Advanced lifetime prediction: advantage of simultaneous application of non-isothermal DSC and HFC data

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ABSTRACT

The rate of the processes leading property changes of high energetic materials during storage depends on (i) the external factors such as geometry, storage temperature, thermal insulation and (ii) the intrinsic properties of the materials such as e.g. kinetic parameters of the decomposition processes. A sound knowledge of the temperature dependence of the decomposition rate is required in recently applied test procedures for the prediction of safe storage and service life of high energetic materials. In the STANAG 4582 test based on heat flow microcalorimetry (HFC) the value of the activation energy used for the prediction of the properties of propellants is assumed to be 80 kJ/mol below 60°C and 120 kJ/mol above 60°C. The presented study contains the results of the evaluation of the kinetics of the decomposition of six propellants: two small calibre types P 3616 Ws (5.56 mm, single base); P 3620 Ws (5.56 mm, EI®) and four medium calibre types FM 3170/21 (23 mm, single base); FM 3031s (25 mm, EI®); VM 0696/102s (30 mm, EI++) and VM 0700/101s (30 mm, EI++). The high temperature experiments were carried out on conventional DSC apparatus in the sealed crucibles with heating rates of 0.25-4 °C/min in the temperature range RT-260°C. The low-temperature isothermal microcalorimetric investigations were done with Thermal Activity Monitor (TAM), Thermometric AB, in the range of 60-100°C. The results of DSC and HFC measurements allowed the determination of the decomposition kinetics based on differential isoconversional method of Friedman. Obtained kinetic parameters can be used for the prediction of the thermal behaviour of the energetic materials under any, arbitrarily chosen, temperature profiles [1-3]. The evaluation of the kinetics of the propellants decomposition by DSC clearly indicated the significant change of the kinetic parameters (activation energy E and pre-exponential factor A in Arrhenius equation) during the decomposition course. These changes are especially significant at low values of the reaction progress between 0-5% of the total decomposition i.e. in the range being very important for the prediction of the service life time. In order to gain better knowledge on kinetic description of the early stage of the decomposition the kinetic parameters were also calculated from the HFC results for the decomposition range 0-2%. The comparison of the kinetic parameters obtained by advanced kinetic evaluation (differential isoconversional analysis) of both, DSC and HFC data, and calculated by some conventional methods (i.e. ASTM, or assumption of the reaction order) and their influence on the prediction of the thermal stability of the propellants will be presented and discussed.

1. Advanced Kinetics and Technology Solutions: http://www.akts.com (AKTS-Thermokinetics software and AKTS-Thermal Safety software).
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