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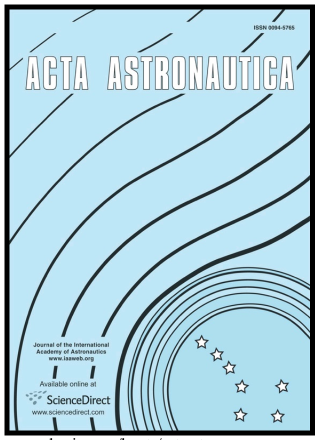

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Dynamic modeling and simulation of an integral bipropellant propulsion double-valve combined test system

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Abstract

For the pressure reducing regulator and check valve double-valve combined test system in an integral bipropellant propulsion system, a system model is established with modular models of various typical components. The simulation research is conducted on the whole working process of an experiment of 9MPa working condition from startup to rated working condition and finally to shutdown. Comparison of simulation results with test data shows: five working conditions including standby, startup, rated pressurization, shutdown and halt and nine stages of the combined test system are comprehensively disclosed; valve-spool opening and closing details of the regulator and two check valves are accurately revealed; the simulation also clarifies two phenomena which test data are unable to clarify, one is the critical opening state in which the check valve spools slightly open and close alternately in their own fully closed positions, the other is the obvious effects of flow-field temperature drop and temperature rise in pipeline network with helium gas flowing. Moreover, simulation results with consideration of component wall heat transfer are closer to the test data than those under the adiabatic-wall condition, and more able to reveal the dynamic characteristics of the system in various working stages.

Keywords: Integral bipropellant propulsion; Double-valve combined test system; Finite volume method; Modularization modeling; Dynamic system simulation

Nomenclature

A cross-sectional area or force action area (m^2)
A_v sectional flow area of valve spool or orifice (m^2)
a sound velocity (m/s) or acceleration (m^2/s)
C stiffness of spring or diaphragm (N/m)
C, C_s perimeters of pipe cross section and pipe-wall deformation region, respectively (m)
C_d flow coefficient
CFL Courant-Friedrichs-Lewy numer
c_p specific heat at constant pressure (J/(kg K))
d diameter or interior diameter of pipe (m)
E, E_v total energy per unit volume (J/m^3)
e internal energy per unit mass (J/kg)
f_x force per unit mass along x direction (N/kg)
f_λ dimensionless friction loss coefficient
(also called Darcy friction factor)

Gr Grashof number
g gravity acceleration (m/s^2)
h valve spool opening (m)
h_d valve-spool movement velocity (m/s)
h_Δ roughness of pipe wall (m)
l length (m)
Ma mach number
m mass (kg)
Pr Prandtl number
p pressure (Pa)
Q thermal increment per unit volume resulted from radiation or chemical energy release (J/(m^3 s))

Q_m mass flow rate (kg/s)