AGGLOMERATION EFFECTS IN ADN/GAP METALLIZED SOLID ROCKET PROPELLANTS

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Addition of metals, typically Al powder under several ways (micron-sized, nano-sized, activated, amorphous, etc.) is a well-known approach to increase the gravimetric as well as volumetric ideal specific impulse of solid rocket propellants. However, it is also well-known that aggregation/agglomeration phenomena, at or near the burning surface, penalizes the specific impulse increase making its delivered value appreciably less than the corresponding ideal value. An impressively large body of literature is available discussing this issue for the classical ammonium perchlorate (AP) / hydroxyl terminated polybutadiene (HTPB) / micrometric Al used for decades in propulsion missions aimed at space access. In this case, the recommended [1] international standard for the 2P flow losses reads as

$$(\Delta I_s)_{2P} = C_3 \frac{(\xi cc)C4 \cdot (dp)C5}{(pcc)0.15 \cdot (\varepsilon)\, 0.08 \cdot (dt)C6}$$

where:
ξ_{cc} = molar fraction condensed products in combustion chamber (moles/100g);
d_p = average diameter of the condensed particles (μm);
p_{cc} = combustion chamber pressure (psi);
$\varepsilon \equiv A_e/A_t$ = geometric expansion ratio of the nozzle;
d_t = throat area diameter (in);
C_3, C_4, C_5, C_6 = correlation constants.

The main difficulty in using this equation concerns the parameters associated with the type of loaded solid propellant before and after combustion (respectively ξ_{cc} and d_p). A survey of the many effects and pathways associated with different metal burning in traditional HTPB bound composite solid rocket propellants was offered some time ago [2]. On the contrary, very little can be found in the open literature regarding the AND/GAP formulation, meant to be a green and highly performing new composite propellant. Which specific path comes out to be the dominating one when AP/HTPB is totally replaced by ADN/GAP at this time is totally unknown. In this work substitution of AP/HTPB with ADN/GAP is experimentally assessed, by comparing a standard AP/HTPB/Al formulation to the corresponding ADN/GAP/Al formulation in terms of burning rate and agglomeration effects. Emission spectroscopic investigations result in temperature distributions of Al-particles and gaseous AlO. Thermochemical calculations are carried out to quantify the ideal performance gain obtainable when adding micrometric Al to ADN/GAP matrix as well as the performance loss reasonably associated with the resulting 2P flow.

References

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