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PERFORMANCE TESTING OF A 7 KN HYBRID ROCKET MOTOR UNDER VARYING PROPELLANT CONDITIONS

Abstract

This paper presents performance test results associated with a series of hot-fire tests of a 7 kN hybrid rocket motor developed by the University of KwaZulu-Natal's Aerospace Systems Research Institute (ASRI). The motor is the fourth developed by ASRI in support of its Phoenix Hybrid Sounding Rocket Programme, and will provide propulsive power to its Phoenix-1D and Phoenix-1E sounding rockets, due to be flight tested in late 2024. As part of the programme, ASRI has conducted six flight tests since 2014, and in 2021 set an African hybrid rocket altitude record of 17.97 km with its Phoenix-1B Mk IIr rocket. At the time, this was the third highest altitude achieved by a university-developed hybrid rocket globally.

The motor under consideration in this study, denoted the M-4, employs a blowdown oxidiser feed system and carbon-fibre combustion chamber, and has the following key design specifications: 7250 N peak thrust, 40 bar peak chamber pressure, 32 kg oxidiser load, 5.4 optimum oxidiser-to-fuel ratio, 14.2 s burn time (liquid phase). The predecessors of the M-4 motor produced average steady-state thrusts of 2768 N (M-1), 3154 N (M-2), and 4920 N (M-3). The core propellant combination, nitrous oxide and SASOL 0907 paraffin-wax, has remained unchanged through the design evolution, although the M-3 motor fuel grain featured 20% aluminisation by mass. This level of aluminisation has again been employed for the M-4 motor fuel grain. Structurally, oxidiser tanks and chamber casings have transitioned from aluminium to carbon-fibre composites during the course of the programme, to achieve a better rocket thrust-to-weight ratio.

This paper describes a series of four hot-fire tests of the M-4 motor, undertaken to qualify the motor's performance under varying propellant conditions prior to flight testing the Phoenix-1D and Phoenix-1E vehicles. Specifically, the performance impact of different aluminium powder additives and initial nitrous oxide tank loadings is investigated. Two distinct types of aluminium powder are evaluated, differing in particle size and shape. Additionally, the tank blowdown physics and correlation between tank loading (half and full tank volume) and burn time are investigated. Finally, test results are compared with performance predictions generated by an in-house motor performance modelling tool, which is also detailed.