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NON-PREMIXED COMBUSTION AND SELF-SUSTAINING MECHANISM OF A RAMJET ROTATING DETONATION ENGINE

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ABSTRACT

Non-premixed inflow in ramjet rotating detonation engines (RDEs) introduces strong mixing inhomogeneity and combustion instability, which severely affect detonation initiation and stable operation. In this study, three-dimensional numerical simulations are performed to systematically investigate the effects of injection parameters, combustor configuration, and inflow conditions on detonation wave dynamics and self-sustaining behavior. The results identify mixing efficiency as the dominant parameter controlling both detonation initiation and mode evolution, and further reveal the existence of a critical mixing efficiency for self-sustained detonation as well as a transition threshold for mode change. Stable single-wave propagation can only be achieved within an intermediate mixing-efficiency range, whereas insufficient mixing leads to failure of detonation initiation and excessive mixing tends to promote multi-wave modes. Increasing injector diameter and mixing section length improves mixing uniformity, while lower hydrogen flow rates require higher mixing efficiency to ensure successful ignition. Compared with inward-expanding combustors, outward-expanding configurations exhibit better wave stability, and a proper expansion angle is found to favor stable wave anchoring. In addition, reduced oxygen concentration or increased inflow Mach number weakens detonation intensity and drives transitions from single-wave propagation to multi-wave or counter-rotating modes. Further analysis reveals a coupling self-regulation mechanism in which the forward-propagating shock generated by the detonation wave enhances upstream mixing through periodic deceleration, compression, and flow perturbation, forming a positive feedback loop, while

mass flow attenuation and reduced heat release provide negative feedback. The competition between these effects enables dynamically balanced and self-sustained operation. These findings provide new physical insight into the mixing-controlled stability of non-premixed ramjet RDEs and offer theoretical guidance for combustor design and wide-operating-range applications.