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Effect of prescription configuration on properties nanothermite composition Bi_2O_3/Al/1Me-3H

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X International Voevodsky conference «Physics and chemistry of elementary chemical processes»

5-9 September 2022
Novosibirsk

NANOTHERMITE

Me_1O/Me_2

e.g.: Fe_2O_3/Al, CuO/Al, MoO_3/Al etc.

Peculiar properties:

- High sensitives to mechanical and electrical influences, which are at the sensitivity level initiating explosive;
- Low critical parameters of combustion performance – burn in thin layer (0.1 mm and below), initiation in microgram quantities;
- The burn rates nanothermites can vary from cm/s to hundreds of m/s, regulated by prescription and technological parameters.

Application:

- initiation systems;
- fast-burning compound;
- MEMS pyrotechnics.

MATERIALS AND PREPARATION OF NANOTHERMITE COMPOSITES

Bi_2O_3 (Sigma Aldrich, USA), a mean particle size of 90-210 nm, main component contain 99.8 %

Al (Advanced Powder Technologies LLC, Russia), a mean particle size of 90-150 nm with 85 % active aluminum

1-Methyl-3-nitro-1,2,4-triazole (**1Me-3H**) insensitive high-energy compound with empirical formula $C_3H_4N_4O_2$, enthalpy of formation ΔH = 1.42 kJ/g, melting temperature $T_m \approx$ 65 °C, and decomposition temperature $T_d \approx$ 240-250 °C.

Preparation nanothermite composites:

- Pre-insertion processing of the components: preliminary deagglomeration of nanopowders, preparation of suspension of the additive in organic solvent (acetone)
- Ultrasonic intermixing of the powders in the suspension of the additive
- Suspension drying
- Grinding of the pyrotechnic mass beneath the layer of the volatile liquid that is not a solvent or plasticizer for a additive (hexane)
- Vacuum-assisted drying of the suspension to obtain a composite representing powdered agglomerated particles of the target composition

METHODS

- The thermodynamic parameters of combustion of nanothermite composites (heat *Q*, combustion products pressure *P*) were calculated using the REAL software package. Conditions of adiabatic combustion of a nanothermite charge were simulated in a confined space.
- Relative explosion force *F* (%) was determined by measuring the amplitude of the signal recorded by an oscillograph when the sample was initiated in a stain gauge sensor (fig. 1). For 100 % of magnitude *F* (basic level) corresponds to the explosion of the nanothermite pair Bi_2O_3/Al.
- The burning rate was determined by the ionization method using two configurations of charges: tube (fig. 2) and thin layer (fig. 3)

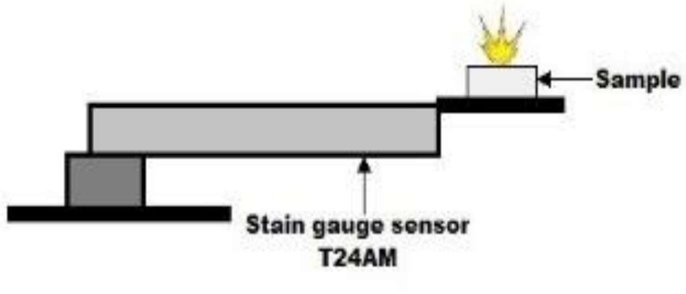

Fig. 1 – Test scheme for determining explosion force

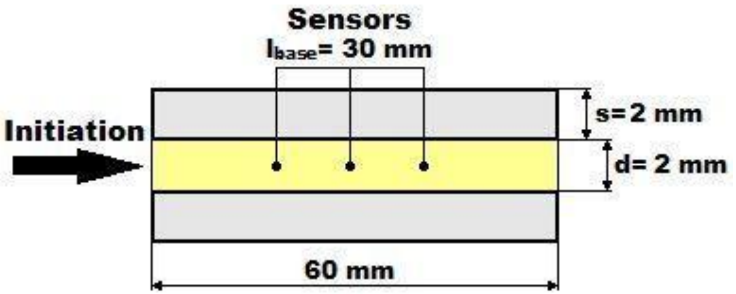

Fig. 2 – Test scheme for determining the burn rate in the tube

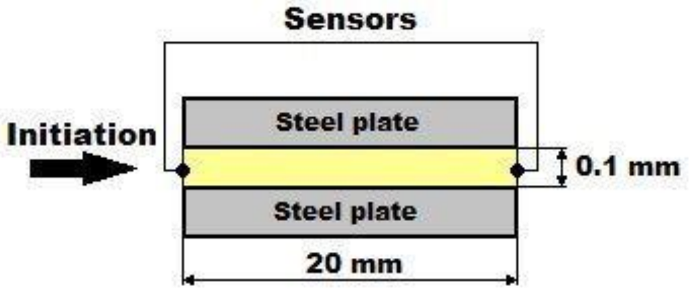

Fig. 3 – Test scheme for determining the burn rate in the thin layer

PRESCRIPTION CONFIGURATION

Configuration I – the ratio of the components of the mixture corresponded to the maximum calculated heat of explosion of the composition (*Q*) at a given content of 1Me-3H.

Configuration II – the ratio of the components of the mixture corresponded to the maximum calculated pressure value (*P*) developed during combustion composition in a closed volume.

Configuration III – the ratio of the components of the base nanothermite pair Bi_2O_3/Al (88/12%), corresponding to the maximum calculated value of *Q* and remained constant in the mixture.

Configuration IV – the ratio of nanothermite components of the base nanothermite pair Bi_2O_3/Al (86/14%), corresponding to the maximum calculated value of *P* and remained constant in the mixture.

RELATIVE EXPLOSION FORCE OF THE COMPOSITION Bi_2O_3/Al/1Me-3H

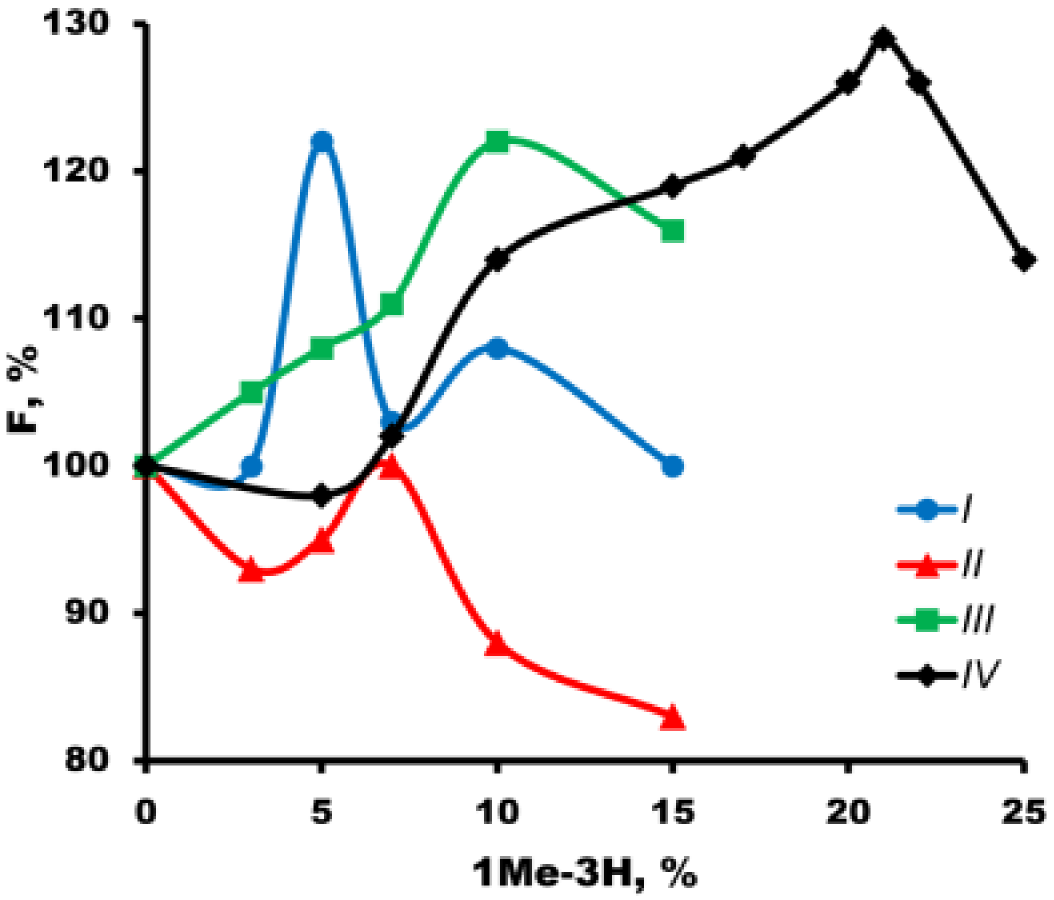

Fig. 4 - Relative explosion force *F* at different contents of additives

Configuration I, III, IV are characterized by the extreme nature of the dependence *F* on the content 1Me-3H.

Maximum *F* is observed at the following concentrations 1Me-3H:

Configuration I – 5 % 1Me-3H – *F* = 122 %;

Configuration III – 10 % 1Me-3H – *F* = 122 %;

Configuration IV – 21 % 1Me-3H – *F* = 129 %.

In the case configuration II, with a content of 1Me-3H – 3, 5 %, there is a decrease in *F* to 93, 95 %. When the additive content is 7 %, the explosion force returns to the level of the base nanothermic mixture.

BURNING RATES NANOTHERMITE COMPOSITION Bi_2O_3/Al/1Me-3H

	Component ratio, %	Density, % TMD	Burning rate, m/s	
			tube	layer
Bi_2O_3/Al	**88/12**	**31**	**380–480**	**210–280**
	86/14	28	400–500	250–300
Configuration I Bi_2O_3/Al/1Me-3H	**77/18/5**	**35**	**400–500**	**270–320**
	57/28/15	**25**	**430–530**	**250–300**
Configuration II Bi_2O_3/Al/1Me-3H	83/10/7	36	410–510	150–200
	77/8/15	36	440–540	120–170
Configuration III Bi_2O_3/Al/1Me-3H	**79/11/10**	**39**	**450–550**	**170–220**
	75/10/15	**37**	**530–630**	**270–320**
Configuration IV Bi_2O_3/Al/1Me-3H	68/11/21	37	590–690	190–250
	73/12/15	37	570–670	380–430

Tube – the burning rate of the nanothermite composition tends to increase in the following sequence II<I<III<IV.

Thin layer– in the case of the ratio of the components of the mixture with max *F*, the tendency to increase the burn rate in the following row II<III<IV<I. For compositions with a content of 1Me-3H – 15%, there is a tendency to increase burn rate in sequence II<I<III<IV.

PHOTOS OF TUBES AFTER MEASURING THE BURN RATE

Fig. 5 – The appearance of the shells after burn rate measurement

As a result of the combustion composition Bi_2O_3/Al/1Me-3H the visually estimated degree of destruction of the shell changes in the following order I≤II<III<IV, which allows us to talk about an increase in the «efficiency» of the nanothermic composition when changing the prescription configuration.

CONCLUSION

1. A significant influence of the prescription configuration of the triple system Bi_2O_3/Al/1Me-3H on its combustion performance has been established.
2. Concentrations of 1Me-3H have been identified at which the maximum values of the explosion force are achieved with various compounding arrangements of the nanothermite composition Bi_2O_3/Al/1Me-3H: I – 122 % by 5 % 1Me-3H; III – 122 % by 10 % 1Me-3H; IV – 129 % by 21 % 1Me-3H. In the case of configuration II, the explosion force of the composition does not increase, only when the additive content is 7%, the *F* value remains at the level of the base mixture.
3. When changing the prescription configuration, there is a tendency to increase the burning rate of the nanothermic composition in the following sequence II<I<III<IV. The maximum values of the burning rate of the composition are characteristic of the configuration IV – 590-690 m/s in tube and 380-430 m/s in thin layer.

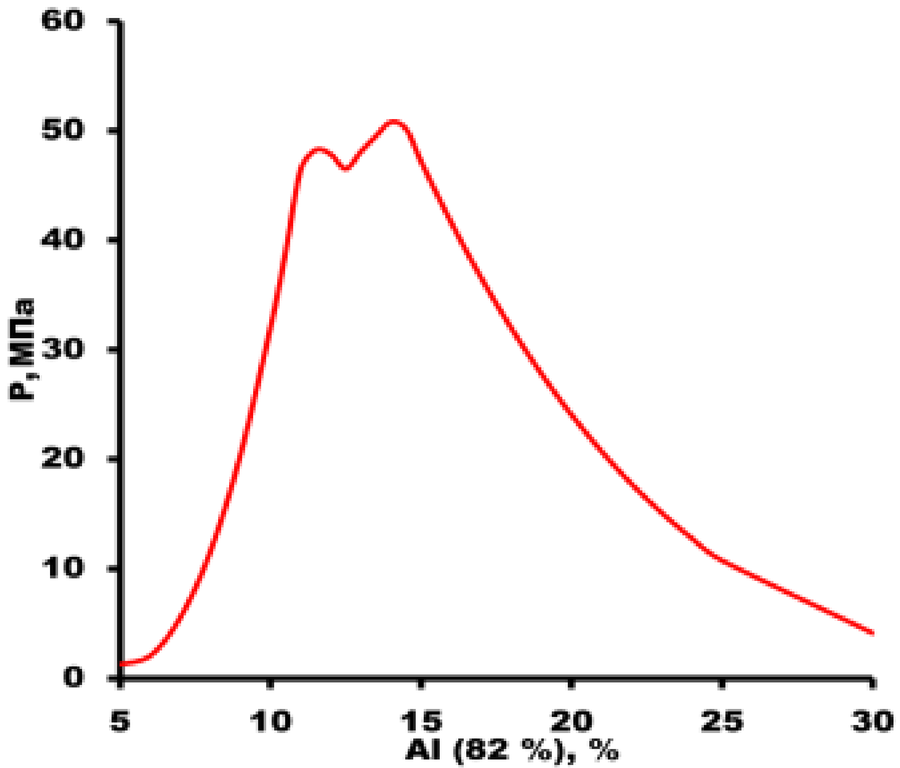

Fig. 6 – Dependence of the calculated pressure of the Bi_2O_3/Al nanothermite mixture on the Al content

When the aluminum content in the nanothermite mixture is 12-13%, a pressure drop is observed, in the case of configuration I (7 % 1Me-3H) and II (3, 5 % 1Me-3H), the ratio of the nanothermite pair in the composition Bi_2O_3/Al/1Me-3H falls into this area, which leads to a sharp decrease in the explosion force.