UDC 662.611:535

DETERMINATION OF SPECTRAL DEPENDENCE OF SOLID BLENDED FUEL TORCH SYSTEM RADIATING ABILITY

M. Yu. Trofimenko, Yu. A. Nitsuk, T. F. Smaglenko, L. I. Riabchuk

I. I. Mechnikov Odesa National University,
Dvoryanskaya Str., 2, Odesa, 65082,
E-mail: nitsuk@mail.ru, Tel. 723-62-27

DETERMINATION OF SOLID BLENDED FUEL TORCH SYSTEM RADIATING ABILITY SPECTRAL DEPENDENCE

M. Yu. Trofimenko, Yu. A. Nitsuk, T. F. Smaglenko, L. I. Riabchuk

Abstract. Multichannel optical pyrometer is described. Temperature measurement and emissivity definition methods are presented. Role of dispersed condensed phase of exterior torch layers is discussed.

Keywords: burning, radiating ability, temperature, condensed phase, flame

ВИЗНАЧЕННЯ СПЕКТРАЛЬНОЇ ЗАЛЕЖНОСТІ ВЕЛИЧИНИ ВИПРОМІНЮВАЛЬНОЇ ЗДАТНОСТІ ФАКЕЛА ТВЕРДОЇ СУМІШНОЇ СИСТЕМИ

М. Ю. Трофименко, Ю. А. Ніцук, Т. Ф. Смагленко, Л. І. Рябчук

Анотація. Описано багатоканальний оптичний пірометр, який виготовлено авторами, і методики визначення з його допомогою температури та випромінювальної здатності на різних довжинах хвиль полум'я. Звертається увага на роль концентрації дисперсної фази зовнішніх шарів факела при визначенні температури і випромінювальної здатності полум'я.

Ключові слова: горіння, випромінювальна здатність, температура, конденсована фаза, полум'я

ОПРЕДЕЛЕНИЕ СПЕКТРАЛЬНОЙ ЗАВИСИМОСТИ ВЕЛИЧИНЫ ИЗЛУЧАТЕЛЬНОЙ СПОСОБНОСТИ ФАКЕЛА ТВЕРДОЙ СМЕСЕВОЙ СИСТЕМЫ

М. Ю. Трофименко, Ю. А. Ницук, Т. Ф. Смагленко, Л. И. Рябчук

Аннотация. Описан многоканальний оптический пирометр, который изготовлен авторами, и методики определения с его помощью температуры и излучательной способности пламени на разных длинах волн. Показана роль концентрации дисперсной фазы внешних слоев факела при определении температуры и излучательной способности факела.

Ключевые слова: горение, излучательная способность, температура, конденсированная фаза, пламя

Introduction

The original multi-channel optical pyrometer, developed by authors, and the methods of temperature and irradiating ability of a flame determination at different wavelengths have been discussed. It is necessary to pay attention to the concentration of disperse condensed phase of outer layers of flame during the determination of temperature and irradiation ability of the flame.

The existing experimental data of coefficient of flame irradiation ability ε were obtained for metal oxides or carbon parts [1-3]. In early papers [4] for solid blended systems (SBS) flames based on per-chlorate ammonia the ε values were detected for local fields of torch experimentally $(2\cdot 0.3)mm^2$ at pressures of (4-6) MPa in the region of spectra about (1-1.8) micrometers.

The use possibility of the SBS for welding doping and obtaining of light sources with determined parameters was the important reason to detect the ε of full torch (or their extended parts) as well as to determinate the flame brightness at the flame temperatures. The measuring regions of working temperatures for those SBS are in 2000-3000 K. The major part of emitted energy of the torch is placed in the wave region of less then 1 μm.

The spectra of SBS to be investigated at pressures of 4 MPa and more have a continual character [9] and consist of two components. The first component is the emission of burning particles of initial SBS and condensed products of their burning (K-phase). Second component is the irradiation of gas phase which is the enveloping curve of the molecular strips (in case of small spectral discrimination of the measuring device) of their electron-rotating structure, the intersection and self-reversal of different strips at high density of burning products.

Sometimes the SBS emission spectra at pressure of 0.6 MPa except of continual irradiation of the flame may be presented the lines and strips specific to some elements or compounds placed in torch. This fact can due to the increasing of probability of entering the one of working wave of the pyrometer to this line, and, hence, the violation the "gray" condition (ε = const) for flame emission. Analyzing of registered flame emission at full number of wavelengths as it is possible in experiment, may sufficiently reduce these measurement errors.

Hence, in order to increase the accuracy of measurement according to [4] it is necessary to enlarge the spectral region of ε, and quantity of working wavelength of the pyrometer and it would be necessary to have a possibility to register the emission of torch part.

Besides, the serial pyrometers which satisfied the previously mentioned conditions, multichannel and large scope in noted spectral region are not manufactured.

So, it is necessary to produce the multichannel pyrometer and measuring temperatures and ε of extended parts of optically solid torch. (Optical solid torch contains the "K-phaze" in a quantity that makes it non-transparent for own irradiation of flame reflected by outer mirror).

The temperature region of flames to be investigated are $(2\div4)\cdot10^3$ K. Maxima of energy are placed in (0.8÷1.5) μm according to Wien displacement law. Moreover, the interesting spectra region of (0.4-0.8) μm because of methodologic error while measuring the brightness temperature is low that in the region of (0.8-1.5) μm.

We produced the 7-channel optical pyrometer with scope of ≈8°. Working wavelengths for registration are determined by changeable interference filters of $\lambda_1 = 0.589$ μm, $\lambda_2 = 0.621$ μm, $\lambda_3=0.766$ μm, $\lambda_4=1.165$ μm, $\lambda_5 = 1.37$ μm, $\lambda_6 = 1.55$ μm, $\lambda_7 =1.8$ μm. We have measured the 7 brightness temperatures, color temperature by spectral dots of continual spectra and as well the color temperatures by two spectral dots. During the same experiment, we calculated the emissive ability ε for optical solid flames in seven dots. The value of relative device error of color temperature in this region of spectra not has not exceeded $\Delta T_я/T_я\cdot100\ \%=1.75\ \%$ [10].

The burning of SBS samples based on ammonia perchlorate reaction with elastic polyacrylates binded with doping of spherical aluminum powder ASD — 1, (dispersion of grains is 16 mm) have been investigated. The burning of samples of 20 mm, height — 20 mm was investigated at pressures of 0.6 MPa in the set of constant pressures (SCP) in nitrogen atmosphere. In order to provide the flat (by layers) burning, the side was sealed by TSIATIM grease.

The outer window of SCP has the round diaphragm diameter of 2.5mm. As far as combustion of standard flame passes through a diaphragm light from more remote of the flat surface of burning samples of flame's area. Building the graph of dependence $\ln b_\lambda\cdot\lambda^5=f(1/\lambda)$ for five wave-lengths from the area of continual spectrum, find the interesting us temperature of initial area (diameter of 2.5 mm) of flame in the set of torch section.

In composition, the explored standards of SBS metals sodium and potassium are present. The sensitiveness of the applied method is such that the lines of radiation are due to the technological admixtures of sodium and potassium, registered by our device through channels with wave-lengths $\lambda_2 = 0.621$μm and $\lambda_3 = 0.766$ μm, accordingly. Values ε in the proper spectral points, the radiation of the indicated metals occasionally approached the value of 0.85. Temperatures of brightness, found at such values of ε near to the color temperatures of distribution. Thus, the possibility of comparison of results appears got in the conditions of the experiment (T_{col}=2250 K; T_b=2205 K).

In the case, when a metal (for example, B) is entered into the explored composition for the improvement of burning parameters of the radiation of products of combustion of metal, it is possible to draw conclusion about his role in the process of burning (start, intensity and the end of reaction with its participation).

Measurement was conducted using the method described in [5]. The offered method, as specified higher, settles in the same experiment simultaneously to define a temperature and estimate the value of a flame radiating ability. The formula for calculation of ε for wavelength λ is shown below:

$$\varepsilon = \frac{e^{\frac{c_2}{\lambda T_i}} - 1}{e^{\frac{c_2}{\lambda T_b}} - 1},$$

here $c_2 = 1.4388 \cdot 10^4$ µm·K — second constant of irradiation at Plank's law, T_b—brightness temperature for wavelength λ, T_i is T_{col} detected for according local-extended parts of the flame.

Measurement of ε was conducted in the spatial areas of torch near to the area, where the maximal values of temperature of flame are achieved and, in our case, maximal values of size of integral radiation. Dependence ε on a wave-length took low-reduced character with multiplying a wave-length (see at Fig.1). The absolute value of a radiating ability for this wavelength (ε_λ) depends on the site of investigated area in a torch [6]. It is stated that dispersion of K-phase and its concentration (in particular in the external cold layer of flame) is different along a torch. Indicated absolute values ε $(1 \div 4) \cdot 10^{-1}$ and motion of dependence ε_λ at a change λ, characteristic as for P = 0.6 MPa, so for P = 0.1 MPa. Advancing pressure up to P = 1.4 MPa type of dependence ε from λ remains as formerly, and the absolute values diminish up to $(2 \div 6) \cdot 10^{-3}$.

With respect to potassium and sodium, it was found by us in the same experiment, the radiate ability is proper to their lines in flame being higher, than in the nearby areas of continuous spectrum. Thus, as far as moving of measured area toward the top of torch there is at first an increase ε (e.g. the intensification increase of the reaction with metals participation) transition of the curve 1 to the curve 2, then fading of reaction (curve 2-5). It is explained, that the admixtures of sodium and potassium are contained in initial composition as connections and appearance of their lines in the spectrum of radiation talks about decomposition of these connections, freeing of the indicated metals and their readiness to react.

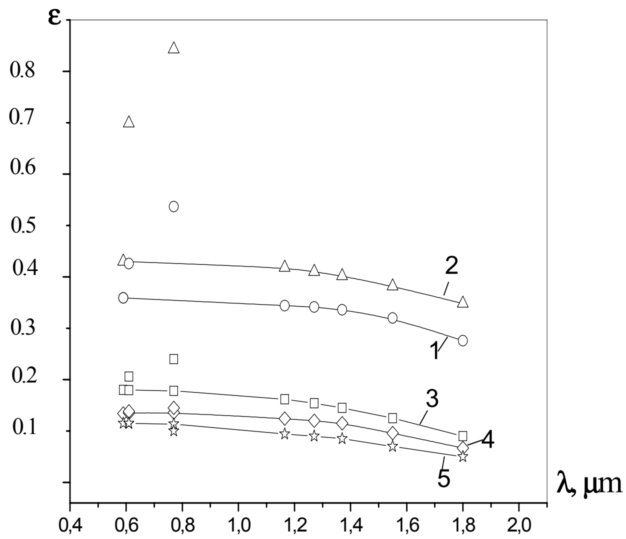

Fig. 1. Spectra dependence of ε for the STS-flame at pressure P = 0.6 MPa.

Numbers of curves are growing accordingly to the distance between the object and sample's flat end. 1 — T = 2220 K; 2 — T = 2250 K; 3 — T = 2914 K; 4 — T = 2742 K; 5 — T = 2417 K.

It is necessary to mark the complicated structure of SBS torch [4,6], consisting of hot radiative central part and more cold external area from the considerable concentration of particles of K–phase. As the influence of the particles is specified in the paper [7], the influence of K — phase particles on the form of distribution ε on wave-lengths can be deciding, and a change dispersion of particles of K-phase change ε in short-wave and long-wave parts of spectrum differently.

That in the conditions when size of particles of d of the condensed phase (appearing particles of not reacted carbon and being in flame, reactive particles of initial SBS) of d ≈ λ, the ε depends on a change λ slightly, the insignificant change of d (advancement is higher on a torch, change of pressure, blowing, reserving, technologically entered additive in the complement of standard) could change both inclination of the got curve and its form (increasing dependence could become decreasing).

At comparison of papers [4, 6] statements, where measurement of ε conducted at pressure of P = 4 MPa and 6 MPa and the present work (P = 0.6 MPa and 1.4 MPa), it is necessary to mark as the general conformities of ε law conduct and the differences. To general conformities to the law behavior detail that with the increase of pressure in both cases, the absolute value of ε diminishes, and the principal reason of it, being as we get the increase of concentration of K-phase and change its dispersion in a torch.

The size of absolute value of a radiate ability depends on a location in the torch of measured area, terms of burning of standard and formation of K-phase.

So in [6] the terms of combustion SBS in SCP at 4 MPa is such, that in the overhead area of torch more homogeneous distributing of temperatures is achieved on the diameter of torch, the concentration of particles of K-phase is less. All of it results in diminishing of radiation dispersion influence of hot kernel in more cold layers of torch.

In the real experiment and, in particular, the measurement ε conducted in area of torch, where the maximal values of size of optical radiation of flame and maximal values of his temperature are achieved. At P = 0.6 MPa, this area could be sufficiently extensive, with the large difference of temperatures between central and external parts of torch. After passing the area of maximal temperature (higher on a torch) intensity of radiation of flame not immediately diminishes and it results in active education and accumulation in the torch of K-phase, that causes its large concentration and small sizes of particles. All of the results, in multiplying the influence of radiation dispersion and diminishing of value ε as far as advancement of the explored area upwards at the torch area of maximal temperature. Detailed information about the spatial distributing of temperatures and change of structure of torch SBS presented in paper [9], K-phase flames SBS on the basis of ammonium perchlorate, presented in [8].

To provide the needed values, the complicated calculation was done, if the task decided in general, and the experimental methods of information receipt are so important on the size and frequency dependence ε in every case.

Conclusions:

The experimental results' discussion have shown that:

1. The original optical pyrometer gives the possibility to extend the spectral region of optical descriptions (parameters) of flame measurement.

2. The offered method lets us to determine the absolute values ε and distribution ε on wave-lengths in different parts of torch at decompressed from the locally extensive (∅ 2.5 mm) areas of flame with the same precision of the temperature measurement.

3. Presence of large number of working wave-lengths in the original optical pyrometer enables to involve part of them for registration of radiation in lines characteristic for a reaction with certain elements or connections (the potassium and sodium in our case), and to conclude about their role in burning and to specify a place in a torch, where their influence is maximal, specifying the same the mechanism of burning SBS.

4. The experimental results specify the complex structure of torch HUSH and considerable role of K-phase (dispersion and concentration) at optical description of flame determination.

5. Size of absolute value of a radiate ability ε depends on a concentration and dispersion of K-phase and area of maximal change ε observed on wave-lengths near to the sizes dispersive particles of K-phase of external layer of torch.

References

1. Belinskiy N. M., Skogarev V. G., Florko A. V. Radiative Characteristics of Magnesium and Aluminium Oxides at the Temperatures of Burning// Physics of Aerodispersive Systems (in Russian). — 1986. — Odesa: № 30. — P. 97-99.
2. Olson O. H., Morris J. Handbook of Thermophysical Properties of Solid Materials, N. Y., Pergamon Press. — 1961. — V. 3.
3. Bloh A. G., Zhuravlyov Yu. A., Ryzhkov L. N. Thermal Exchange with Radiation. Energoatomizdat. — Moskva. — 1991. — 431p.
4. Trofimenko M. Yu., Chesnokov M. N., Smaglenko T. F. Changes of Radiative Ability of the Solid Mixture Systems Torch in Dependence on the Pressure // Physics of Aerodispersive Systems (in Russian). — 2002. — Odesa: № 39. — P. 95-99.
5. Trofimenko M. Yu. Studies of the Solid Mixture Systems Burning with the Use of the Optical Methods /Proceedings of XXI International Pyrometrical Seminar. Moskva, Russia. — 1995. — P. 884-890.
6. Trofimenko M. Yu., Chesnokov M. N., Smaglenko T. F. Measurement of the Radiative Ability of the Optically Dense Flames of the Solid Mixture Fuel Systems. // Physics of Aerodispersive Systems (in Russian). — № 38, Odesa. — 2001. — P. 106-111.
7. Ilchenko E. P., Florko A. V. The Influence of the Gaseous Mixture Parameters on its Optical and Radiative Abilities (heterogeneous burning). / Reports

of the XX Scientific Conference of former USSR countries “Dispersive systems”. — Odesa. — September 2002. — P. 118-119.

8. Chesnokov M. N. Creation Dynamics and Physical Characteristics of the Condensed Dispersive Phase in Low-Temperature Plasma of the Model Aluminized Fuels. Dissertation of the Doctor of Science Degree in Physics. – Odesa. — 1986.
9. Trofimenko M. Yu. Peculiarities of the Flame of Solid Mixture Systems Structure Based on the Ammonia Perchlorates. Dissertation of the Kandidate of Science Degree in Physics. — Odesa. — 1999.
10. Trofimenko M. Yu. Evaluation of the Mixture System Flame Temperature on the Local Fluctuations of the Brightness in Torch // Physics of Aerodispersive Systems (in Russian). Odesa. №35. — P. 38-45.