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Title

Effect of surface roughness on jet impingement cooling of a superheated wall

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Abstract

In the development of rocket engines, thermal management is an important topic. Bipropellant thrusters widely used for attitude control of small spacecraft and satellites employ a liquid film cooling technique, in which a part of the liquid fuel is injected from discrete holes of the faceplate to the chamber wall. The formed liquid films prevent the chamber wall surface from exposure to the combustion gases. They gradually evaporate farther downstream owing to the heat input from the combustion gases and chamber wall and eventually dry out at a certain axial location. To avoid thermal failure, the chamber wall requires sufficient cooling. On the other hand, the increase in the flow rate of fuel for film cooling leads to the reduction of the thrust performance [1]. Therefore, the length of the liquid-cooled region (i.e.; liquid film length) should be optimized for achieving higher thrust performance and heat resistance.

To optimize the flow rate of fuel for film cooling, the liquid film/wall interaction should be further investigated because the surface state of the chamber wall can affect the liquid film behavior. Recently, Sako et al. [2] investigated the heat transfer characteristics between the liquid film and the high-temperature wall. For a deeper understanding of the film/wall interaction, the effects of the surface roughness of the wall on the liquid film behavior especially need to be examined because the liquid film length drastically changes when the surface roughness of the chamber wall varies even though the injection condition is the same.

Therefore, in the present study, the jet impingement cooling of the heated metal plates with different surface roughness was conducted to consider the effect of the surface roughness on the liquid film behavior and heat transfer characteristics between the liquid film and the heated wall. In the cooling tests, we measured the liquid film and wall temperature simultaneously by using a high-speed camera and an infrared camera, respectively. The cooling processes were evaluated by the wall temperature at the leading edge of the liquid film, maximum heat flux.

References

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[2] N. Sako, et al., "Quenching of a heated wall with spatial temperature gradient using a liquid film through oblique jet impingement," International Journal of Heat and Mass Transfer, vol. 192, Article 122925, 2022.