

creases with increase in oxidizer concentration. Thus, increase in n_{OX} from 0.23 to 0.35 produces growth from $\delta_{\gamma'} = 730$ to $\delta_{\gamma'} = 2200 \mu\text{m}$. The degeneration diameter $\delta_{\gamma'}$ increases with decrease in wall temperature.

Thus, it has been shown that consideration of radiant heat loss leads to qualitatively and quantitatively new principles in heterogeneous ignition, extinction, combustion, and degeneration conditions for coarse particles.

NOTATION

Q_c , surface heat liberation power due to chemical reaction, $J/(\text{m}^2 \cdot \text{sec})$; Q_t , net thermal flux density of molecular convective Q_{mc} and radiant Q_r sources, $J/(\text{m}^2 \cdot \text{sec})$; δ , particle diameter, m ; t , time, sec ; T_1, T_2, T_w , temperature of particle, gas, and chamber wall, K ; ρ_1, ρ_2 , density of particle and gaseous medium, kg/m^3 ; c_1, c_2 , specific heat of particle and gas, $J/(\text{kg} \cdot \text{K})$; Ω , stoichiometric coefficient; Nu , Nusselt number; λ_2, D , gas thermal conductivity and diffusion coefficients, $W/(\text{m} \cdot \text{K})$, $\text{m}^2 \cdot \text{sec}$; q , thermal effect of chemical reaction, J/kg ; n_{OX} , relative mass concentration of oxidizer in gas mixture; E , activation energy, J/mol ; R , universal gas constant $J/(\text{mol} \cdot \text{K})$; k_0 , pre-exponential factor, m/sec ; $\rho_{20}, \lambda_{20}, D_0$, gas density, thermal conductivity and diffusion coefficients at temperature T_0 ; ϵ , emissivity; σ , Stefan-Boltzmann constant, $W/(\text{m}^2 \cdot \text{K}^4)$; α, β , heat and mass transport coefficients, $W/(\text{m}^2 \cdot \text{K})$, m/sec . Subscripts: 1, particle; 2, gas; i, ignition; e, extinction; eq, equilibrium; cr, critical; c, combustion; m, maximum; γ , degenerate; c, limiting.

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DEFLAGRATION OF TITANIUM IN OXYGEN FOR VARIOUS RATES OF EXPOSURE OF JUVENILE METAL SURFACE

V. I. Bolobov, K. M. Makarov,
and A. A. Prokof'ev

UDC 669.295;620.193

We present the results of an experimental study of the process of deflagration of titanium VT1-0 samples during fracture in oxygen at various pressures. We propose an empirical equation, which describes the critical deflagration pressure of the samples as a function of the exposure rate of juvenile metal surface.

It is known [1-5] that a necessary condition for deflagration of titanium constructions in oxygen-containing media at normal temperatures is the emergence of juvenile (freshly exposed) metal surface. At the same time, the question of the rate at which juvenile surface must be formed for this process to occur has not been sufficiently studied. So, for example, [5] merely points out that titanium alloys deflagrate only when fracture of the structure takes place "rapidly"; "slowly" developing fracture does not lead to deflagration. Data from [2] indicates that the rate of uniaxial elongation of samples during their failure in oxygen does not significantly influence the critical deflagration pressure P_{cr} of titanium α alloys. (These experiments were carried out in the range of clamp displacements of $V = 0.017$ - $2.3 \text{mm}/\text{sec}$). In this case, the value of P_{cr} depends essentially on the geometrical dimensions

State Institute of Applied Chemistry, St. Petersburg. Translated from Inzhenerno-Fizicheskii Zhurnal, Vol. 62, No. 3, pp. 443-445, March, 1992. Original article submitted March 1, 1991.

TABLE 1. Emergence Rate of Juvenile Metal Surface and Critical Deflagration Pressure for Titanium Samples in Oxygen

Governing parameter	Samples with two-sided notches: thickness δ , mm				Samples with one-sided notches: thickness δ , mm		
	2	0.05	0.09	0.025	0.025	0.05	0.09
V_s	1600	130	105	17	9	1.5	0.13
P_{cr}	2.5	3.5	7.0	8.0	8.0	9.0	10.00

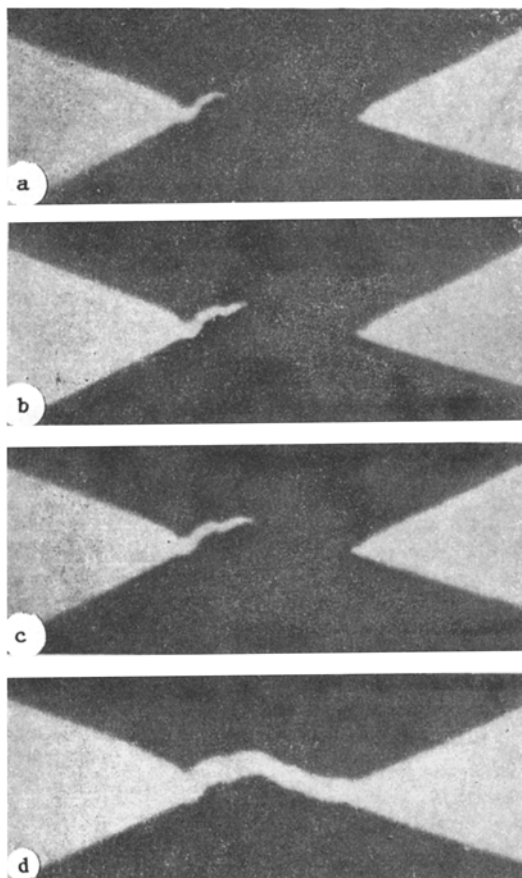


Fig. 1. Photographs of crack development in a titanium sample during sample elongation ($\times 10$, two-sided notch). Time $t = 9$ corresponds to the instant of crack formation: a) $t = 3.000$ sec; b) 3.210 sec; c) 3.318 sec; d) 3.319 sec.

(thickness) of the fracturing samples. It decreases (at room temperature) with increasing sample cross-sectional area. The goal of our work is to attempt to establish the quantitative dependence of the critical deflagration pressure of titanium sample of different cross sections on the rate of exposure of juvenile metal surface.

Flat samples (40×10 mm) of foils and plates of technical titanium VT1-0 of thickness $\delta = 0.025, 0.050, 0.090, 2.0$ mm served as experimental subjects. These were subjected to uniaxial elongation ($V = 0.17$ mm/sec) until fracture in an oxygen medium at a prescribed pressure. Different exposure rates of juvenile metal surface were obtained by incising special notches 3 mm long on one or both sides of the middle of the sample. At a single pressure, 3-5 samples of a given cross-section and notch configuration were fractured. To determine the critical deflagration pressure, samples of each form were subjected to the minimum pressure of oxygen at which a burn center was observed on the fracture surface after specimen failure. The determination of P_{cr} was carried out through successive pressure increments in steps of 0.5 MPa.

The rate V_s of exposure of juvenile surface was estimated according to the linear velocity \bar{V}_l of crack propagation in the sample. (The crack forms at the vertex of the notch.) To determine \bar{V}_l , titanium samples like those used to determine P_{cr} , were subjected to fail-

ure in oxygen, and the failure process was photographed (framing camera SKS-1M, 1500 frames/sec). For each sample, we constructed the increment in the length of the crack as a function of time by using the results of data processed from the photographs (see Fig. 1). From this we determined the maximum velocity V_{ℓ} of crack propagation, which was used in subsequent calculations.

The estimate of V_s was done according to:

$$V_s \simeq \bar{V}_{\ell} \delta, \quad (1)$$

where \bar{V}_{ℓ} is the arithmetic mean of the values V_{ℓ} , established according to the results of photographs of the failure process for 3-5 samples of the given thickness and notch configuration. (The scatter in the values of V_{ℓ} for samples of one form reached 120%.)

As is obvious from Table 1, the values of V_s and P_{cr} for the samples vary significantly, depending on sample thickness and notch configuration. A clear dependence is traced between the values of these parameters: with decreasing rate of exposure of juvenile metal surface, the critical deflagration pressure of the samples grows. To a first approximation, this dependence can be expressed in the empirical form

$$P_{cr} = \ln(B/V_s)^n, \quad (2)$$

where $B \approx 2.3 \cdot 10^4$; $n \approx 0.93$.

We can comment on the relation established between P_{cr} and V_s in the following way. During failure of titanium samples in oxygen, the newly formed, as yet oxygen-film-free surface is subjected to intensive oxidation, with the generation of a significant quantity of heat. In this case, the oxidation rate and as a consequence, the rate of incoming heat flow, is a function of the oxygen pressure [4]. In the case of relatively slow failure and insufficient high pressure, the heat of the oxidation reaction moves out to the surrounding "cold" zone of the sample. As a consequence, the reacting surface is not subjected to any significant heating. For a sufficiently high exposure rate of juvenile surface and an oxygen pressure corresponding to (2), the introduction of heat into the reaction zone consistently begins to exceed heat removal, the surface temperature reaches the melting point of the metal, and the sample deflagrates [4]. Since the exposure rate of juvenile surface depends on the cross-sectional area of the sample and the notch configuration (see Table 1), the critical deflagration pressure of the titanium alloys also depends on these factors.

Thus, as follows from the results of our work, the present interconnection between the configuration of the titanium samples undergoing failure and their critical deflagration pressure in oxygen can be explained by the difference in the rates at which juvenile metal surface is exposed during sample failure.

CONCLUSIONS

1. We determined the critical deflagration pressure for titanium samples of various form during failure in oxygen. For like samples, we estimated the exposure rate of juvenile metal surface using the results of photographs of crack propagation during failure.

2. We proposed an empirical equation which describes the critical deflagration pressure of titanium samples during failure in oxygen, as a function of the rate of exposure of juvenile metal surface.

3. We suggested that this dependence of the critical deflagration pressure on sample configuration can be explained by the difference in the rates of exposure of juvenile metal surface during the failure of the titanium samples in oxygen.

NOTATION

δ , sample thickness, mm; V , rate of displacement of the clamps of the failure machine, mm/sec; V_s , rate of exposure of juvenile surface in the metal, mm²/sec; V_{ℓ} , maximum propagation rate of failure cracks, mm/sec; \bar{V}_{ℓ} , mean value of V_{ℓ} for samples of a given form, mm/sec; P_{cr} , critical deflagration pressure of titanium samples of a given form, MPa; B and n , constants.

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METHOD FOR MEASURING THE INTEGRAL RADIATION, TRANSMISSION,
AND REFLECTION COEFFICIENTS FOR SELECTIVE TRANSLUSCENT MATERIALS

G. K. Kholopov

UDC 535.3

An account is given of the main conclusions and results of testing a method for the determination of the integral radiative properties of materials.

The development of many segments of the national economy (machine building, power industry, construction industry, etc.) requires the use of new materials not only with desired mechanical, electrical, and thermal properties but also with known optical properties. It is impossible to obtain such materials without controlling optical production parameters both at the production stage and during operation as parts of products or structures. In turn, a highly efficient control and measurement instrument cannot be created without refining measurement methods.

The (spectrally) integrated radiation, transmission, and reflection coefficients of materials are among the most important opticophysical quantities characterizing the material properties that are to be measured or controlled. The goal of the present report is to validate a new method of measurement of the named integral coefficients which is applicable to spectrally selective translucent materials at moderate, close to normal, temperatures.

The optical methods and instruments for the measurement of radiation (or absorption), transmission, and reflection coefficients of translucent light-diffusing materials at high [1, 2], medium, and reduced [3-5] temperatures are known. Thus, according to [4], a plane sample of a material thermally stabilized at temperature T_2 is placed in an isothermal chamber which simulates a blackbody cavity at a temperature $T_1 \neq T_2$ and, using a photodetection system (PDS), the irradiances of chamber wall L_1 and of sample L_{11} on top of the chamber background are measured. Next, a blackbody at temperature T_2 is placed behind the sample and the irradiance of sample L_{12} is measured on top of the blackbody background. After removing the sample the irradiance of the blackbody L_2 is measured. These results determine the quantities

$$\varepsilon = (L_{11} - L_1)/(L_2 - L_1), \quad (1)$$

$$\varepsilon + \tau = (L_{12} - L_1)/(L_2 - L_1). \quad (2)$$

Method [4] has a limitation related to its applicability for only carrying out spectral measurements and to the impossibility (or to large errors) of measurements of the integral quantities ε , τ , and ρ for spectrally selective materials. The latter is a consequence of the temperature dependence of these integral quantities. Thus, due to the different relative spectral irradiance blackbody distributions at temperatures T_1 and T_2 , $L(\lambda, T_1)/T_1^4 \neq L(\lambda, T_2)/T_2^4$ even if the spectral coefficients are temperature independent:

$$\begin{aligned} \varepsilon(\lambda, T_1) &= \varepsilon(\lambda, T_2) = \varepsilon(\lambda), \\ \tau(\lambda, T_1) &= \tau(\lambda, T_2) = \tau(\lambda), \\ \rho(\lambda, T_1) &= \rho(\lambda, T_2) = \rho(\lambda) \end{aligned} \quad (3)$$

so that the following inequalities hold true:

$$\varepsilon(T_1) \neq \varepsilon(T_2), \quad \tau(T_1) \neq \tau(T_2), \quad \rho(T_1) \neq \rho(T_2). \quad (4)$$

Translated from *Inzhenerno-Fizicheskii Zhurnal*, Vol. 62, No. 3, pp. 446-452, March, 1992.
Original article submitted May 12, 1991.