Study of Ammonium Nitrate-based Gas Generator Propellants

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***Abstract*:- Solid propellant-based gas generators are popularly used for industrial and space applications. Ammonium Nitrate (AN) could be preferable when considering the most desirable properties like Burning rate, Thermal decomposition and Low flame temperature. For analysis purpose the configurations of AN composite propellants with potassium nitrate (PN), guanidine nitrate (GN) and hydroxyl-terminated polybutadiene (HTPB) were selected and tested. Propellant characterizations were carried out through burn rate test, differential scanning calorimetric (DSC) study, and thermal gravimetric analysis. Upon increasing the chamber pressure and solid loading the burning rate of the propellant is found to be linearly increasing. Also it is found that when increasing Ferric Oxide(FO) the burn rate and adiabatic flame temperature of the propellant is also increased but reduced flame temperature.**

Keywords: Ammonium nitrate, Potassium nitrate, Guanidine nitrate, burning rate.

1. INTRODUCTION

Solid propellants have been widely in use for gas generator applications that require a large volume of gas to be produced in a short time. Such composite propellants are preferable for space-based applications. They are composed of a oxidizer binder, fuel, and a curing agent. Hydroxyl-terminated polybutadiene (HTPB) is a preferred binder which is stable during storage and operating conditions, for solid composite propellants [1]. Ammonium nitrate (AN) is a good oxidizer because of its properties like better gas horse power per unit weight, yielding noncorrosive exhaust and low flame temperature. However 'AN' compositions take longer to ignite and hence require other catalyst to be added to promote ignition at a low pressure and to achieve smooth and stable burning [2].

HTPB is a commonly used catalyst to bind the fuel and the oxidizer in solid propellant-based rocket motors. The present study focuses on the adiabatic flame temperature of different configurations of gas propellants based on flame temperature [3]. The focus of this paper is to formulate a propellant that gives low flame temperature.

2. EXPERIMENTATION

Particle size ranging from 200 to 300 µm for 'AN' and 150 µm for PN Samples are separately pulverized into fine powder and mixed thoroughly to the required masses using dematerialized water [4]. The mixture is solidified and dried by heating mandrel at 50°C for 3 days. The AN/PN powder can then be mixed with HTPB and ferric oxide (FO) and casted to the required shape in a pressurized casting chamber [9]. The propellant is cured inside an electric oven for 1 week at 50°C. Now the propellant is ready for strand burner testing and DSC and TGA Study. Fig.1 shows the specimen of a propellant called as strand [5].

Table: 1 Chemical composition of propellant samples

Constituents	Percentage in each sample			
	1	2	3	4
Ammonium nitrate	70.20	70.20	66.40	68.00
Potassium nitrate	14.00	13.500	14.50	13.00
Ferric oxide (catalyst)	-	0.25	-	0.21
Guanidine nitrate	-	-	-	-
Solid loading (1–4)	85	85	80	83
HTPB system	13	13	17	17.50

Differential scanning calorimeter (DSC) study is a method of thermal analysis to study thermal transitions and reactions [8]. The DSC analysis of endothermic or exothermic processes provides information about the physical and chemical changes. In this current study, sample mass from 2.0 to 3.0 mg, temperature at 20–350°C, and heating rate at 5 K/min were chosen for this analysis. Fig.2 shows the set up of strand burner [10].

Fig.1 Specimen of a propellant (strand)

Fig.2 Set-up of a strand burner

Each propellant strand measuring 40×4×4 mm was electrically ignited and the time taken for each strand to burn along its full length is measured. Pressure range of 30 to 75- bars is used. Now the burn rate is obtained.

3. RESULTS AND DISCUSSION

3.1 Burn Rate Characteristics

For the present study, four such propellant samples were prepared with different oxidizer, fuel ratio, and binder proportions. It has been found that when the pressure is increase the burn rate of propellant also increased linearly, in the range of 1.20 to 3.00 mm/s. For example, burn rate for AN/PN/HTPB on 80% solid loading was 1.30 mm/s at 35 bar and 2.5 mm/s at 75 bar, whereas for AN/PN/HTPB/GN, it was 1.60 mm/s at 35 bar and 3.00 mm/s at 75 bar at the same solid loading. Hence the burn rate is a direct function of chamber pressure as well as the proportions of oxidizer, binder, and plasticizer used in a propellant. It could be noted that guanidine nitrate (GN) increased the burn rate of the propellant. Also adding FO to AN/PN/HTPB has increased the burn rate slightly at the solid loading rates of 80% and 82.5%. However the burn rate has increased with decreasing quantity of HTPB, and flame temperature decreased with increasing quantity of HTPB. Fig.3 to Fig.5 shows the variation of burn rate with pressure.

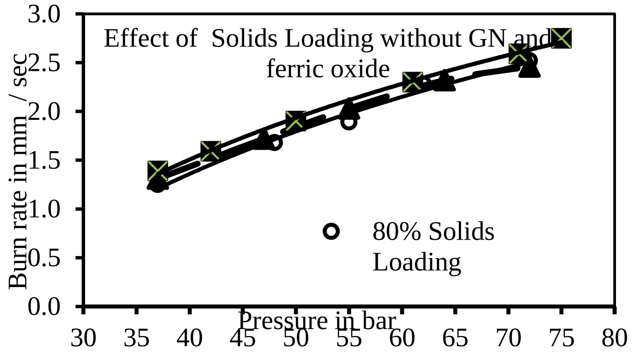

Fig.3 Shows the variation of burn rate with pressure

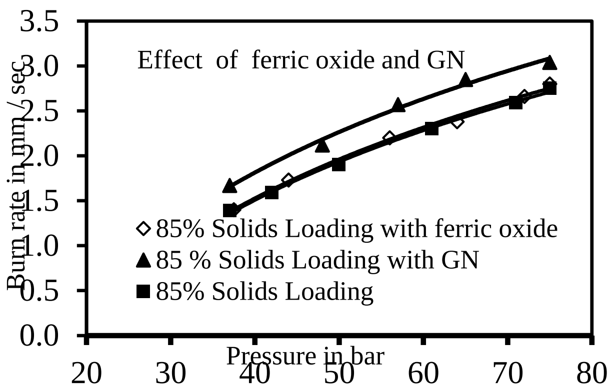

Fig.4 Shows the variation burn rate with pressure

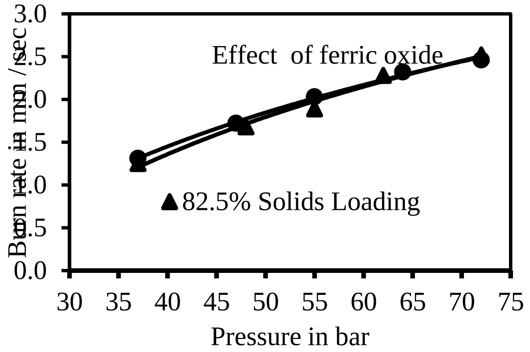

Fig.5 Shows the variation burn rate with pressure

3.2 DSC Study

The thermal decomposition of propellant samples was carried out at a heating rate of 5 K/min in nitrogen gas environment. The DSC curves have two endothermic dips followed by an exothermic peak. The endothermic peaks were due to the phase transitions in AN.

3.3 Flame Temperature

As the proportion of oxidizer increased in the sample, the flame temperature increased. Flame temperature increased with increasing pressure and solid loading for all samples. For AN/PN/HTPB at 80% solid loading, flame temperature at 90 bar was 1502°C, and for AN/PN/HTPB at 82% solid loading, flame temperature at 90 bar was 1240°C. For AN/PN/HTPB/FO at 85% solid loading, flame temperature at 90-bar was 1520°C, whereas for AN/PN/HTPB/GN, flame temperature was lowest at 1200°C.

4. CONCLUSION

Remarkable burn rate and flame temperature have been obtained for the GN-based propellant for the four different compositions of propellants subjected to the present study, the gas generated during combustion has also been of lower in temperature. Thus, GN is found to have good potential for use as a base material in solid propellants for aerospace applications and in heavy industries.

5. REFERENCES

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