Analysis and Modeling of the UL-94V Test

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The UL-94 Vertical Burning test (UL-94V) is a frequently used bench scale test to qualitatively understand a material's susceptibility to vertical flame spread. The test consists of subjecting a small polymeric bar specimen to a Bunsen-burner-type flame for 10 s and recording the time the sample remains aflame. The capability of existing models to simulate UL-94V tests is lacking. Additionally, measurements characterizing the UL-94V test, especially of the flame heat flux, have been limited and have had large discrepancies. Thus, this work sought to carefully characterize the boundary conditions of the UL-94V test and to develop an improved model of the UL-94V test. A modified UL-94V apparatus was constructed to provide additional diagnostics of burner heat flux, burner flame temperature, flame heat flux, and visual flame height. UL-94V tests were conducted using poly(methyl methacrylate) (PMMA). Heat fluxes were measured with a water-cooled heat flux gauge at multiple positions relative to the bottom of a sample. Two-dimensional simulations of the UL-94V test were performed using a numerical pyrolysis solver, ThermaKin2Ds. Boundary conditions for the burner were derived from the measurements while boundary conditions for the flame were based on previously developed models for flame height and flame heat feedback of laminar wall flames on several polymers; the flame heat feedback model was scaled according to this work's flame heat flux measurements on PMMA. The decomposition kinetics and thermodynamics were determined previously using inverse-analysis of milligram-scale thermogravimetric analysis and differential scanning calorimetry experiments. Radiative and thermal transport properties were determined previously from inverse-analysis of gram-scale gasification experiments. The possibility of enhanced decomposition due to surface oxidation from the partially premixed burner flame was explored by performing steady state oxygen measurements of the burner flame. Measurements found burner oxygen content to be significant. Subsequently, thermogravimetric analysis was performed on PMMA in an aerobic environment of similar oxygen concentration to develop a model for the surface oxidation. Inclusion of a surface oxidation reaction significantly improved the model's prediction; the flame height predicted by the model is comparable to experimental results.