

Statistical Validation of Burn Rate Consistency in Sym-Sorted Solid Rocket Motor Boosters for the Gaganyaan Mission

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Abstract

This paper presents a comprehensive statistical validation of burn rate consistency in sym-sorted SOLID ROCKET MOTOR boosters for the Gaganyaan mission. The study focuses on the critical requirement of thrust balance in paired booster segments, where consistent burn rates are essential for mission success. For this study, segments SYM-SORTED SEGMENT-1 and SYM-SORTED SEGMENT-2 were selected, identified for the Gaganyaan mission, in which critical raw materials such as ammonium perchlorate (AP coarse and fine) and activated copper chromite (ACR) that influence the Agni Grain Burn Rate (AGBR) were sym-sorted to minimize inter-segment variability. The AGBR data were subjected to detailed statistical validation. Descriptive statistics confirmed low variability with %CV < 1%, while skewness and kurtosis values were close to zero, indicating near-normal distribution. Histograms and boxplots showed uniform distribution without extreme outliers. Normality tests further confirmed data normality, validating the use of parametric methods. Variance comparison using the F-test ($p = 0.438$) showed no significant difference between segments. The two-sample t-test ($p = 0.117$) revealed no significant difference in mean burn rates, and effect size analysis indicated the difference was practically negligible (Cohen's $d = -0.34$). Equivalence testing (TOST) confirmed that the mean difference was within the engineering tolerance margin (± 0.0125 mm/s). Bland-Altman analysis demonstrated strong agreement, though limits of agreement (-0.0251 to $+0.0196$) were slightly wider than tolerance, highlighting the effect of raw material dispersion. Control charts showed all data points within 3σ limits, with no trends or special-cause variation, confirming process stability. Overall, the results validate that sym-sorting of critical raw materials effectively minimizes inter-segment burn rate differences and enhances the reliability of SOLID ROCKET MOTOR booster processing for the Gaganyaan mission.

Keywords

AGBR, Burn Rate Consistency, Statistical Validation, Solid Rocket Motor Boosters.