

Supplementary Information for:
Effect of Carbon Black and Aluminum Additives on Combustion
Instability in Paraffin/GOX Hybrid Rockets

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Supplementary Table S1: Complete experimental runs

The following table presents the full dataset of 31 successful firing tests. Notation: G_{avg} = average oxidizer mass flux ($\text{kg}/\text{m}^2\cdot\text{s}$), $\dot{r}$ = average regression rate (mm/s), $r_{0.7}$ = regression rate at 70% burn (mm/s), Δm = total fuel mass loss (kg).

Table 1. Experimental runs summary for PC, PA, and PAA fuels.

Run ID	Fuel	Nominal t_{burn} (s)	t_{burn} (s)	G_{avg} (kg/m ² ·s)	$\dot{r}$ (mm/s)	$r_{0.7}$ (mm/s)	Δm (kg)
1_1	PA	4	3.43	59.00	2.036	2.084	0.0118
1_2	PA	4	3.56	56.46	2.116	2.183	0.0131
1_3	PA	4	3.57	60.01	1.978	2.047	0.0120
1_4	PA	6	5.73	40.72	1.499	1.565	0.0176
1_5	PA	6	5.75	43.68	1.660	1.687	0.0190
1_6	PA	6	5.81	38.50	1.618	1.629	0.0198
1_7	PA	7.5	7.33	36.08	1.345	1.378	0.0213
1_8	PA	7.5	7.33	34.39	1.337	1.419	0.0217
1_9	PA	7.5	7.34	31.10	1.408	1.440	0.0240
1_10	PA	7.5	6.90	32.70	1.680	1.703	0.0264
1_11	PA	7.5	6.82	32.25	1.351	1.377	0.0212
2_1	PC	4	3.32	71.06	1.887	2.001	0.0086
2_2	PC	4	3.63	64.63	1.869	1.905	0.0098
2_3	PC	4	3.39	64.95	2.043	2.080	0.0100
2_4	PC	6	5.41	47.71	1.589	1.610	0.0145
2_5	PC	6	5.68	46.45	1.557	1.568	0.0150
2_6	PC	6	5.55	45.86	1.612	1.641	0.0152
2_7	PC	7.5	7.15	41.49	1.268	1.288	0.0163
2_8	PC	7.5	6.92	40.52	1.326	1.399	0.0166
2_9	PC	7.5	7.15	34.33	1.451	1.465	0.0206
2_10	PC	7.5	6.91	34.64	1.310	1.331	0.0177
3_1	PAA	4	3.64	62.56	1.956	2.023	0.0119
3_2	PAA	4	3.80	52.28	1.823	1.873	0.0126
3_3	PAA	4	3.47	62.25	2.010	2.039	0.0116
3_4	PAA	6	5.52	41.89	1.698	1.704	0.0189
3_5	PAA	6	5.77	41.99	1.582	1.630	0.0185
3_6	PAA	6	5.92	40.52	1.560	1.587	0.0190
3_7	PAA	7.5	7.15	33.07	1.391	1.432	0.0227
3_8	PAA	7.5	7.13	33.09	1.299	1.358	0.0210
3_9	PAA	7.5	7.29	34.85	1.399	1.457	0.0224
3_10	PAA	7.5	7.00	38.14	1.374	1.402	0.0203

Note: The table includes all 31 successful firings. Regression rates are calculated via the time-averaged mass loss method [1]. Uncertainties: $\dot{r} \pm 5\%$, $G_{\text{avg}} \pm 3\%$.

References

- [1] Nagata, H., Nakayama, H., Watanabe, M., Wakita, M., and Totani, T., “Accuracy and applicable range of a reconstruction technique for hybrid rockets,” *Adv. Aircr. Spacecr. Sci.*, Vol. 1, 2014, pp. 273–289.