Thermal Decomposition Study of AP- PVC based Composite Solid Propellants

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Abstract— The mechanism of thermal decomposition of each composition have been determined by NETZSCH simultaneous thermal analyser, comprising differential scanning calorimeter (DSC) and thermo- gravimetric analyser (TGA). The data indicate that the burn rate increases with increase in oxidizer loading as well as with pressure.

Key words: Thermal Decomposition; AP; PVC

I. Introduction

Solid propellant rocket motors have found wide application primarily owing to inherent simplicity, high degree of reliability due to absence of moving parts and flexibility among other advantages. This system is a ready - to - use system and hence finds wide use in military applications for both tactical and strategic weapons. It is capable of delivering large quantum of thrust for a short duration required for the boosters. It may be mentioned here that with the advances made in propellant chemistry and processing techniques, solid propellants are now being used for fairly long burning times to find acceptance in space shuttle application.

Solid propellant pose less toxicity hazard, therefore it is easy to handle. Moreover, multi staging and clustering is very much possible to augment the generated thrust. The density of solid propellants is much higher than liquid counterpart which amply compensates for its comparatively lower performance expressed as specific impulse. The combustion chamber pressure in the solid propellant engine is generally higher than in the liquid propellant rocket motors.

II. Objective of Work

Although the initial work in solid propellant engines centered on the homogenous propellants, composite propellants have found wider use due to a number of reason: the characteristics of composite propellants can be altered easily by changing particle size of the oxidizer. Also, the oxidizer to fuel ratio can also be very easily controlled yielding altogether different combustion characteristics.

III. 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 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 Unanalyzed & Catalyzed AP-PVC based Composite Solid Propellants

A. *Thermal Decomposition Study*

Simultaneous TGA-DTA/DSC measures both heat flow and weight changes (TGA) in a material as a function of temperature or time in a controlled atmosphere. Simultaneous measurement of these two material properties not only improves productivity but also simplifies interpretation of the results. The thermal decomposition studies of composite solid propellant with and without catalyst were carried out on a NETZCH Simultaneous Thermal Analyzer (STA 409 / PG) shown in Fig. 3 and Fig 4.

The apparatus consist of furnace, thermostat, vacuum pump, system controller, power unit and gas control unit. The unit is a heat flux DSC which is coupled with an integral cooling facility. The heart of the instrument is furnace unit consisting of special sensor made of high resistance corrosion resistant alloy. The sample and the reference crucibles were accurately positioned in the circular wells within the furnace unit. The sensor plate is closely coupled to the cell body which is constructed from 99.99% silver. The cell purge gas is important in maintaining calorimetric accuracy and in ensuring that corrosive gases evolved from the sample are safely vented away. Nitrogen gas is used in this study.

The procedure included the temperature calibration of DSC/TGA which was done in the temperature range of ambient temperature to 600^0C using standard samples of Indium to ensure the accuracy of results and a perfect base line was obtained. About 1mg of propellant sample is taken in the aluminum crucible. The crucible with the weighed sample was placed in the furnace unit. The blank crucible is also placed in its place. The experiment is started when the thermostat attain the temperature is 2^0C more or less than ambient temperature. Then the nitrogen gas was started. The temperature range was set from ambient to 600^0C. The furnace was programmed to attain a heating rate of 10 ^{0}C/min. The heat flow rate was recorded as a function of temperature by the NETZCH software. The thermograms were used for the interpretation of thermal decomposition data of various samples studied. The TGA studies are also done simultaneously and mass loss with increase in temperature are calculated.

Fig. 1: Simultaneous Thermal Analyzer

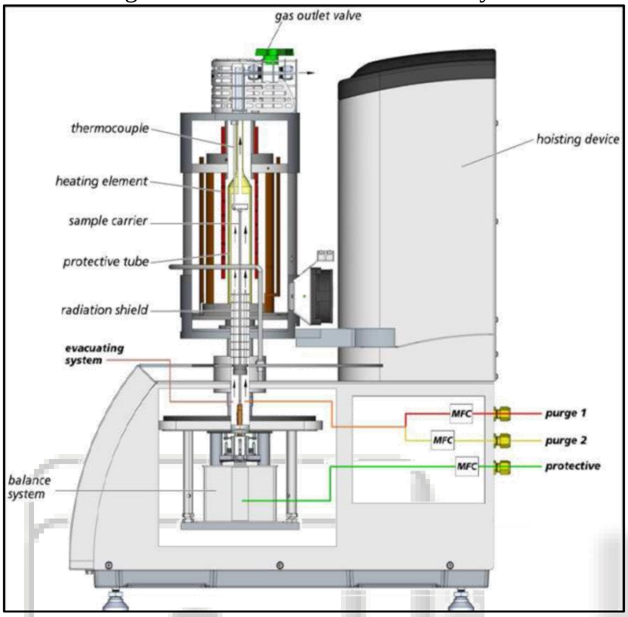

Fig. 2: Internal Structure of the Simultaneous Thermal Analyzer

IV. RESULTS & DISCUSSION

A. Thermal Decomposition Studies of AP-PVC Composite Solid Propellants

The DSC thermograms of AP – PVC composite solid propellants are given in figure 6. A DSC comparison of AP - PVC composite solid propellants is given in the figure 6. It is clearly shows that the onset temperature comes in between 106±2 except 70 wt% composition. The endothermic peak from orthorhombic to cubic crystal forms at 245 ± 2 ^{0}C and subsequent exothermic decomposition at 378.7 ^{0}C (table 4). But in presence of Fe_2O_3 the exothermic peaks reduces at 301 ^{0}C.

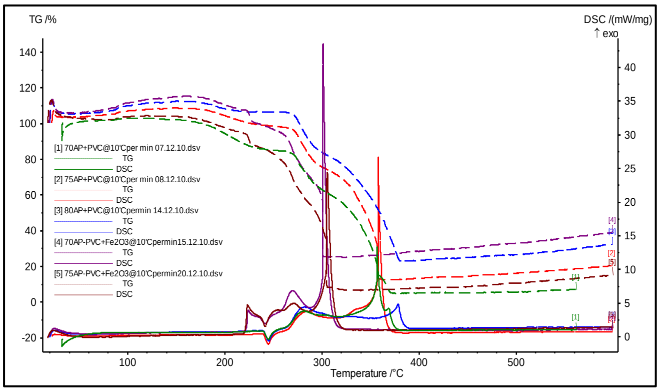

Fig. 3: Comparison of STA graph showing DSC/TG of AP - PVC composite solid propellant

Types of propellant	Onset temperature (°C)	Endothermic peak temperature (°C)	Exothermic peak temperature (°C)		Net Exothermicity (J/g)	
			I[st]	II[nd]	I[st]	II[nd]
70% AP - PVC	142.3	245	282	357.3	252.2	417.3
70% AP - PVC with 3% Fe_2O_3	105.7	242	270.5	301.7	420.3	914.6
75% AP - PVC	116.6	245	235.5	358.6	273.2	429.7
75% AP - PVC with 3% Fe_2O_3	106.5	242	271.0	305.9	356.0	790.3
80% AP - PVC	103.5	246	282.9	378.7	395.7	212.8

Table 2: DSC Results of Uncatalyzed & Catalyzed AP - PVC based Composite Solid Propellants

B. Thermo-Gravimetric Analysis

The thermo-gravimetric studies of AP-PVC based composite solid propellants have been carried out under nitrogen atmosphere at a heating rate of 10 ^{0}C/min using Simultaneous Thermal Analyzer. The thermograms of all the five sample and comparison of the present investigation have been recorded in Figure 6. The AP - PVC data reveals that all the composite solid propellant are stable up to temperature of 257 ± 40 ^{0}C. An analysis of result that the 20% mass loss and corresponding temperature reveals that initial decomposition process occurs at 257 ^{0}C. The themal decomposition temperature in case of Fe_2O_3 is lesser as comparison to uncatalysed AP - PVC composite solid propellant.

V. CONCLUSIONS

1) The thermal decomposition of AP - PVC clearly shows an endothermic phase transition peak appears at 245 °C and subsequent exothermic peak temperature value decreases with the addition of ferric oxide.
2) The thermo - gravimetric analysis shows that 80% mass loss in AP - HTPB based propellants decomposes at 397.6 °C.

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