

Combustion of Polymethylmethacrylate Spheres at Normal and Reduced Gravity

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Abstract

Polymer combustion is a highly complicated process where chemical reactions may occur not only in the gas phase, but also in the condensed phase as well as at the solid-gas interphase. The complication arises due to the coupling between the condensed phase and gas phase phenomena. While some polymers form a char layer during combustion, others exhibit swelling, bubbling, melting, sputtering, and multi-stage combustion. The combustion of polymeric materials is related to many applications including solid and hybrid rocket propulsion, and of recent interest, waste incineration.

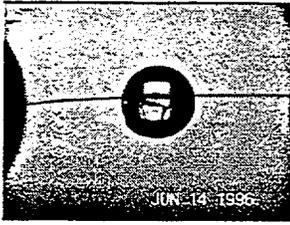
Two sets of experiments have recently been carried out to characterize the combustion of polymethylmethacrylate (PMMA) spheres at normal and reduced gravity. The low gravity environment is obtained by performing the experiments aboard the NASA DC-9 Reduced-Gravity Research Aircraft flying parabolic trajectories. The experiments were conducted using different initial diameters (from 3 mm to 7 mm) of PMMA spheres at an ambient oxygen concentration of 25 % and 0.101 MPa. PMMA is selected as a representative thermoplastic for the study because of its well-documented thermophysical properties. A spherical sample geometry for reduced gravity experiments is chosen because it is the simplest configuration in terms of analysis and reduced gravity hardware design requirements. Furthermore, a burning solid sphere in reduced gravity is a one-dimensional flame with overall combustion characteristics, in many aspects, similar to the combustion of a liquid fuel droplet, a research area with many well-developed theories and models.

The experimental apparatus, which is also used for normal gravity studies, is designed for reduced gravity combustion experiments aboard the NASA DC-9 Aircraft. It consists of a combustion chamber, a sample holder for the suspended PMMA sphere, two opposing micro-torches (miniature bunsen burners using butane fuel) for igniting the sphere in a symmetrical manner, a retraction mechanism to remove the torches from the burning sphere upon its ignition, two CCD cameras with close-up lenses for viewing the interior bubbling behavior of the condensed phase and the combustion characteristics of the sphere, and a lap-top computer for data acquisition and control. The experiments were conducted using a PMMA sphere suspended on a K-type thermocouple with its junction embedded inside the sphere. The thermocouple is used to monitor the temperature of the burning sphere.

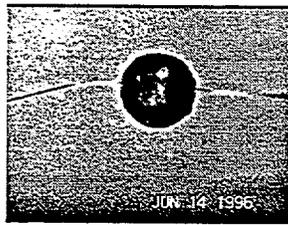
The accompanying figure is a video sequence of a 6.35 mm PMMA sphere burning at reduced gravity. The video was taken at 30 frames/second. The ignitors appear in the field of view in the first four frames of the sequence. The change in gravity level during the parabolic flight is also apparent from the change in flame shape. Detailed experimental hardware for reduced gravity flight experiments and further experimental results will be presented and discussed.

Acknowledgments

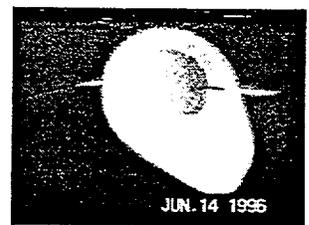
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Before ignition ($t = 0$ s)



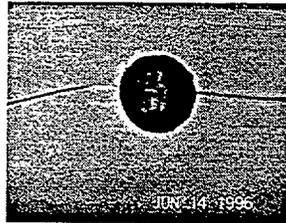
$t = 4.00$ s



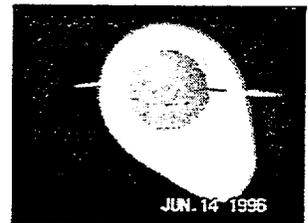
$t = 8.00$ s



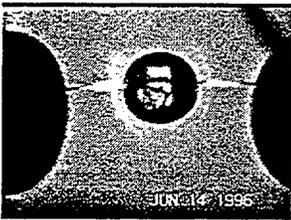
$t = 0.67$ s



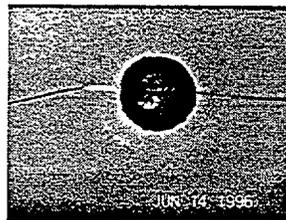
$t = 4.67$ s



$t = 8.67$ s



$t = 1.33$ s



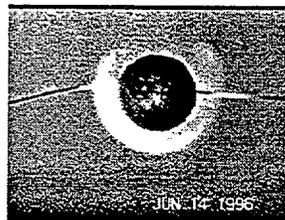
$t = 5.33$ s



$t = 9.33$ s



$t = 2.00$ s



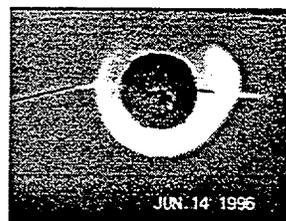
$t = 6.00$ s



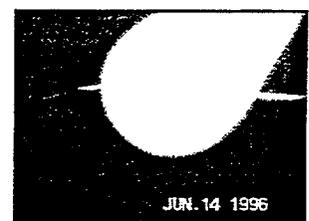
$t = 10.00$ s



$t = 2.67$ s



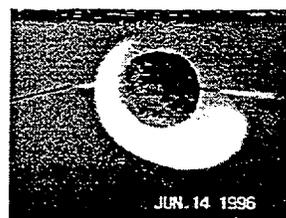
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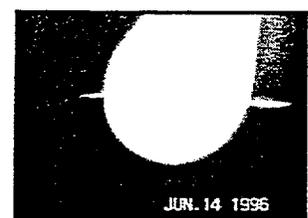
$t = 10.67$ s



$t = 3.33$ s



$t = 7.33$ s



$t = 11.33$ s