely determined by the temperature of the walls and the distance between them. To compute the characteristic slot width l at which combustion instability develops as a result of heat losses through conduction, we substitute the approximate values of its constituent components in (6): $E\approx 4\times 10^3$ J mol^{-1}, $Q\approx 36.6\times 10^9$ J m^{-3}, $W\approx 4\times 10^{-4}$ kg m^{-3} s^{-1}, $R\approx 8.3$ J mol^{-1} K^{-1}, and $T_b\approx 1200$ K. Then $l\approx 1.3\times 10^{-3}$ m. The resulting value agrees with the data in [17, 18] with a relative error of 5% and corresponds to exactly half the width of the slot at which the spin nucleus forms.

The instability of heat transfer in a horizontal slot due to thermal conductivity is worsened by the simultaneously developing Benard convection, the critical condition of which is determined by the minimal value of the Rayleigh number [21]

$$\mathrm{Ra}_{\min} = \frac{g\beta(T_b - T_w)(l/2)^3}{va} \approx 1708\,,$$

where β is the thermal expansion coefficient, v is the kinematic viscosity coefficient, and a is the heat conduction coefficient. For the experimental conditions described in [17, 18], $\mathrm{Ra}_{\min}\approx 1700$.

A comparison of the experimental data in [17, 18] with the above estimates indicates that the spin flame front forms under the near-critical conditions for heat exchange and diffusion.

5. The potential of modern experimental methods for the investigation of the spin flame front

The formation of the spin flame front during combustion of limiting gas mixtures is a physical phenomenon whose study started only quite recently. The processes governing heat and mass exchange, as well as kinetics of chemical reactions, require an in-depth investigation with the use of up-to-date diagnostic and measuring techniques.

Modern software tools for processing digital images allow obtaining photometric pictures of glowing flame fronts in the visible wavelength range. Photometric images are efficient and very convenient for the study of critical thermal phenomena associated with the flame front propagation. Each of them is a set of isolines of the resultant energetic luminosity. Once the Stefan–Boltzmann law of thermal black-body radiation is fulfilled, the photometric image of the flame front can be used for high-precision calculation of instantaneous spatial temperature distributions.

We used the digital photometric technique to measure temperature at different points of the flame front immediately after the ignition of the gas mixture in a narrow slot. It turned out that the temperatures of the adjacent front portions separated by the distance $5l-10l\approx 5\times 10^{-3}-1\times 10^{-2}$ m differ by 50–100 K. Similar results were obtained using a thermovision camera. A drop in temperature corresponds to the flame temperature sensitivity $E(T_a-T_b)/(2RT_a^2) > 10^{-1}-10^{-2}$. Here, T_a is the adiabatic combustion temperature, T_b is the flame temperature, and E is the activation energy. Elevation of the critical threshold of temperature sensitivity leads, according to [11], to the quenching of certain flame portions.

The combination of digital photometry and high-speed filming allows studying the dependence of the flame front cooling rate on the tangential speed of elementary front parts and estimating the role of hydrodynamic expansion in the mechanism of spin nucleus formation.

Helical gas rotation in the spin flame front under the effect of hydrodynamic expansion changes the residence time of an elementary volume of the reacting mixture. The residence time determines the kinetics of intermediate reactions of chemical conversion and the composition of combustion end products. Additional data can be obtained using the laser-induced fluorescence technique.

The discovery of spin propagation of a gas–air flame in narrow channels necessitates research on the regulation of spin combustion regimes, such as

— elucidation of the regularities of alterations of kinematics of spin front propagation depending on variations of the channel width and shape and the gas mixture composition;

— estimation of the possibility of simultaneous formation of more than two spin nuclei;

— investigation of the influence of obstacles on the formation of the spin nucleus;

— investigation of the effects of external body forces, e.g. gravity and acoustic vibrations of the gas column in a microchannel;

— investigation of spin flame front disruption resulting in the formation of a few dozen small combustion centers.

These issues are of great scientific interest and have important practical implications.

6. Conclusion

It follows from experimental data that a decrease in the slot width to a critical value leads to the absolute hydrodynamic instability of the laminar flame front manifested in the combustion of gas mixtures from the lower to the upper flammability concentration limit. The trajectories of spin nuclei formed in a narrow range of flame propagation speeds determine the kinematics of spin flame front propagation. Spin propagation of the gas–air flame in a narrow slot is accompanied by structurally nonuniform vortex motion of the gas.

Previous estimates indicate that the critical phenomena of diffusion and heat release from the combustion zone into the chamber walls constitute the physical mechanisms governing the spin flame front formation.

A combustion chamber in the form of an infinite slot ensures the formation of the simplest spin flame front propagating along the surfaces bounding the gas motion. It can be expected that the use of combustion chambers with complex wall surfaces (the surfaces of coaxially positioned cylindrical tubes, channels with variable cross section, etc.) will make it possible to obtain a greater variety of spin flame front shapes.

Investigations of the patterns of spin flame front propagation and the governing mechanisms of combustion by modern diagnostic and measurement methods will provide a basis for new technology applications.

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