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Thrust Measurement of a Multicycle Partially Filled Pulse Detonation Rocket Engine

Jiro Kasahara* and Masao Hirano†
University of Tsukuba, Tsukuba 305-8573, Japan
Akiko Matsuo‡ and Yu Daimon§
Keio University, Kanagawa 223-8522, Japan
and
Takuma Endo‡
Hiroshima University, Hiroshima 739-8527, Japan

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In the present research, we experimentally verified the partial-fill effect in a multicycle pulse detonation rocket engine. The intermittent thrust of a pulse detonation rocket engine was measured by using a spring-damper mechanism that smoothed this intermittent thrust in the time direction. The intermittent mass flow rates were assessed by gas cylinder pressure or mass difference measurement. The maximum specific impulse was 305 ± 9 s at an ethylene and oxygen propellant fill fraction of 0.130 ± 0.004. When the fill fraction was greater than 0.130, the specific impulse was increased as the partial-fill fraction was decreased. When the fill fraction was less than 0.130, the specific impulse was sharply decreased as the partial-fill fraction was decreased. This decrease was due to diffusion between propellant and purge gases and the short length of the transition from deflagration to detonation. The multicycle pulse detonation rocket engine had a partial-fill effect that may have been mainly due to the suctioned air and was consistent with the single-cycle partial-fill model of Endo et al. [Endo, T., Yatsufusa, T., Taki, S., Matsuo, A., Inaba, K., and Kasahara, J., "Homogeneous-Dilution Model of Partially-Fueled Simplified Pulse Detonation Engines," *Journal of Propulsion and Power*, Vol. 235, 2007, pp. 1033–1041.]

Nomenclature

A_e	=	control-volume surface area through which an exhaust jet flows
c	=	attenuation coefficient of a damper
F_f	=	force acting on the pulse detonation engine tube by the rail in the x direction
F_{kc}	=	force acting on the pulse detonation engine tube by the spring-damper system in the x direction
F_{lc}	=	force acting on the spring-damper system by the load cell in the x direction
F_p	=	force acting on the pulse detonation engine tube by the fluid in the x direction
F_t	=	force acting on the pulse detonation engine tube by the supplying tubes in the x direction
F_0	=	plateau thrust
$ff_{\mathrm{air,est}}$	=	estimated suctioned air fill fraction
$ff_{\mathrm{propellant}}$	=	propellant fill fraction
ff_{purge}	=	purge gas fill fraction
g	=	gravitational acceleration
I	=	impulse acting on the pulse detonation engine tube by the fluid in the x direction
I_{sp}	=	specific impulse
I_{total}	=	absolute value of the total impulse acting on the pulse detonation engine tube by the fluid in the $-x$ direction during all cycles
$I_{\mathrm{total},x}$	=	total impulse acting on the pulse detonation engine tube by the fluid in the $-x$ direction during all cycles
k	=	spring constant
M_c	=	molecular weight in the cylinder
m_d	=	mass of weight
$m_{\mathrm{propellant}}$	=	propellant mass during all of the cycles
m_{purge}	=	purge gas mass during all of the cycles
m_t	=	pulse detonation engine tube mass
p_a	=	ambient pressure around the control volume
p_e	=	exhausted-jet pressure on the control surface
R_c	=	gas constant of the gas in the cylinder
T_c	=	gas temperature in the cylinder
t	=	time
t_{cyc}	=	period of one cycle
t_{pl}	=	time during which the plateau thrust is maintained
t_{total}	=	time during all of the cycles
u_e	=	fluid velocity component in the x direction, on the control surface
u_x	=	fluid velocity component in the x direction
V	=	volume
V_c	=	volume of the cylinder
v_s	=	horizontal velocity of a solid element
v_w	=	velocity of the weight
x	=	horizontal axis fixed in the control volume
x_p	=	pulse detonation engine tube position in the x axis, of which the origin is the natural length of the point of a spring
Y	=	mass fraction that equals the propellant mass divided by the total mass of both the propellant and the purge gases
Δm_c	=	mass difference between the initial and final masses of the gas in the cylinder
Δp_c	=	pressure difference between the initial and final pressures of the gas in the cylinder

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*Associate Professor, Department of Engineering Mechanics and Energy. Senior Member AIAA.
†Graduate Student, Department of Engineering Mechanics and Energy.
‡Professor, Department of Mechanical Engineering. Member AIAA.
§Graduate Student, Department of Mechanical Engineering. Member AIAA.