EFFECT OF THE PHYSICAL STATE OF THE ACTIVATORS ON THE COMBUSTION OF COMPOSITE ROCKET PROPELLANTS.

I. THE APPLIED CATALYSTS.

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UDC 536.46

The effects on the burning and thermal decomposition of composite rocket propellants, based on ammonium perchlorate and butyl rubber, of oxide coated catalysts applied to the surface of the ammonium perchlorate crystals and introduced into the propellant in the form of a colloidal suspension are investigated. It is shown that the possibility of changing the burning rate by means of applying the catalyst on the oxidizer crystal surface is determined by the chemical nature, the content of the compounds deposited on the oxidizer surface, and by the structure of the coating formed on the ammonium perchlorate surface. Excluding the agglomeration of the catalytic additives using the developed methods, the variation in their dispersivity and the nature of localization in the propellant are the indicators of the propellant’s performance efficiency within the region of small additive concentrations (up to 0.5%) in the propellant.

The present work is the first in a series of articles dedicated to the investigation of the effect of the activator’s physical state on the burning of composite rocket propellants (CRP). Here, the activator’s physical state is to be understood as its state of aggregation, the particle shape, and the localization nature in the propellant and in the combustion zone.

In the present paper we generalize the results of the investigation of the effect on the burning and the thermolysis of the CRP of the oxide catalysts applied to the surface of the ammonium perchlorate crystals and introduced into the propellant in the form of a colloidal suspension.

It should be noted that some aspects of the effects of the CRP dispersivity and of the specific surfaces of the oxidizers and catalytic additives on combustion had been considered in [1-4]; however, their results do not allow to draw any definitive conclusions. Thus, according to the data of [1], upon being applied to the surface of the oxidizer crystals, the effectiveness of the ferrocene-containing catalytic additives did not change. The results of [2] also indicate that the effect of the specific surface of the oxide catalysts on the burning of CRP is not great. At the same time, according to [3], the burning rate of composite propellants depends significantly on the specific surfaces both of the catalyst and of the oxidizer. An analysis of the effect on the burning of the rocket propellant porosity and of the particle dispersity of the ammonium perchlorate has shown [4] that the propellant burning rate increases with oxidizer porosity and with decreasing particle size.

Methodology of the Experiment

The iron and chromium oxides were applied to the surface of the ammonium perchlorate (APC) crystals by a pyrolysis of the vapors of the acetyl acetones of the pertinent metals, passing for a 10 min period through an oxidizer layer at a 230-250°C temperature. The iron oxide (II, III) was made in accordance with [5].

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Fig. 1. Variation of the effectiveness of the applied (1) and powdered (2) oxides and RS (3) with the additive content in the propellant.

Fig. 2. Variations of the relative activity of Cr_2O_3 (1), Fe_3O_4 (2) and Fe_2O_3 (3) upon application on the surface of ammonium perchlorate crystals.

The catalytic activity of the investigated additives was determined from the effect on the combustion of unhardened model propellant composites (α = 0.30) containing APC and butyl rubber and was characterized by the ratio of the combustion rates of the catalyzed and noncatalyzed CRP (Z = U_{cat}/U_0).

The thermal decomposition of the CRP was studied by the differential scanning calorimetry method using a DSC-1B calorimeter in a helium atmosphere at a 8 K/min heating rate. Tin and indium were used as the standards in the determination of the thermal CRP decomposition effects. The investigation of the composition and structure of the applied catalysts was accomplished by the methods of electron microscopy, electron diffractometry and Mössbauer spectroscopy.

The Mössbauer spectra were recorded using an electrodynamic type apparatus operating in the constant acceleration regime at room temperature and the liquid nitrogen temperature. The Co^{57} isotope in the chrome matrix was used as the source of the γ-quanta. The rate scale was calibrated with metallic iron.

The electron microscopic and microdiffraction investigations were performed with a UÉMV-100M electron microscope.

Experimental Results

Catalytic Activity. It follows from Fig. 1 that the characteristic feature of the applied catalysts is the fact that the most significant rise in the combustion rate is observed in the region of small concentrations (c ≤ 0.2-0.3%). With increasing additive content its effectiveness either does not change (chrome oxide), or decreases (iron oxide).

A comparison of the activities of the applied catalysts and the powdered iron oxide obtained by the calcination of the pertinent hydroxide has shown that in the investigated concentration interval the applied additives are by 15-30% more active than the powdered. The differences are the greatest in the region of small concentrations.