Burning Rate Study of AP- PVC based Composite Solid Propellants

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Abstract— An experimental analysis has been performed to study combustion of AP- PVC based composite solid propellant using Crawford bomb setup. Dependence of burning rate on pressure, oxidizer loading and oxidizer particle size has also been studied.
Key words: Burn Rate; AP; PVC

I. INTRODUCTION

A solid rocket motor employs solid rocket propellant in its combustion chamber which may account up to 80 - 90% of its weight. A solid propellant is blend of two major chemical entities - a fuel and an oxidizer. As propellant has to undergo a self - sustained combustion, the presence of an oxidizer with fuel is essential. When ignited, propellant undergoes combustion in a controlled manner producing large volume of gaseous combustion products accompanied by high release of heat energy.

II. EXPERIMENTAL

In the present work, it has been attempted to use AP - PVC composite solid propellant and study their combustion aspects. The different composition were used for experimentally studies with prior experience of the mechanical and combustion behavior of AP - PVC propellant at the laboratory. The bimodal AP is taken with mess size 150 and 300. The AP are loaded at 70, 75 and 80 percent's by weight in PVC plastisol processed with equal amount of DBP plasticizer. The basic formulations of the samples consisted of AP - PVC + catalyst are shown in Table 1.

Sr. No.	AP (wt %)	PVC (wt %)	DBP (wt %)	Fe2o3 (wt %)
01	70	15.0	15.0	-
02	75	12.5	12.5	-
03	80	10.0	10.0	-
04	70	15.0	15.0	3
05	75	12.5	12.5	3

Table 1: Formulation of Uncatalyzed & Catalyzed AP-PVC based Composite Solid Propellants

A. Measurement of Burning Rate

The burning rates of AP-PVC composite propellants with and without catalysts have been determined at ambient condition and at different pressures, 2.06, 4.76 and 6.89 MPa, using a conventional strand burner. Nitrogen gas has been used to pressurize the bomb. The dial type pressure gauges have been used to record incoming pressure and pressures in bomb and line. A surge tank has been provided in the set- up to ensure that a strict pressure level is maintained in the bomb. This has been shown clearly in figure 1 and figure 2.

The propellant strands, having two fine drilled holes at a distance of 5 cm to position the fuse wires, were installed in the bomb and igniter wire was suitably placed at apex of the strand. The cap, with the provision for electrical connections in it was tightened on to the bomb. The bomb was then pressurized with nitrogen gas to required pressure level. The necessary electrical connections were made and the strand was ignited to record time with the help of an electrical timer. Similar procedure has been followed for each strand. The burning rates were then determined from the time elapsed between the two fuse wires.

Fig. 1: High Pressure Strand Burner Setup

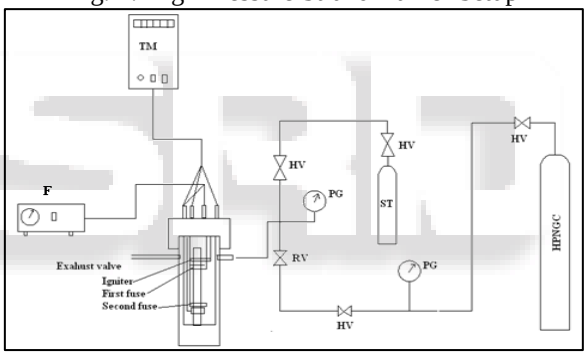

Fig. 2: Line Diagram of High Pressure Strand Burner

III. RESULTS & DISCUSSION

A. Burning Rate Studies of AP-PVC Composite Solid Propellants

The burning rate for 70, 75 and 80% AP and PVC constituents has been explained in Table 2. The nature of the plots in all the cases is identical and the burning rate is found to increase in the combustion chamber by varying nitrogen gas at similar pressure which is used previously.

The increase in the burning rate may therefore be viewed as directly because of its dependence on the combustion pressure in each case. The increase in oxidizer loading also increases the burning rate. The main emphasis has been put in the present investigation is higher loading of AP i.e. 80 wt% does not sustained, which shows brittle nature is not applicable for experimental work.

At 0.101 MPa almost all propellants gives same burning rate i.e. 2.010±0.1. But the result changes with increase in pressure from 5.810 to 9.891 mm sec^{-1} upto 6.895 MPa. The highest pressure shows high burning rate and it also dependent on higher loading. 75% and 80% oxidized loading gives higher burning rate with high combustion index 0.376.

The nature of the plots in all the cases is identical and the burning rate is found to be increase with combustion pressure. On comparing of the three set of burning rate data (Figure 3), when the AP loading increased in the propellant, the burning rate, as also the nominal combustion pressure increases. The increase of AP loading ensures the combustion reaction to reach its completion and even the burning surface temperature and rate of condensed phase reactions may be taken have increased, not to say that the gas phase reactions and the heat in flux to the burning surface would definitely increase.

It is observed that incorporation of Fe_2O_3 as a catalyst increases the burning rate of AP-PVC propellants at all pressures. However increases in burning rate due to addition of catalyst depends on the nature of catalyst incorporated.

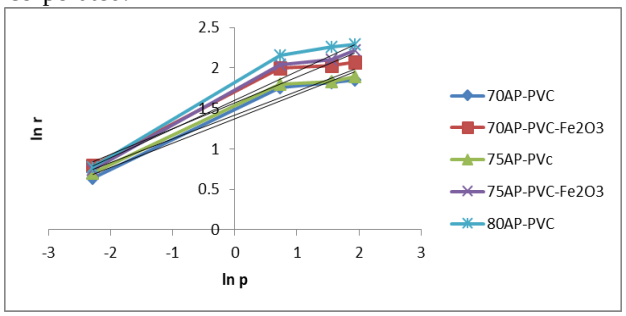

Fig. 3: Comparison of Burning Rate 70, 75 & 80% of AP-PVC Composite Solid Propellant with Catalyst

Types of Propellant	Burning Rate (mm sec^{-1}) Pressure (MPa) 0.101	4.760	2.068	6.895	a	n
70% AP - PVC	1.89	5.810	6.172	6.410	4.66	0.301
70% AP - PVC with 3% Fe_2O_3	2.20	7.352	7.64	7.93	5.84	0.316
75% AP - PVC	2.010	6.03	6.261	6.626	4.87	0.292
75% AP - PVC with 3% Fe_2O_3	2.101	7.66	8.163	9.216	5.91	0.356
80% AP - PVC	2.164	8.62	9.619	9.89	6.55	0.376

Table 2: Burning Rate of Uncatalyzed and Catalyzed AP- PVC based Composite Solid Propellants at Different Presures

Types of Propellant	ln r ln p -2.292	0.726	1.56	1.93	ln a	n
70% AP-PVC	0.637	1.759	1.820	1.857	1.539	0.301
70% AP-PVC with 3% Fe_2O_3	0.791	1.994	2.033	2.070	1.764	0.316
75% AP-PVC	0.698	1.796	1.834	1.891	1.583	0.2927
75% AP-PVC with 3% Fe_2O_3	0.742	2.036	2.099	2.220	1.776	0.356
80% AP-PVC	0.771	2.154	2.263	2.291	1.879	0.376

Table 3: Pressure Dependence of Burning Rate of AP - PVC based Composite Solid Propellants at Different Pressure

IV. CONCLUSIONS

1) It was observed that the burning rate increases with increase of chamber pressure and also, the combustion pressure rate increases with increase in oxidizer loading for all the cases. Further, the phase transition, melting and decomposition processes of the oxidizer are pressure sensitive and associated peaks register a positive temperature shift with pressure.
2) Conversely, the addition of catalyst with 3 wt% ferric oxide especially in high pressure region shows drastic increase in burning rate with increase in AP % loading.

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