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Title

Diode Laser Ignition Characteristics of ABS and Oxygen hybrid rocket motor

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Abstract

Hybrid rocket motors (HRMs), which store oxidizers and fuel in different phases with physical separation, are considered as an intermediate form of liquid and solid rocket motor. Compared with solid rocket motors, HRMs have a similar level of energy management as liquid rocket motors, especially in terms of multiple restart capability. Meanwhile, the simple structure allows HRMs to provide significantly higher safety during multiple restart processes compared with liquid rocket motors.

A class of igniter that is widely used for this task on hybrid motors is referred to as a gas torch ignition system. This type of igniter, which uses gaseous fuel, gaseous oxidizer, and a spark plug to initiate a pilot flame, requires a secondary gaseous fuel to be carried onboard and adds extra tubing, hardware, and an additional control valve. The application of laser ignition in hybrid rocket motor systems is becoming mature resulting from the introduction of diode lasers and the maturing of semiconductor technology. Furthermore, the inherently effective at ignition stability and energy density make lasers ideal for hybrid rocket motor systems.

The most practical application of laser ignition systems is based on non-resonant breakdown techniques, which involve the creation of an electric field strength that is sufficient to cause electrical breakdown of a gaseous reactant. However, the surface regression and high ignition energy requirements of solid fuels dictate that non-resonant breakdown techniques are not suitable for the hybrid rocket motor. Thermal initiation can effectively overcome these problems and heat the solid target to produce ignition without an electrical breakdown of gas.

Currently, most researches of multiple restart process in HRMs based on the gas torch ignition system. There is insufficient understanding of diode laser ignition characteristics, especially in the wide pressure and flow range. The coupling characteristics between laser heating efficiency and solid pyrolysis variation remain ambiguous.

The objective of the present work is therefore fourfold. First, fire experiments were conducted to capture the instantaneous phenomenon of laser ignition using an optical access slab burner with a diode laser system. Then, the coupling characteristics between laser power, oxidant properties and pyrolysis rate of solid fuels are investigated. Finally, a two-dimensional transient numerical model taking into account the optical heat of the diode laser coupled with dynamic pyrolysis process of solid fuel grain was proposed. Fire experiments were conducted to validate the developed model in predicting ignition pressure, ignition delay, and ignition stability.

References

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