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Effect of Additives on KNO_3 based Solid Propellants

Prakhar Jindal
Department of Aerospace Engineering,
Amity University Haryana, Gurgaon.

ABSTRACT

This paper involves the study of optimization of burn rate techniques. Addition of small amount of inorganic and organic substances alters the burn rate. The purpose of this paper is to study the effects of additives on burn rate. Also optimization is done using changing the composition of the reacting species in the propellants. We used AP-PVC and black powder based propellants for the optimization. Additives, Al powder and Iron oxide were used in same propellants strand formulation. These materials are generally used in 1-5% of amount of basic propellants by weight. Optimization of propellant was studied by observing their burning characteristics of the propellant. The result shows that burn rate increase for some additive and decrease with some additive based on the composition of the additives and basic propellant.

I. Introduction

The basic thing of any propellant is computation of burn rate before its use and it is helpful in further calculation. This paper describes the optimization of burn rate of specific propellants based on potassium nitrate (KNO_3) and Ammonium Perchlorate. Since these compounds contain a high amount of oxygen content, the study is constrained to this oxidizer in the above propellant only. KNO_3 is a neutralized salt from nitric acid that has very high oxidizing power and any potassium base say potassium hydroxide and Ammonium perchlorate is a derivative of perchloric acid that also contain high percentage of oxygen. Apart from content of oxygen in KNO_3 it is very cheaply available and can be manufactured in very less amount of time. Industrial production of KNO_3 is very inexpensive. It is like a conventional oxidizer used from 80's. Ammonium perchlorate is another latest and high oxygen content used in the propellant. This study is based on Ammonium perchlorate and polyvinyl chloride propellant in which PVC acts as multifunctional substance as fuel as well as binder. This significant property made us to study the burn rate of these propellants and their optimization using some additives.

Additives used here are Aluminium powder of industrial grade and Fe_2O_3 powder. Use of these additives is based on their property of heat absorption. Considering activation energy of any reaction, if after taking the activation energy from the environment gives more energy in the combustion then it is suitable for the addition in the basic propellant formulation. Since metal have the above described property, they are used for the burn rate optimization and Aluminium contains three electrons in its outer shell and thermal property is low i.e. low melting point. These characteristic features lead this metal for distinguishing burning and use in the propellants as an additive.

Burn rate empirical formula was given by;

$$r = aP^n$$

where, r is the burn rate

a is proportionality constant
P is the chamber pressure
n is Pressure index

II. Literature Review

S.R Jain [11] presented a study about the different binders used in solid propellants based on the property of binding and environmental concern. He proposed AP is a good binder and fuel but only disadvantage of thus is formation of HCl gas during oxidation of AP which is a harmful gas. The first sugar rocket was made by colburn in 1947[12] Gordon and McBride in 1974 said that burn rate is altered by combustion instability inside the combustion chamber. K Kishore et.al [13] worked on the ignition delay of AP propellant. He has given empirical relation on the basis of concentration of propellant. He proposed ignition delay is inversely proportional to 2.32th power of concentration of oxidizer below 65% and at a temperature of 595K, Also it is inversely proportional to 1.14th power of concentration above 65% of oxidizer. Krishnan, [14] described that the procedure of mixing of additives in the propellant also plays great role in determining the burn rate. Bozic v.[15] worked on Ammonium perchlorate based propellants and its derivative and found out that basic ammonium perchlorate with PVC gives burning rate of 3 mm per second(averaged).

After going through the literatures certain research gaps are as follows:

- Optimization of burn rate using additives.
- Chemical effects of additives on the burn rate of propellant.
- Compatibility of different additives with different compositions of propellant.

III. Methodology

Selection of propellants

Our study is focused in the burn rate of Black powder, sugar based propellant and Ammonium perchlorate propellant. The selection criteria for these propellants include the following points

- Economy
- Availability
- Amount of Oxidizer content
- Amount of fuel content
- Amount of solid materials residue after combustion
- Reaction temperature
- Amount of exhaust gases

These criteria make the study more easy and link to the recent use of rocket propulsive fuels Casted in another plate as describes above, and cut in strands of same dimensions as above.

Assortments of these chemicals are done on the basis of comparative study of their properties. Black powder is the basic and conventional explosive used in Indian history and has very high burn rate. It consists of charcoal and sulfur mixed with potassium nitrate.

Ammonium perchlorate, a salt of perchloric acid containing high amount of oxygen that can be used as an oxidizer. Polyvinyl chloride acts as fuel and binder as well that is also cheaply available. These special properties of species make us to choose it as a propellant in our study.

Propellant Processing

The reactions taking place in the propellant are given under as for black powder is

$$16KNO_3 + 6S + 13C \rightarrow 5K_2SO_4 + 6N_2 + K_2S + 11CO_2$$

Reaction of ammonium perchlorate as combustion is

$$NH_4ClO_4 \rightarrow HClO_4 + NH_3 \rightarrow 2O_2 + HCl$$

Ammonium perchlorate a salt of per chloric acid and ammonia gas was mixed with a binder PVC i.e. polyvinylchloride and mixed with demoisturised di-butyl phthalate as a plasticizer. After mixing the species according to required number of moles it was stirred thoroughly for 3-4 hours continuously. 8-10% of plasticizer was added to make the mixture able of stirring at initial stage but since it is volatile we had to use 30-40% of plasticizer for the stirring purpose. The mixture was carried to next stage casting, making strands and for the curing about 100°C in the oven for 20 hours and finally taken out as strands of above dimensions.

The preparation of the gunpowder starts with obtaining a fine mixture of all the components such as Potassium Nitrate, Charcoal and Sulfur. To obtain the fine mixture of the components ball milling process for each component is carried out. After this process the required amount of components as Potassium Nitrate (75%), Charcoal (13%) and Sulfur (12%) is taken and mixed properly .After the mixing process, water (8%) is added in a step wise manner along with the mixing of the propellant is done until a thick clayey paste is obtained. In order to remove the excessive water, numbers of clusters from the clayey paste is made and are allowed for soaking using the soaking paper. After the excess water is removed then the casting of the propellant is done in the appropriate container.

Smaller the particle size of combining species better will be the combustion. This mixture is carefully made into strands of standard size as discussed above, such that no air bubbles should trap in the propellant. Air trapped will alter the burn rate as presence of extra air will provide extra oxygen and less propellant.

IV. Results and Discussion

This section deals with the graphical representations for the results obtained from the above experimentations. These results will be used for the explanations regarding the burn rate for the propellant combinations with certain additives.

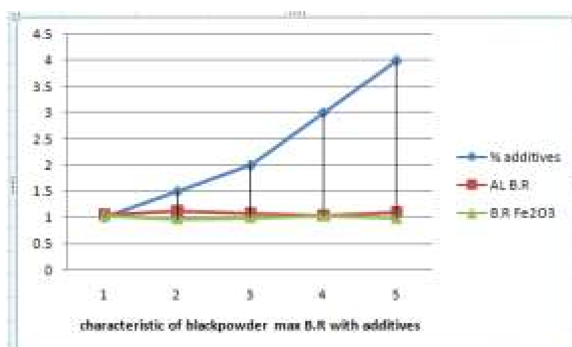

Fig.1 Burn rate of Black powder with additives

Fig.1 represents the burn rate of black powder along with the addition of different additives. From the following graph we can analyze that the burn rate of the black powder is maximum when aluminium is replaced by fuel for 2 percent but upto some extent after which even increase in the additive decreases the burn rate of the propellant. In case of the additive as Fe_2O_3 the burn rate is maximum for 1 percentage in place of fuel. From this graph we can study that the burn rate of propellant increases for only a certain amount if additives added after it even decreases as of normal propellant.

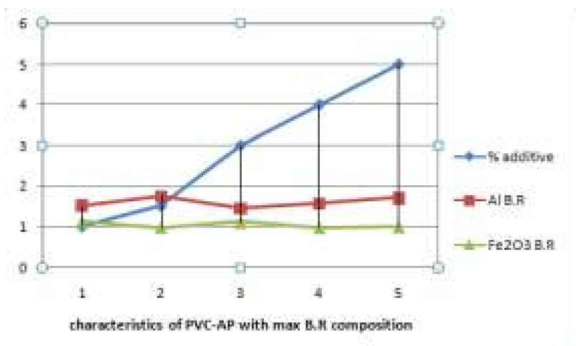

Fig.2 Burn rate of PVC/AP with additives

Fig.2 represents the burn rate of PVC/AP along with the addition of different additives. From the following graph we can analyze that the burn rate of the PVC/AP is maximum when aluminium is replaced by fuel for 2 percent but upto some extent after which even increase in the additive decreases the burn rate of the propellant .In case of the additive as Fe_2O_3 the burn rate is maximum for 1 percentage in place of fuel. From this graph we can study that the burn rate increases if we add additives with the normal composition for some extent but after which the increase in the additive doesn't affect the burn rate characterization of the propellant instead it decreases further with increase in additives.

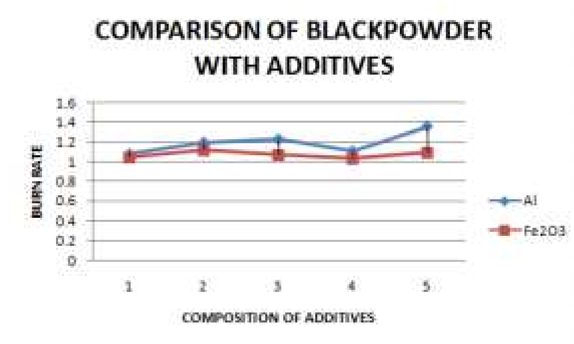

Fig.3 Burn rate comparison of Black Powder with additives

The above graph represents the burn rate comparison for Black powder with different additives. According to above graph, it can e seen that the burn rate is high for the propellant with Al additive as compared to that of the Fe_2O_3. The reason leads with the presence of more number of electron at the outer orbit or shell as compared to Fe_2O_3 which makes Al more reactive than Fe_2O_3. Other reason may lead Al being a single or neutral element and Fe_2O_3 being compound, hence making it more element.

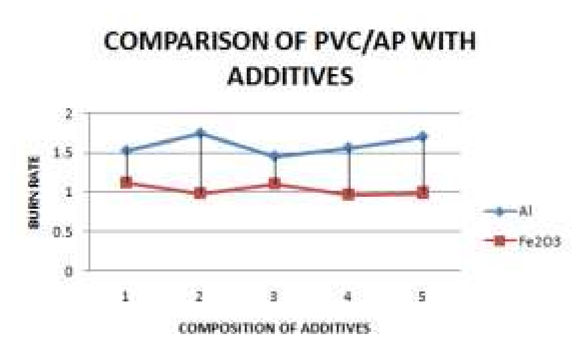

Fig.4 Comparison of Burn rate of PVC/AP with additives

This graph signifies the burn rate of PVC/AP for different additives. The reason behind is the presence of more number of electrons at the outer orbit of aluminum than that of the Fe_2O_3. From the following comparison it can be seen that burn rate of Al is higher of PVC/AP than the Black powder.

V. Conclusion

- Burn Rate of propellants increases with addition of the additives such as Al and Fe_2O_3 .
- The increase in the burn rate of propellant with the addition of additives is limited to some extent, after which the burn rate decreases with increase in additive.
- Burn rate of both the propellant is higher when Al is added as an additive in normal composition as compared to Fe_2O_3 addition.
- In case of PVC/AP it gives higher burn rate when Al is added as additive as compared to Black Powder

References

[1]Wan Khairuddin Wan Ali; Ang Kiang Long; Mohammad Nazri Mohammad Jaafar,"Experimental Solid and Liquid Propellant Rocket Development" ,University Technology Malaysia : 1992-2011

[2] Ian von maltitz," Black powder manufacturing, testing and optimization"

[3] Dr. Abhijeet Singh, "Sugar Based Rocket Propulsion System- Making, Analysis & Limitations"

[4] Sutton and biblarz; "Rocket propulsion elements"

[5] A.K Chatterjee; "Combustion studies of aluminized PVC plastisol"

[6] A.R Kulkarni, K.C Sharma;" Burn rate modeling of solid rocket propellant"

[7] Sidhant Singh; "Solid Rocket Motor for Experimental Sounding Rockets", University of Petroleum and Energy Studies Dehradun, India.

[8] David Newey, "Optimization of ammonium nitratesolid rocket fuel", Brigham Young University – Idaho, December 2013

[9] Burning rate control factoring solid propellants Eleventh & Twelfth Quarterly Technical Summary Report. For the Period 1 July 1961 to 31 December 1961

[10] Bozic Effects of Burning Rate Modifiers on the Modified Polyvinyl Chloride-Based Propellants. Ministry of Environment and Spatial Planning, Belgrade, Serbia.16-18 June, 20

[11] S R Jain,. "Solid propellant binder"

[12] Stuart Leslie et al "Proposal for the Inclusion of KNO3/Sugar Propellants", October 4, 2002

[13]K. Kishore and S.Sankaralingam "Studies on the Pyrolysis of Composite Solid Propellants leading to Ignition" July 19

[14] Krishnan, S.; Swami, R. D. Effect of Catalyst Mixing Procedure on the Combustion of AP/HTPB Solid Propellants. Journal of Propulsion and Power 1997, 13(2), 207-212.

[15]Bozic. V" Effects of Burning Rate Modifiers on the Modified Polyvinyl Chloride-Based Propellants" International Conference on High Energetic Materials and Dynamics of Ultrafast Reactive Systems; Varna, Bulgaria;june 2010.