[23] Method for determining the tensile properties of solid rocket propellants[M]. CPIA Publish SPIA, 1957: 8.
[24] 赖建伟. 固体推进剂药柱低温力学性能与结构完整性研究[D]. 西安: 火箭军工程大学, 2013.
LAI Jian-wei. Research on mechanical properties and structural integrity of solid propellant grain at low temperature [D]. Xi′an: Xi′an Hi-Tech Institute, 2013.
[25] 张晓军, 常新龙, 赖建伟, 等. HTPB推进剂低温拉伸/压缩力学性能对比[J]. 固体火箭技术, 2013, 36(6): 771-774.
ZHANG Xiao-jun, CHANG Xin-long, LAI Jian-wei, et al. Comparative research of tensile and compressive mechanical properties of HTPB propellant at low temperature[J]. *Journal of Solid Rocket Technology*, 2013, 36(6): 771-774.
[26] 张兴高. HTPB推进剂贮存老化特性及寿命预估研究[D]. 长沙: 国防科学技术大学, 2009.
ZHANG Xing-gao. Study on the aging properties and storage life prediction of HTPB propellant[D]. Changsha: National University of Defense Technology, 2009.
[27] Nevie`re R. An extension of the time-temperature superposition principle to non-linear viscoelastic solids[J]. *International Journal of Solids and Structures*, 2006, 43(17): 5295-5306.
[28] 侯林法. 复合固体推进剂[M]. 北京: 中国宇航出版社, 2009: 382-383.
HOU Lin-fa. Composite solid propellant[M]. Beijing: China Astronautic Publishing House, 2009: 382-383.

Failure Criteria of Three-component HTPB Composite Solid Propellant at Low Temperature Under Dynamic Loading

QIANG Hong-fu, WANG Zhe-jun, WANG Guang, GENG Biao
(*Xi′an Hi-Tech Institute, Xi′an* 710025, *China*)

Abstract: Based on uniaxial and quasi-biaxial tensile tests and microscopic damage observation experiments of three-component Hydroxyl-Terminated Polybutadience (HTPB) composite solid propellant at different thermal accelerated aging time (0, 32, 74, 98 d), temperatures (−50, −40, −30, −20, 25 ℃) and strain rates (0.40, 4.00, 14.29, 42.86, 63 s^{-1}), the effects of loading conditions on the initial elastic modulus, strength and the corresponding strain have been analyzed. Moreover, failure criteria of the propellant under the tests have been determined. It has been indicated that HTPB propellant fails more easily due to tensile stress under dynamic uniaxial loading, and the thermal aging can further reduce this capability. Thus the strain at maximum tensile stress can be considered as the uniaxial failure criterion. In addition, tensile-compressive strength ratio can better reflect the different properties of the propellants under dynamic uniaxial loading. This value is 0.4 and 0.2−0.3 at room temperature and low temperatures, respectively. The strain at maximum tensile stress of HTPB propellant under quasi-biaxial tension is significantly lower than that in uniaxial tension. Furthermore, the extent of reduction increases with extended aging time and decreased temperature. The proportion for unaged and aged propellants is 60%−85% and 40%−60%, respectively. Finally, this strain is independent of stress state and strain rate at the lower temperature and higher strain rates. Thus the strain at maximum tensile stress under dynamic biaxial tension can be considered as the failure criterion of HTPB propellant. It can also be used to analyze the structure integrity of propellant grains for tactical missiles during ignition of solid rocket motor (SRM). Moreover, its value can be determined with the master curves and aging models.

Key words: Hydroxyl-Terminated Polybutadience (HTPB) propellant; failure criteria; low temperature; dynamic loading; thermal accelerated aging
CLC number: TJ55; V512 **Document code:** A **DOI:** 10.11943/CJEM2018340
(责编:张 琪)

读者·作者·编者

《含能材料》“含能共晶”征稿

含能共晶是不同含能分子通过氢键等相互作用力形成的具有稳定结构和性能的分子晶体。含能共晶充分组合了单质含能分子的优点,呈现出感度低,综合性能优良的特点,具有潜在的应用前景,共晶研究已经引起国内外含能材料学界的高度关注。为推动含能共晶的研究和交流,本刊特推出“含能共晶”专栏,主要征稿范围包括含能共晶晶体设计与性能预测、含能共晶的制备、结构解析、性能等。来稿请注明“含能共晶”专栏。

《含能材料》编辑部