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EFFECT OF REYNOLDS NUMBER AND FLOW CHANNEL GEOMETRY ON FUEL REGRESSION CHARACTERISTICS IN CAMUI TYPE HYBRID ROCKET

Abstract

The authors have developed CAMUI type hybrid rockets to realize an explosive-free small launch system. By separating conventional cylinder-shape solid fuel grain with a central port into multiple cylinder blocks, the combustion gas repeatedly collides with upstream end faces of fuel blocks to accelerate the heat transfer to the fuel. To design initial fuel shape appropriately, regression formula for each burning surface is necessary. Previous researches revealed that regression rate of an upstream end face increases in proportion to the nth power of the mass flow density in the upstream ports. Because the dependence of regression rates on the mass flow density in the upstream ports comes from the dependence of Nusselt number (Nu) on Reynolds number (Re), the exponent n is the same of the exponent of Re in a function giving Nu. The exponent n varies from 0.5 to 0.8, depending on the flow conditions. The purpose of this study is to investigate the effect of Re and flow channel geometry on the Re exponent n.

Static firing tests were carried out with various L/D, ratio of port length L to port diameter D, and Re. L/D and Re ranged from 0.4 to 2.7 and 50,000 to 250,000, respectively. The test motor uses polyethylene and liquid oxygen as propellants. A fuel grain consists of four or five fuel blocks stacked in axial direction. There are two axial ports of 22 mm in inner diameter in a fuel block. The outer diameter of a fuel grain is 100 mm. After each firing test with a prescribed firing duration, the fuel grain was recovered from the combustion chamber to measure regression rates of burning surfaces. The Re exponent was obtained empirically by adopting least square method.

The empirical values of Re exponents in larger Re range were around 0.8. With smaller Re ranges, on the other hand, the value approaches 0.5. By increasing L/D the exponent approaches 0.8 at a larger Re. Laminar boundary layer theory gives the exponent to be 0.5 in a stagnation region and 0.8 in a wall jet region. Considering that Nu in a wall jet region increases more rapidly than that in a stagnation region with increasing Re, it is likely that the heat transfer in the wall jet region becomes dominant with increasing Re, resulting in the change of the Re exponent from 0.5 to 0.8.