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SPACE PROPULSION SYMPOSIUM (C4)
Advanced Propulsion: "Non Electric Non Chemical" (8)

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NUMERICAL INVESTIGATE ON THE EFFECTS OF THE LENGTH OF THE FLAT-ROOFED PARABOLIC NOZZLE ON THE MULTI-PULSES LASER PROPULSION

Abstract

As an innovative propulsion power of spacecraft, the air-breathing mode of laser propulsion must work at a sequence of multi-pulses on certain repeating rates. The partial filling rate of breathed air in nozzle has a critical influence on the propulsion performance when the air was not fully replaced by flesh air. The flat-roofed parabolic is beneficial to breathe the air, and the nozzle length will affect the propulsion performance. Theoretical analysis and numerical simulation with a radiative hydrodynamic code explain a sequence of physical processes in multi-pulses; meanwhile, the effects of thruster's structure such as focal length and scale on propulsion performance for multi-pulses are investigated.

The simulation results show that it is beneficial to breath the air in nozzle when the ignite position locate near nozzle exit, The 5th pulse average Cm decreases 27.6% to single pulse, which is less than the other two conditions which are 41.9% and 37.0%. Furthermore, six nozzles with different lengths are employed for multi-pulses. The Cm of multi-pulses varies slowly when the ratio of the nozzle length to the exit diameter ranges from 0.6 to 0.7, and increases linearly when the ratio changes from 0.7 to 0.9 and decreases sharply when the ratio excesses 0.9. Theoretically, a longer nozzle length leads to a better propulsion performance, but excessive length brings about shortcomings. Negative force will appear before shock wave spreading to nozzle exit for lower energy and longer nozzle, and the lengthening nozzle needs a long time to breathe and recover the air. The Cm decreases with the number of the laser pulses; the ratios of the impulse to the mass loss of air in nozzle have been found to be fairly constant after several pulses. Besides, an uneven density distribution in nozzle is found when we calculate the initial flow fluids before the next pulse starting, Numerical results demonstrate that the partial filling rate of breathed air in nozzle has a critical influence on the pulses propulsion performance. The nozzle with such parameters, as the ignite position near the nozzle exit and the ratio of the nozzle length to the exit diameter being 0.9, is found to have a best propulsion performance for multi-pulses.

The conclusions may provide useful information for studying the mechanism and designing the optimal laser thruster. The future research can focus on optimizing the structure of parabolic nozzle by changing its angle and incident laser frequency.