SPACE PROPULSION SYMPOSIUM (C4)
Propulsion Systems I (1)

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STUDY ON THE STARTUP CYCLOGRAM OF A LIQUID ROCKET ENGINE

Abstract

The startup characteristic of the liquid propellant rocket engine(LRE) should give stable ignition of the combustion chamber and the gas generator. Also, it should minimize the propellants consumption during this period which doesn't contribute to the flight thrust by the quick transition to the nominal state. The present article suggests a numerical approach to find the optimal startup cyclogram before the tests. The present method uses the commercial flow system analysis program Flowmaster which is readily applicable to one dimensional transient analysis of LRE. The combustion chamber(CC) model was developed considering the residual gas quantity and its chemical properties to calculate the choking flow rate through the nozzle throat. Also the ignition delay time was considered as an invariable input. The propellants feed pipelines were modeled by characteristic method in the Flowmaster, so the pressure perturbations in the pipelines and propellants prime time into the empty cavity can be calculated accordingly. Turbopump(TP) was modeled with the input of head and torque curve with respect to the flow rate. And the inherent flow characteristics of shutoff valves were considered to verify its effect on the shutoff phenomena. For the optimal startup the turbine starter's specifications – working duration, power level and the profile of flow rate – were determined according to the criteria that the rotational speed of the turbopump should be built up to 50% of nominal value. Then the priming time of propellant into the cavity volume was calculated. Based on this priming time the gas-generator shutoff valves' opening times were determined. During this process the pump discharge pressure should be high enough to give reasonable pressure difference across the injectors. Finally, the CC shutoff valves' opening times can be given based on the criteria that the CC should be ignited among 50% to 70% of nominal TP rotational speed and there should be no pressure peak larger than the nominal pressure value of CC at the instance of ignition. In conclusion, a novel startup analysis methodology based on the Flowmaster is proposed to find the optimal startup cyclogram which can minimize the pressure peak of CC and reduce the thrust buildup time.