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Title

Experimental estimation of the amount of residual slag remaining inside orbital insertion stage solid rocket motor

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Abstract

The composite propellants currently used in solid rocket motors (SRMs) contain aluminum powder to improve 'specific impulse'. This aluminum powder changes to alumina (AL_2O_3) by reacting with oxidants contained in the propellant as ammonium perchlorate. Most of alumina is discharged within the combustion gas-flow from the propellant surface to the nozzle outlet. However, it is well known that a certain proportion is trapped in a stagnant flow field around the submerged nozzle. The term "slag pool" is used to describe the slag that remains after firing conventional solid rocket boosters with a submerged nozzle design. Furthermore, during any actual flights, it was observed that multiple lumps formed from the residual slag were ejected from the nozzle at the end of combustion of SRMs [1]. Therefore, when a SRM is used for the orbital insertion stage, there is concern that the residual slag will become space debris and affect other objects in orbit.

Whereas, improvements aluminum combustion efficiency in orbital-insertion stage (3rd and kick stage) SRMs have continued for decades in Japan. As a result of this activity, it has been confirmed in any static fire tests that the ultimate reduction in the amount of residual slag has been achieved [2,3]. Therefore, from the orbital insertion stage SRMs developed in Japan, the blowout of residual slag at the end of combustion will be tiny. Currently, activities to quantify the degree of impact on orbital objects by the latest solid rocket "Epsilon S launch vehicle" under development in Japan are being undertaken by the following procedures.

1) The amount of slag will be measured in the static fire test of third-stage "E-31" for Epsilon S launch vehicle.
2) The effect of acceleration on the amount of residual slag trapped inside SRMs is confirmed by ground fire tests, and the effect of acceleration during flight will be added to the above results.
3) Based on the final estimate of residual slag, the collision probability of ejected SRM slag during its orbital life will be calculated.

In this paper, the latest research results on step 1 and 2 of this procedure conducted in March of 2023 will be reported.

References

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