SAND2016-3759C

Comprehensive Chemical and Material Analysis of TKP and TH_xKP Pyrotechnic Powders to improve Pyrotechnic Degradation and Performance Models

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Pyrotechnic performance modeling and simulation efforts are underway at Sandia National Laboratories (NM). Pyrotechnic performance is largely influenced by the propensity of a material to develop a critical ignition kernel suitable for transition to sustained combustion. Parallel efforts studying ignition thresholds of titanium potassium perchlorate (TKP) and titanium sub-hydride potassium perchlorate (TH_xKP) powder compacts have yielded results as a function of heating rate and scale. Experiments and a global diffusion-limited kinetics model spanning several orders of magnitude ($10^{-2} – 10^{1}$ grams) linearly heated at rates between 1 – 10^0C/min have been completed using a full- and quarter-scale ignition apparatus.[1,2]

The performance modeling work was supported by DSC tests at small scale (small pressed pellets of ~10^{-3} grams) linearly heated at rates between 1 – 150^0C/min. The powder compacts for all three test apparatuses were at initial nominal densities of 82% TMD and any decomposition gases were allowed to vent during heating. Two different types of TKP were tested which differed in terms of the titanium particle characteristics, most notably the surface roughness. Related work involves better understanding how TKP and TH_xKP age and degrade over time. To support all of these efforts, a mature chemical and materials analysis framework has been implemented to provide chemical and morphological information and aging trends for these powders.

Currently, pyrotechnic powders are mainly analyzed for their thermal, safety, and performance properties.[3,4] However, the chemical and morphological properties of these powders is also important because they may correlate with powder performance behavior, especially as a function of feedstock material quality and powder age. It is also necessary to assure that all aspects of the explosive train inside pyrotechnic components remain functional. This includes the interfaces of the bridgewire to the powder and the interfaces over which the deflagration must transition. In the event that changes are observed, it is the objective of the mature chemical and materials analysis framework to assess how those changes affect the performance of the pyrotechnic component, if at all.

Recent and current work characterizing TKP and TH_xKP will be presented. Specifically, recent data will be presented on characterizing pyrotechnic powders by optical microscopy, scanning electron microscopy (SEM), ion chromatography (IC), and micro-computed tomography (microCT). The results of this work provide a broad and in-depth picture of a powder's chemical and material properties which can then be used to establish trends with regard to age and performance and to support modeling of pyrotechnic performance.

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2. Erikson, W. W., M. L. Hobbs, M. A. Cooper, and M. S. Oliver (2011). Modeling the Ignition Thresholds of Titanium Subhydride Potassium Perchlorate (THKP) Pyrotechnics. In: *Joint Army-NASA-Air Force (JANNAF) 44th Combustion Subcommittee Meeting*. April 18-22. SAND2011-2708C (OUO-ECI). Arlington, VA.
3. Sorensen, D.N., et al., *Investigation of the thermal degradation of the aged pyrotechnic titanium hydride/potassiumperchlorate*. Journal of Thermal Analysis and Calorimetry, 2006. **85**(1): p. 151-156.
4. Bauer, A.J.R., *Analysis of Pyrotechnic Components: Results of chemical, thermal, and mechanical insult testing of components of four fireworks samples*, 2013, U.S. Chemical Safety Board: Washington D.C.