

Modeling the Thrust Curve of a Solid Fuel Black Powder Model Rocket Engine

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Abstract

This research project developed a mathematical and computational model for predicting thrust curves of black-powder model rocket engines. The model represents combustion as a two-phase process, consisting of an initial expansion phase and a subsequent tailing phase, governed by the propagation of a three-dimensional flame front through the solid propellant. A parametric thrust-curve formulation was constructed to map motor geometry and burn dynamics to time-dependent thrust output, enabling extraction of key performance metrics including total impulse, average thrust, peak thrust, tailing thrust, and burn duration. A Python-based analysis pipeline was implemented to process rocket motor datasheet specifications, fit model parameters, and batch-analyze thrust curve data from CSV files. The model constants were optimized to minimize prediction error across motor classes ranging from $\frac{1}{4}$ A to E. Results showed low median error in average thrust, maximum thrust, and tailing thrust predictions, while larger deviations were observed in total impulse and burn-time estimates, indicating sensitivity to late-stage combustion dynamics and manufacturing variability.