Aerospace Europe Conference 2023
Joint 10th EUCASS – 9th CEAS Conference

Abstract #XXX *(to be filled by the organizers)*
Preferred Topics: PROPHY / AEROFLIPHY *(3 maximum from the list of topics)*
Corresponding author: Changjin Lee
e-mail of corresponding author: cjlee@konkuk.ac.kr
Type: Oral
Status of corresponding author: Regular

Title

Transition of Pressure Oscillations in Hybrid Rocket Combustion using Paraffin Wax Fuel

Authors

*Wonjeong Hyun [1], Sojung Park [2], Changjin Lee [3]**

** Corresponding author*
[1] Graduate student, Konkuk University, Neungdongno 120, Gwangjin-gu, Seoul, 05029, Korea, gdw3433@konkuk.ac.kr
[2] Undergraduate student, Konkuk University, Neungdongno 120, Gwangjin-gu, Seoul, 05029, Korea, pistarty@hotmail.com
*[3]*Professor, Konkuk University, Neungdongno 120, Gwangjin-gu, Seoul, 05029, Korea, cjlee@konkuk.ac.kr*

Abstract

Paraffin wax has a liquified layer on the surface during combustion, and fuel droplets are entrained in the combustion gases. In addition, the molten layer flows into the post chamber to create another liquified layer, leading to additional combustion. With the post chamber, strong fluctuations in the pressure are observed. However, relatively stable combustion is observed without the post chamber even though the average combustion pressure is decreased. This result implies that although the post chamber provides an enthalpy increase, there are some physical processes leading to combustion pressure oscillations. Meanwhile, it is well known that combustion instability in the low-frequency band occurs in the combustion using paraffin[1]. They conducted a combustion test using SP-1a (a kind of Paraffin wax) and Gox system and observed the strong combustion instability in the 30Hz band.

With the low melting point of paraffin wax, many droplets are formed during the combustion. However, as the combustion temperature increases, the combustion condition of the paraffin wax shifts to a supercritical condition, where the surface tension of the droplet becomes insignificant. The properties of paraffin ($C_nH_{2(n+1)}$) in the supercritical condition depend on the carbon number 'n'. For example, when n = 32, the critical pressure and temperature are 6.5 bar (94 psi) and 860 k, respectively. In particular, the combustion in reference [1], where combustion instability was observed, is assumed to be a supercritical condition.

This study confirmed that combustion becomes to a supercritical condition when the oxidizer flow rate increases over 50 g/s. In particular, at a low oxidizer flow rate (20 g/sec), low-frequency combustion pressure oscillations are observed only at the beginning of combustion. However, as the oxidizer flow rate increases, it moves to the middle of combustion, and pressure beats in the high-frequency band (400-600Hz) are observed simultaneously with combustion instability. This is very similar to the characteristics of combustion instability observed in hybrid rocket combustion using PMMA/Gox[2]. Therefore, this study aims to investigate the transition of pressure oscillations as the oxidizer flow rate increases and to understand how the occurrence of combustion instability interacts with the post chamber when paraffin fuel burns in the supercritical condition. Previous studies have reported that the interaction of additional combustion of unburned fuel in the post chamber is the main cause of low-frequency combustion instability. From this point of view, it seems necessary to verify whether the results of previous studies can be equally applied to paraffin wax combustion at supercritical conditions.

References

[1] S.D. Zilwa, A. Karabeyoglu, G. Zilliac, L. King, M. Reinath, Combustion Oscillations in High-regression-rate Hybrid Rockets, 39th Joint Propulsion Conference and Exihibit, 20-23 July 2003, AIAA Paper 2003-4465.
[2] W. J. Hyun, C. J. Lee, Ignition Delay and Thermoacoustic Coupling in Hybrid Rocket Combustion, 73th International Astronautical Congress(IAC), 18-22 September.