Linear Burn Rates of HAN-Based Propellants Gelled Using Hydrophilic Fumed Silica

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Abstracts

This study aimed to investigating the burn rates of HAN-based gel propellants through strand burner tests conducted in a pressure chamber. HAN (hydroxyl ammonium nitrate) is a promising "green" liquid monopropellant that shows potential for replacing the highly toxic space propellant, hydrazine. Gel propellants modified their rheological properties by adding gallant into aqueous solution. Gelation of liquid fuel not only overcomes storage and transportation challenges but also retains the safety and performance advantages of propulsion. There is a critical issue associated with HAN aqueous solution in propulsion systems is the significant increase in burn rate observed between 1.1 and 2.1 MPa. Prior research has demonstrated that adding methanol to the HAN solution effectively reduces the burn rates rate and mitigates the sudden increase in the transition zone. Another approach explored in this study involves gelation of HAN solutions using hydrophilic fumed silica (CAB-O-SIL m5), which has shown similar effects. To explore the effect of CAB-O-SIL gelation on the combustion characteristics of HAN-based propellants, 5 wt.% CAB-O-SIL gel was added to 80 wt.% HAN gel and SHP163 gel propellant for strand burner experiment, the regression rate of the liquid surface during the combustion process was recorded using a high-speed camera. The experimental results showed that under an ambient pressure of 2.1 MPa in an argon gas environment, HAN aqueous solution and the HAN gel exhibited self-sustained reaction, as shown in Figure 1 and 2, self-sustained reaction also can observe in the SHP163 aqueous solution and SHP163 gel, as shown in Figure 3 and 4. It was observed that gelation of the propellant resulted in a decrease in ignition delay. Notably, the HAN gel exhibited a lower limit of pressure for self-sustained reaction, which could be as low as atmospheric pressure. In contrast, the HAN aqueous solution and the SHP163 formula propellant required pressures above 0.6 and 1.1 MPa, respectively. After gelling the two HAN-based propellants, compared with HAN aqueous solution, the burning rate of HAN gel was reduced from 469.8 mm/s to 25.96 mm/s, as for the burning rate of SHP163 aqueous solution compared with SHP gel was increased from 2.9 mm/s to 3.78 mm/s, shown in Figure 3. The pressure-dependent index of both HAN-based gel propellants were reduced within the range of 0.1 to 3.1 MPa, effectively mitigating the sudden increase in burn rates observed in HAN solutions.

Overall, these findings contribute to understanding the combustion characteristics of HAN-based gel propellants and highlight the effectiveness of gelation with CAB-O-SIL in reducing burn rates.

(a) (b) (c) (d) (e) (f) (g) (h) (i) (j)

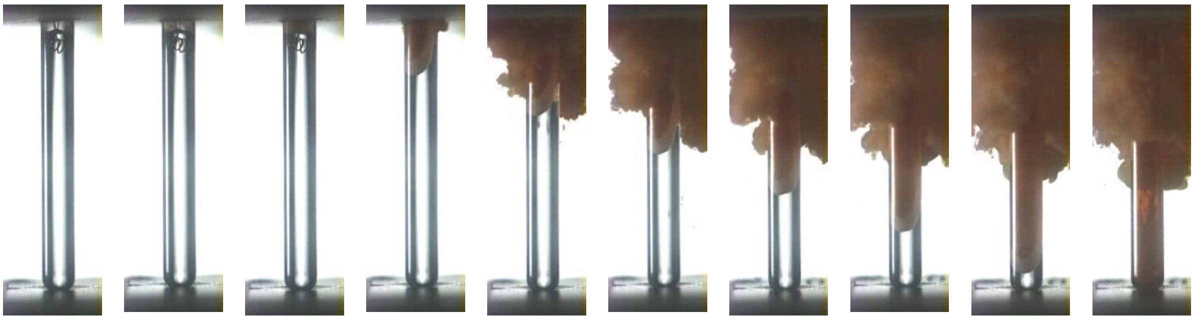

Figure 1. The time sequence of the reaction transfer of HAN solution at 2.1 MPa, (a) before reaction, (b) the reaction begins at 1.274 sec after 0.036 sec, the timing of(c)-(j) is 0.015 sec after the previous image.

(a) (b) (c) (d) (e) (f) (g) (h) (i) (j)

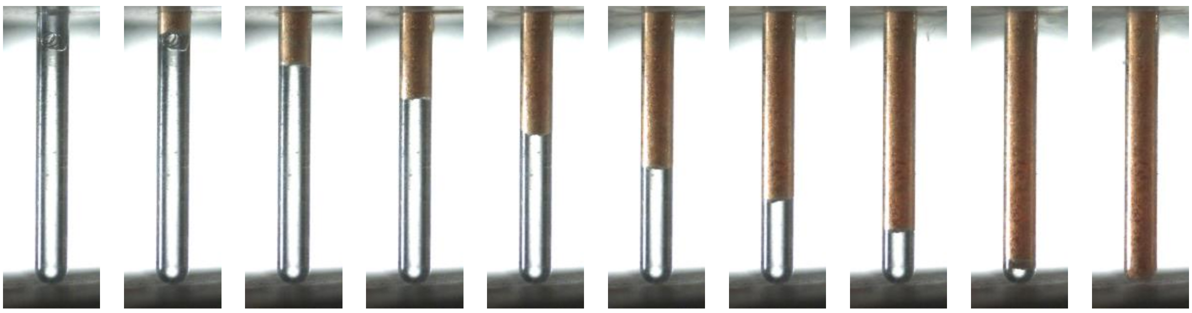

Figure 2. The time sequence of the reaction transfer of HAN solution at 2.1 MPa, (a) before reaction, (b) the reaction begins at 0.375 sec after 0.47 sec, the timing of(c)-(j) is 0.188 sec after the previous image.

(a) (b) (c) (d) (e) (f) (g) (h) (i) (j)

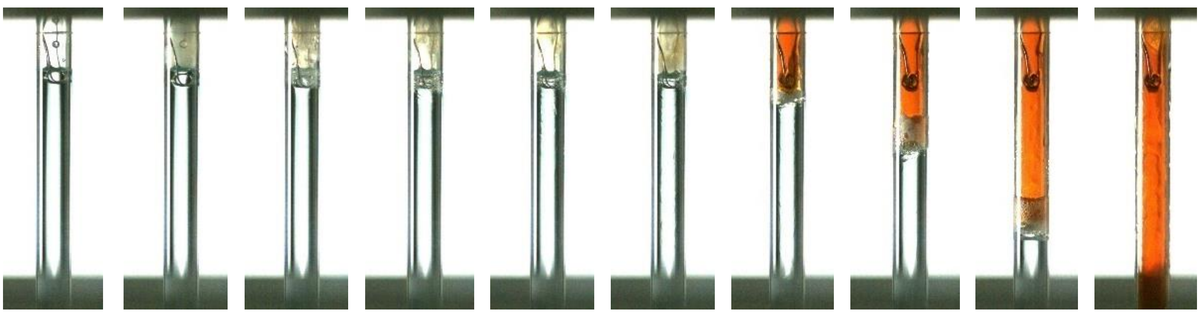

Figure 3. The time sequence of the reaction transfer of HAN solution at 2.1 MPa, (a) before reaction, (b) the reaction begins at 0.36 sec after 2.66 sec, the timing of(c)-(j) is 4.66 sec after the previous image

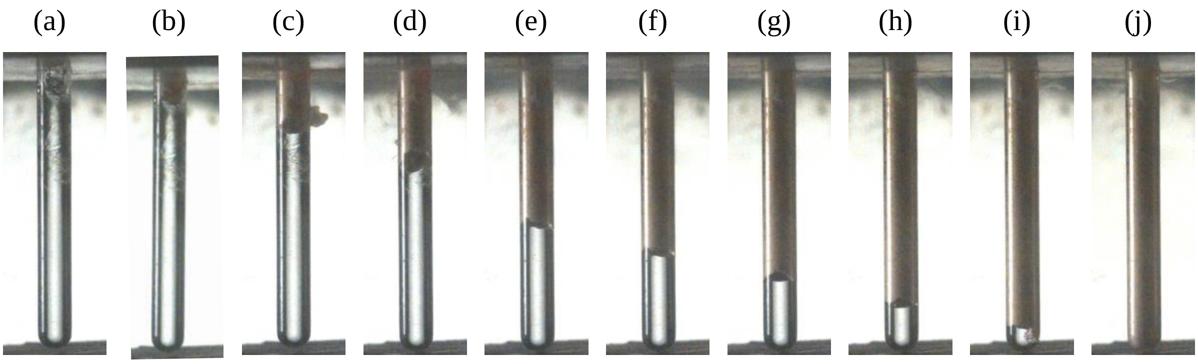

Figure 4. The time sequence of the reaction transfer of HAN solution at 2.1 MPa, (a) before reaction, (b) the reaction begins at 1.25 sec after 2.27 sec, the timing of(c)-(j) is 1.25sec after the previous image

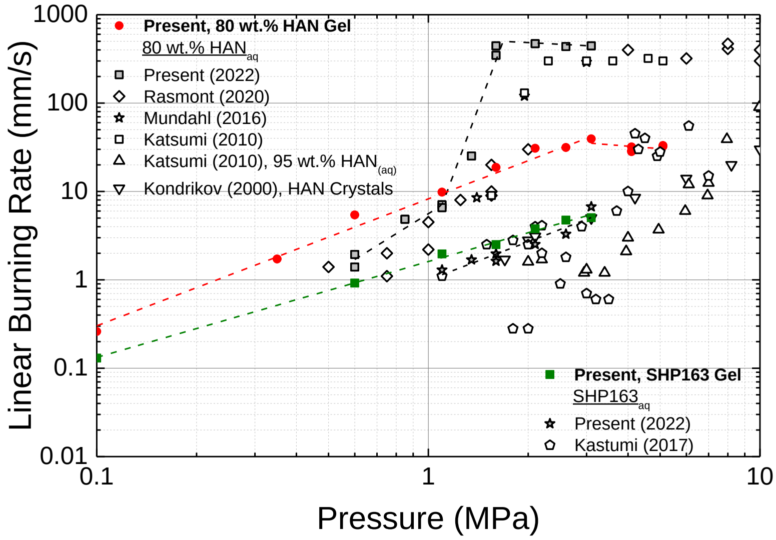

Fig.5. The effect of gelation on the linear burn rates of propellant at different pressures.