EXPERIMENTAL STUDY OF REGRESSION RATES IN PARAFFIN WAX BASED HYBRID ROCKET MOTOR WITH AERO-SPIKE NOZZLE

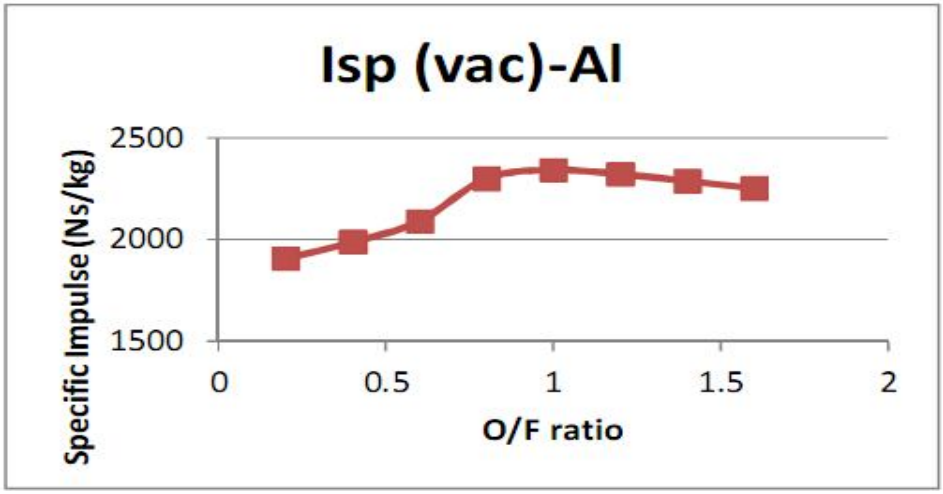
[1]VISHNU.P.R, [2]P. A. RAMAKRISHNA

[1]MS Student, Indian Institute of Technology-Madras, Chennai-India
[2]Assistant Proffessor, Indian Institute of Technology-Madras, Chennai-India

A Hybrid rocket motor is a propulsion system in which the oxidiser is in the liquid form which is injected into a chamber containing solid fuel. Hybrid rocket propulsions have several advantages. Some of which are safe handling of motor without risk of explosion as fuel and oxidisers are stored separately, throttling capabilities to get variable thrust, more environment friendly than conventional solid rocket motors. Hybrid propulsion systems have a few disadvantages as well. Conventional fuels used in hybrid rocket motors have very low regression rates, limiting the amount of thrust that can be produced for a given motor. This leads to use of multiple ports in the fuels resulting in low volumetric loading. Oxidiser to fuel ratio changes along the length of the motor even under steady state operation which results in varying Specific Impulse(ISP). Hybrid fuel regression rates are sensitive to the rate of heat transfer between the combustion layer and fuel surface, aerodynamics of the flow through the chamber. As a result a change in geometry of the motor or scale of the motor has been found by previous research to alter the regression rates of the fuel.

Despite the disadvantages, the use of HTPB/N_2O based hybrid rocket motor as the propulsion system in the Spaceship two spacecraft has reignited the interests in use of hybrid propulsions systems as a very good option for commercial suborbital space flights. Research and development at Stanford University on liquefying hybrid fuels has led to a new class of paraffin wax based fuel which increases the fuel regression rate by fuel entrainment mechanism [1]. The high regression rate of paraffin wax fuel enables use of simple, single port fuel grains with high volumetric loading.

Use of powdered aluminium along with wax has been found to increase the ISP and reduce the O/F ratio, which has the advantage of carrying less oxidizer and structural weight of rocket motor can be reduced. A fuel composition of 50% wax + 50% Aluminium was found to have a vacuum ISP of 2342.4 Ns/kg using CEA software and is used in the experiment.



Rajiv et al [2], showed that use of bluff body near the injector increases the regression rate resulting in a more uniform uniform regression rates from head end to nozzle end compared to the case without the bluff body. Also the combustion efficiency was observed to improve from 61% without bluff body to 82% with the use of bluff body.

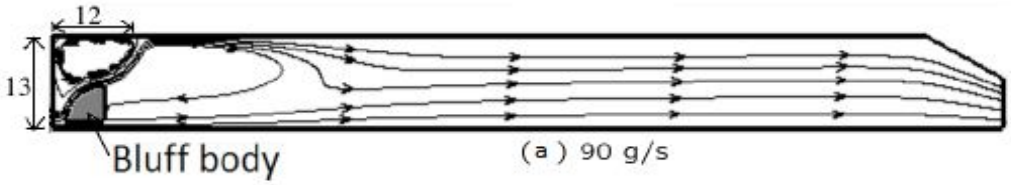


Fig 2, Flow pattern with bluff body at injector end at oxidiser flow rate of 90g/s and constant oxidiser mass flux G_{ox} = 17g/cm^{2}s

The cold flow analysis in ansys fluent with bluff body and, bluff body with aerospike nozzle are as shown in the figures. Preliminary CFD cold flow analysis shows that, with the normal nozzle, the flow separates from the fuel surface, reducing the amount of heat transfer which directly influences the regression rate. With the aerospike nozzle, the flow is connected to the fuel surface along the length of the fuel grain. This might increase the heat transfer rate to the fuel surface resulting in enhanced fuel regression rates. Also we expect the presence of recirculation regions near the convergent section of the nozzle to enhance the combustion efficiency.

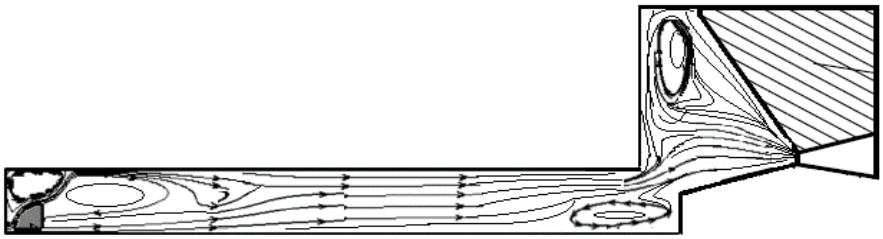


Fig 3, Flow pattern with bluff-body and aerospike nozzle for the same oxidiser flow rate and oxidiser mass flux G_{ox} = 17g/cm^{2}s

An aero spike nozzle has been designed and fabricated as shown in the figure.

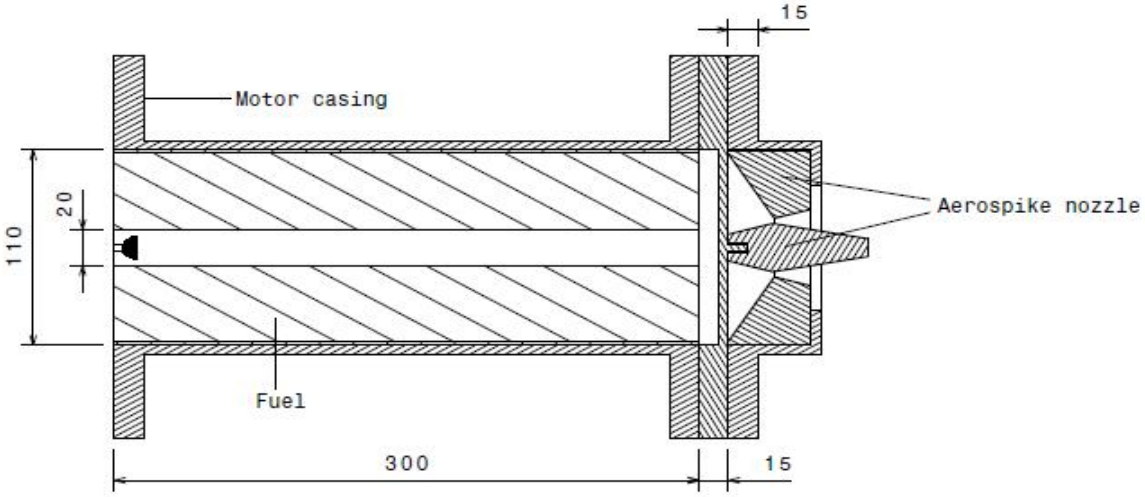


Fig 3, Hybrid motor setup with Aerospike nozzle

Experimental investigation of regression rates will be carried out at different oxidiser mass fluxes to determine if using an aerospike nozzle can have any significant effect on the regression rates and combustion efficiency of the hybrid motor.

REFERENCES

[1]. Karabeyoglu, M. A., Altman, D., and Cantwell, B. J., "Combustion of Liquefying Hybrid Propellants: Part 1, General Theory", Journal Of Propulsion and Power, Vol. 18, 2002, pp. 610_620.

[2]. "Regression rate studies using wax as a hybrid fuel", Phd Thesis, Rajiv Kumar

★★★