Ability Test of Solid Composite Propellant Burning Rate Based on Composition of Fuel-Binder Ratio Using LAPAN's HTPB

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Abstract: One of the most important parameters for designing the rocket motor is the burning rate of the propellant used, therefore it is important to know the effect of changes in raw material composition comprising propellant oxidizer, fuel-binders and additive metal on the burning rate. Fuel-binder used is polyurethane which is the reaction product of HTPB and TDI. HTPB used herein are local material that is the synthesis of HTPB in LAPAN's laboratory. Before it can be declared fit for use as a propellant binder, it must do some validation. One of validation that has been done is to test the value of the burning rate of propellant produced with local HTPB binder. In this study has been testing the propellant burn rate at three different compositions using the method of Crawford Strand Burner. The composition is made by changing the oxidator and aluminum content, and the content of binder used while maintaining at ratio of HTPB / TDI, 7 : 1. The test results showed the composition II has the lowest burning rate value, while the composition III has the highest burning rate. With this burn rate measurability, then this self HTPB fit for use as a binder for the manufacture of the solid composites propellant.

Key Words: local-HTPB, fuel-binder, propellant, burning rate, strand burner

1. Introduction

Propellant in rocket motors, categorized into; propellant homogeneous, heterogeneous and composite. Selection of propellant determine the difference in input parameter of a rocket motor. The key point in understanding the influence of propellant is the fuel rate[1]**.** Heterogeneous solid propellant composite consists of three basic components: an organic polymer that acts both as a binder or fuel, oxidizer that contribute to the formation of gas and metals (fuel-metal) which provide additional energy in the propellant[2].

The burning rate propellant is one of the most important parameter in the design of the performance of a rocket motor[3]. The burn rate or burning rate is the quantity of a linear burn rate of a compound such as a candle or a solid propellant. It is measured in length per unit time, and the most influential variable is pressure and temperature. For solid propellant, the method most commonly used to measure the rate of fuel is Crawford Type Strand Burning Rate Bomb System (also known as Crawford Burner or Strand Burner), as specified in MIL-STD-286C[4].

Burning rate measurement results expressed in a graph of length per unit time vs pressure, or length per unit time vs. Temperature. High burning rate (exceeding the speed of sound) is known as detonation; a few meters/sec is known as deflagration; a few cm/sec is known as burn or smoldering. While the burn rate of 0.01 mm/sec to 100 mm/sec called rapidly decomposing. The burning rate obtained from a strand burner generally smaller 4-12% than the burning rate obtained from the static test rocket motor. It is caused by high-temperature conditions in the combustion chamber of rocket motors are not represented on a strand burner. Also the heat propagation characteristics are different.

The high burn rate of propellant help maintain thrust at a high level without requiring the complexity of the design geometry grain. Applying a high burn rate that can simplify the geometry of the propellant grain, which is not only easier to produce, but also tend to have better mechanical strength, it is important for all missiles experiencing high G acceleration. Following that, the high burn rate of propellant causes the acquired volumetric loading is also higher, so overall can reduce the dimensions and weight of the missiles[5-7].

The success of the rocket motor design and development depends significantly on the knowledge of the behavior of the selected propellant burn rate to operating conditions and limitations of the design[7].

This study aims to obtain the burn rate from several compositions of LAPAN's composite solid propellants, using the fuel-binder results of independent development. The results of the composition tested using strand burner to get the burn rate data vs pressure. Burn rate data obtained will be used to assess whether self HTPB can be used in the design of propellant for rocket motors.

2. Theory

Solid propellants has several advantages over liquid propellant, composite propellant is more expected in several applications. All the solid propellant has a very high reliability in design. Once ignited, the solid rocket will operate normally in accordance with the thrust that is designed, primarily determined by the configuration of the propellant grain. The amount of thrust that can be obtained from the design grain is mainly determined by the composition of the propellant. The composition of the propellant used is usually made up, oxidizer, binders, additives (curative, plasticizers, bonding agent) and metal. Ingredients used in this study are outlined below8).

2.1. Oxidizer

The main use of ammonium perchlorate (AP), NH_4ClO_4, is as oxidizer in solid propellants. It is also used in explosives, mining, and fireworks. It is produced from anhydrous ammonia, dilute hydrochloric acid, and sodium perchlorate. Ammonium perchlorate is a white crystalline solid with a molecular weight of 117.49 and a specific gravity of 1.95. Ammonium perchlorate slightly soluble in water. Pure ammonium perchlorate, stable below 65.6 °C and undergo an endothermic reaction at 240°C, followed by two exothermic stages at 275°C and 470°C. Get contaminated with metal salts such as copper, chromium, and iron.

Ammonium perchlorate is a strong oxidizer that does not explode unless it is contaminated. This is an extreme fire danger in contact with oxidizable substances, organic substances, ammonium compounds, cyanide, sulfur and sulfur compounds, powdered metals, phosphorus and metal salts. Strong acids can react with perkhlorat to produce perchloric acid, dangerous explosives when in contact with a material that can be oxidized.

Ammonium perchlorate containing 34% oxygen, is much less than with sodium or potassium salts. However, due to the weight fraction of solids in the combustion gases, the propellant of ammonium perkhlorat has overall performance characteristics exceeding that obtained using other oxidizer. Also have the advantage because they do not produce smoke. Ammonium perchlorate propellant can produce hydrogen chloride and other chlorine compounds during combustion. In high moisture or humid atmosphere, the hydrogen chloride will condense into fog dangerous hydrochloric acid. The exhaust gases from the rocket motor is toxic, as well as being highly corrosive to many metals.

Grain shape and particle size of the oxidizer is very important in the formulation of the propellant, affect the rate of fuel, processing properties and physical properties of the propellant. In general, a decrease in particle size resulted in an increase in the rate of fuel, with the most significant effect in the submicron range up to about one hundred microns. The influence of crystal size is sometimes very important because all the propellant can be made with the same composition just by varying the particle size.

In practice, most composite propellant is multi-modal, which consists of several different sizes oxidizer in a particular ratio. Grain larger than 200μ and 400μ (round or spherical shape) is used to produce the smallest possible surface area per volume oxidant. Finer oxidizer crystals then enter into a gap between the larger particles. The end result is a solid propellant with high solid loading and thereby maximize the ISP and the mechanical properties of the propellant.

2.2. Binder

Hydroxyl-terminated polybutadiene (HTPB) is a clear liquid form long chain polymers. First used as a binder and fuel in the solid propellant by Aerojet in 1962. HTPB is a polyurethane because cured with isocyanate 9). Reaction to crosslinking provided by the hydroxyl radical (-OH) at several points along each chain, and at the end of the terminal10,11,12). This is a three-dimensional matrix of cross-linked rubber chains that imparts essential mechanical properties to the propellant. Propellant ability to withstand againts high strain rate is directly related to the low-temperature properties of its binder, such as extension and brittle point. With a glass transition temperature near or below -100, HTPB has excellent characteristics.

HTPB is a binder material that is most widely used. High solid fraction (88% to 90% AP and Al) can be obtained and have relatively good physical properties at temperatures of -50 to 65ºC**13)**. Several different chemical formulas can be found on HTPB, one of which is in fig 2.2.1, with the molecular formula $C_{10}H_{15}.4O0.07$; a molecular weight of 136 752 g/mol; oxygen balance -323.26%; the density of 0.916 g/cc; the melting point of 241ºC and enthalpy -51.88 kJ/mol (-90.68 kcal/kg).

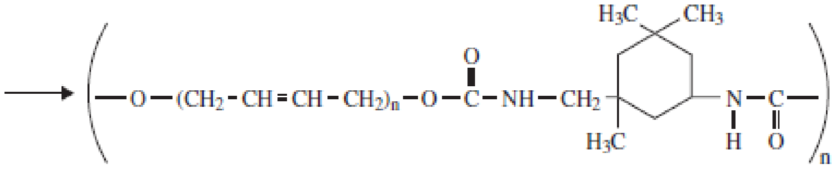

HTPB Binder

Fig 2.2.1 . Molecular structure of HTPB[9, 14)].

2.3. Curative

As mentioned earlier, HTPB cured with isocyanates. Some require a high temperature (oven) of 125 °F to activate, while others such as isophorone diisocyanate (IPDI) or PAPI, active at room temperature. All curative are toxic compound, with some more than others. Among the room temperature curing agent, toluene diisocyanate provides the shortest pot-life and most toxic.

Curing reaction between HTPB hydroxyl groups and crosslinking and isocyanate group TDI causes the dough viscosity increases over time. Propellant mixture should be printed before the curing reaction causes the propellant is no longer pourable. The time needed to reach the threshold condition is commonly called a pot-life of the dough propellant.

2.4. Fuel Metal

Fine metal powders added to virtually any propellant composition.These additions provide multiple benefits and create very complex interaction during combustion. Spheroidal aluminum is the metal most used in the composite propellant, the formulation between 1% and 18%, propellant ballistic performance is greatly improved, the Isp can be increased up to 10% compared with the same formula but without the metal[11)]. It should be underlined, that this effect is not significant on a small rocket. This happens because the metal does not remain in the combustion chamber in a long time, and immediately exhausted exit the nozzle in molten form.

The addition of aluminum in the propellant also provides acoustic oscillation damping, then minimizes the chance of cracking of grain at the beginning of ignition, also makes it easier ignited, especially on a small rocket motors.The effect of adding aluminum to the burn rate is usually not too large, it can be positive or negative.

2.5. Burn Rate

2.5.1. Burn rate equation

The burn rate of propellant is influenced by several factors, the most important are: the composition of the propellant; propellant conditions; rocket motor combustion chamber pressure; temperature first propellant grain; combustion gases velocity across the surface of propellant combustion; local static pressure; as well as the motor speed or spin.

Representation of the effect of pressure on the burn rate is expressed by equation Saint Robert's Law:

$$r = r_o + a.P^n \qquad (1.)$$

Where r is the burn rate, r_o is a constant (usually taken zero), a is the burn rate coefficients and n is an exponent of pressure. a and n are determined empirically for a particular propellant composition, and can not be predicted theoretically.

When plotted on a log-log scale, Saint Robert's function in the form of a straight line. Some propellants, can deviate from it and form a sharp change in the behavior of the burn rate. This type of propellant called plateau or mesa, as shown in Fig 2.5.1.1. The occurrence of plateau and mesa may be affected by the result of differences in surface regression (as a function of temperature) as compared to the particle binder oxidant.

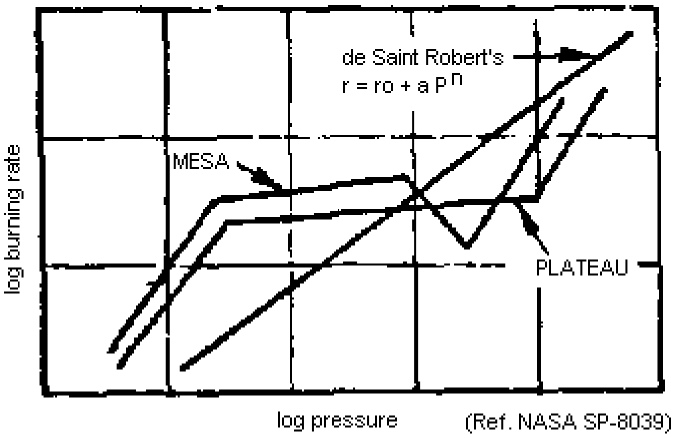


Fig. 2.5.1.1. Profile of plateau and mesa on burning rate[15)].

The burn rate can be very sensitive to pressure exponent, n, (the slope of the log-log), a high value of n which can produce large changes in the burn rate and combustion chamber pressure. That is the reason why the high burn rate which is very undesirable, as their low sensitivity to pressure, particularly in the area of low pressure. This will lead to difficult propellant burned.

If the value of this pressure exponent, n = 1, the burn rate is directly proportional to the pressure of the combustion chamber. The slope of burn rate versus pressure is a straight line. Whereas when this exponent value is low (n <1), the burn rate will be changed very quickly at low pressure, provide good ignition ability. If the value is close to zero, the burn rate is not sensitive to pressure, combustion instability will occur. Therefore, the pressure exponent is expected to be in the range from 0.3 to 0.6 on the operating conditions steady.

Temperature will affects the rate of a chemical reaction, and the initial temperature of the grain affect the propellant burn rate. If at a certain propellants demonstrate significant sensitivity to initial temperature of grain, operations will affect the thrust versus time profile of the rocket motor. In the majority of the propellant, the velocity of the combustion gases across the surface leads to increased the burning rate. This is called erosive burning, which changes depending on the type of propellant and combustion chamber pressure. Effect of erosive burning can be minimized by designing the rocket motor with rasio of port-area ratio to throat area (Ap/At) were big enough. The port-area is the sectional of propellant grain used erosive relationship to the flow rate of gas in the combustion chamber, is given by:

$$r = a.P^n[1 + k(G - G^*)] \qquad (2.)$$

where k is a constant, G is the specific mass flow rate of the combustion gases, and G* is the threshold flow rate.

2.5.2. Burn rate measurement

There are several ways for determination of a propellant burn rate. Three ways the most commonly used are :

1. Strand Burner type of Crawford.
2. Analysis of the burn rate based on the pressure-burning time curve in a static test.
3. Evaluation of the ballistic rocket motor, Ballistic Evaluation Motor (BEM).

Strand Burner method, samples of propellant burned in a closed vessel at constant pressure (at least approximately constant). Each propellant, called the strand, in the form of a square stem. Strand electrically lit on one side and the time duration strand burned through the determined position is measured. Strand is usually isolated on its outer surface to ensure that combustion occurs only perpendicular to the surface (type of cigarette). Nitrogen is used to gives pressure on the vessel. Tests performed several times at varied pressures, ranging from a few atmospheres up to 100 atm.

2.5.3. Burn rate modification

Sometimes it is desirable to modify the rate of fuel to match the grain configuration and design expected. For example, when designing the grain by end burning (cigarette), generally has a small burn surface area, high burn rate required. There are several ways that are used to modify the burn rate, including :

a) Reduce the size of the oxidizer particles.
b) Reduce or increase the content of oxidizer (ratio O/F).
c) Increase the catalyst of combustion rate.
d) Operate the engine at low or high pressure.

Some compounds arranged in a way to modify the burn rate of a propellant. Many that can provide a positive catalyst effect, some of them such as oxamide actually reduce the burn rate due to the heat wave isolator and slow the burn rate. The addition of inert or replace oxidizer compounds are less active (ammonium chloride, sulfate) in the section of AP in a propellant will also reduce the burn rate. So far, most of the modifications carried out with a catalyst to enhance the burn rate. At this point, it will suffice to say that the influence of the catalyst occurs in association with combustion pressure and concentration.

3. Method

3.1. Experiment

For the manufacture of the propellant, the raw material are the HTPB which have isomers cis-1.4, 1,2-vinyl and trans-1.4 respectively 39.52819%, 25.02443% and 35.44738%, OH numbers 2236.98 mgrek/KOH, the molecular weight of 5067. TDI which have 42.11319% for 2.4-TDI and 57.7886% for 2.6-TDI, the number of isocyanate (NCO) = 38.3486%. Ammonium Perchlorat and aluminum in the form of a fine powder

Propellant to be tested, formed into a square rod with a size of 5 x 5 mm with a length of 10 cm. For each pressure test on a different propellant compositions prepared 16 pieces of samples. Samples were then coated with an insulator (epoxy resins). This coating is intended to combustion occurs in a direction perpendicular cross-sectional sample. Samples were coated with isolator left to dry for 8 hours, this is called strand. Strand that has formed is then paired wire sensor on five points with a distance of 2 cm from the top end and 1 cm from the bottom end (strand standing position).Wire sensor fitted sleeves, then put on the stand strand on strand burner.

Tests were conducted at three pressure conditions; 20 bar, 40 bar and 60 bar with 5 samples for each pressure. The burn rate data obtained at each point of the sensor wire in each strand tested. Using Excel software, calculated by plotting the burn rate on pressure with a log-log scale, then obtained value of constants, a, and exponential pressure, n. Furthermore, the burn rate can be calculated using Eq. (1).

3.2. Propellant Composition

Composite propellant with AP/HTPB often found in the production of rocket motors, as well LAPAN. To investigate the performance of the propellant with local HTPB (fuel/binder), propellant selected are; has a simple formula, easy to handle when mixing, molding and curing time, and avoid other additives. Although the ability to regulate the burn rate propellant encourage the aerospace industry to be able to find a propellant formula using some additive. Some additives can affect the burn rate of propellant AP/HTPB, characteristic curing, and the structural integrity of the propellant.

Propellant prepared for this study consisted of three compositions, which can be seen in Table 3.2.1. In each composition, the ratio between HTPB:TDI kept constant at 7:1. Only on the composition II, having different weight content. The composition of propellant used in the form of monomodal. Composition I, with 80% AP of the total weight with an addition of 5% aluminum and 15% fuel/binder at ratio HTPB:TDI, 7:1 (see Table 3.2.1). While the composition II, by increasing the content of fuel/binder up to 20% with a fixed ratio equal to the composition I, the aluminum content is same but with the reduction of AP. While the composition III, retain fuel/ binder same with I, but with a change in the content of the AP/Al.

Table 3.2.1. Propellant Composition

Material	Composition		
	I	II	III
AP	80%	75%	82,5%
Al	5%	5%	2,5%
Fuel/Binder	15%	20%	15%
HTPB:TDI	7 : 1	7 : 1	7 : 1

4. Results and Discussion

4.1. Results

Measurement data using a burner strand are presented in Table 4.1.1 below. In each of the pressure for each composition will be obtained an average value. From this average value then a and n is determined. The average burn rate is given in Table 4.1.2. Using the values of a and n that has been obtained, it can be determined the burn rate at some combustion pressure (Table 4.1.3). From Table 4.1.3 can be obtained burn rate profiles against the pressure on each propellant composition, as shown in fig 4.1.1.

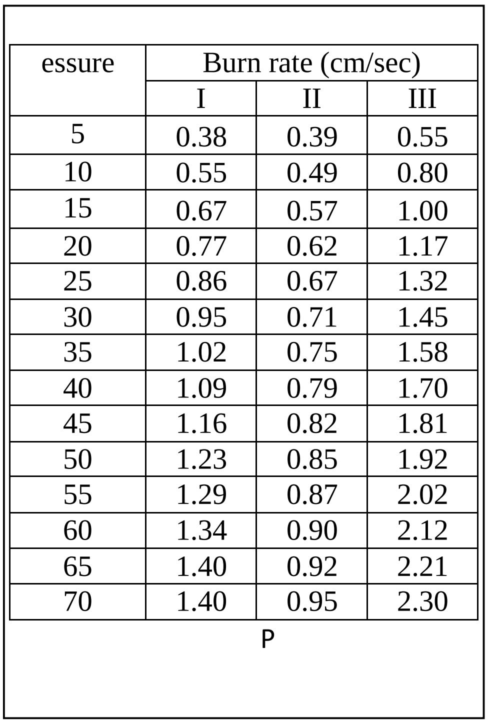
Table 4.1.1. Data of burn rate test of composition I, II dan III.

	Composition I				Composition II				Composition III			
distance/time	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4
	0.78	1.57	2.36	3.15	0.78	1.57	2.36	3.15	0.78	1.57	2.36	3.15
290 Psi (20 bar)	2.7	5	7.4	9.9	3.1	6.5	9.4	12.5	1.6	3.4	5.3	6.9
	2.7	5.1	7.8	10.2	3.4	6.6	9.6	12.5	1.6	3.5	5.4	6.8
	2.5	5.2	7.7	10.2	3.5	7	10.4	13.9	1.5	3.2	4.9	6.3
	2.8	5.8	8.7	11.5	3.3	6.7	10.4	13.5	1.7	3.5	5.1	6.5
580 Psi (40 bar)	1.9	3.8	5.6	7.2	2.4	4.9	7.7	10.2	1.1	2.4	3.9	4.8
	1.8	3.9	5.6	7.3	2.5	5	7.5	9.6	1.6	2.9	4.1	5.1
	2	3.6	5.7	7.6	1.8	4.2	6.6	9.3	1.1	2.2	3.4	4.7
	2	3.9	5.9	7.6	2.4	5	7.4	9.7	1.2	2.4	3.7	4,9
870 Psi (60 bar)	1.3	3.6	4.6	5.4	2	4.1	6.1	8.2	1	2	3.1	4
	1.3	3.1	4.5	5.6	2	4	6.1	8.7	0.9	1.7	2.7	3.7
	1.2	3.1	4.4	5.8	1.7	3.9	6.7	9	1	1.8	2.8	3.9
	1.5	3.5	4.7	6.2	1.8	3.6	6.2	8.7	1	1.9	2.5	3.4

Table 4.1.2. The average burn rate of Strand Burner result.

Ratio	composition	Pressure (Bar)	a	n	Burn rate (cm/sec)	r_{normal} (cm/sec)
AP/Al/Fuel Binder (HTPB:TDI) 80/5/15(7:1)	I	20 40 60	0.0176	0.503	0.77 1.09 1.34	0.734 1.063 1.318
AP/Al/Fuel Binder (HTPB:TDI) 75/5/20(7:1)	II	20 40 60	0.1037	0.335	0.62 0.79 0.90	0.601 0.777 0.890
AP/Al/Fuel Binder (HTPB:TDI) 82.5/2.5/15(7:1)	III	20 40 60	0.0213	0.542	1.17 1.70 2.12	1.111 1.656 2.083

Table 4.1.3. The burn rate at some pressure obtained from calculation



essure	Burn rate (cm/sec)		
	I	II	III
5	0.38	0.39	0.55
10	0.55	0.49	0.80
15	0.67	0.57	1.00
20	0.77	0.62	1.17
25	0.86	0.67	1.32
30	0.95	0.71	1.45
35	1.02	0.75	1.58
40	1.09	0.79	1.70
45	1.16	0.82	1.81
50	1.23	0.85	1.92
55	1.29	0.87	2.02
60	1.34	0.90	2.12
65	1.40	0.92	2.21
70	1.40	0.95	2.30

P

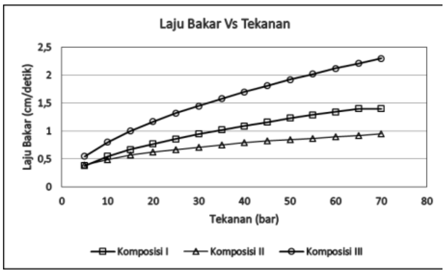


Fig 4.1.1. Effect of pressure and composition on the propellant burn rate.

4.2. Discussion

4.2.1. Composition factor on burning rate

Deflagration wave (linear burning) in solid energetic material generally consists of initial condensation phase and gas phase. The interface between the condensate phase and gas phase is called surface burning. The rate of propagation at the interface is called the burning rate, physically, this can be seen as a regression of the rate of condensation phase. Actual surface burning and evolution time depends on the geometry of grain (particle size/molecular, distribution and ratio) and the overall combustion process (flame temperature, flame temperature and the distance between the burning surface, combustion stability and perfect chemical reactions).

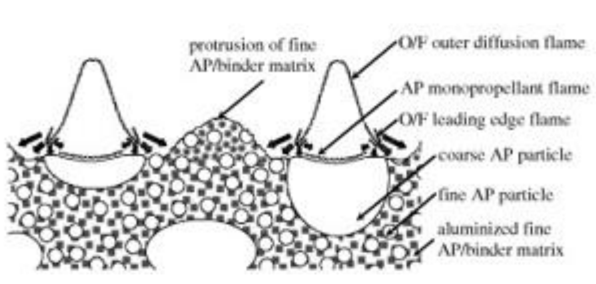
Because the factors that most influence the burn rate is a composition and firing conditions, then the formula propellant used as research material made simple as described above. The mechanisms that responsible for the change of burn rate are; melting of the binder layer, oxidizer behavior, and the influence of additives16). Ballistic properties and mechanical properties of the propellant is heavily influenced by oxidizer due the largest amount in the composition.

From the calculation seem that the composition III has the highest burn rate. This is due to the content of AP in the composition III is higher if compared to the composition I that has a lower content of AP. This means that increasing number of AP can increase the value of the burn rate. The increases in the fraction of the oxidizer in the propellant formulations are usually followed by the decreasing amount of binder content, but in composition I and II, the amount of binder content is kept constant. For AP monomodal particle size, increasing AP (increasing the ratio O/F) tends to decrease the combustion anomalies that occur in the propellant bimodal17).

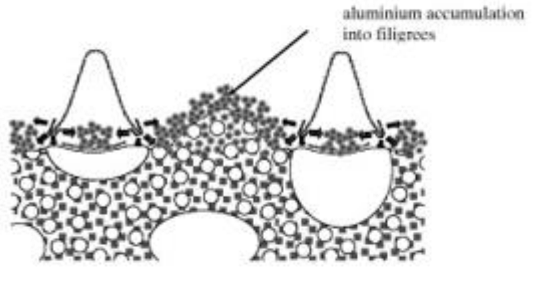
The increases in the burning rate of propellant affects the size of the gas that accumulates in the combustion chamber, it is also influenced by the particle size. The use of Ammonium Perchlorate because it has several advantages, among others; capable of producing oxygen is relatively larger, have a high density, low heat generation and generating large combustion gas so that the accumulation of gas in the combustion chamber will be higher.

Performance of propellant itself is directly proportional to the enthalpy released by oxidizer and content of fuel as a result of combustion, and inversely proportional to the molecular weight of the gas produced in the combustion reaction2). At several static test conducted by LAPAN, aluminum is used as a fuel has a relatively high molecular weight as combustion products, and in many cases, not the overall form of gas, but solid. However, the release of enthalpy by burning aluminum is very large. Other materials that affect performance is ammonium perchlorate that used as an oxidizer. This material has a high formation of negative enthalpy, restricting the release of energy during combustion, and in addition, to produce hydrogen chloride, a toxic gas with a relatively high molecular weight.

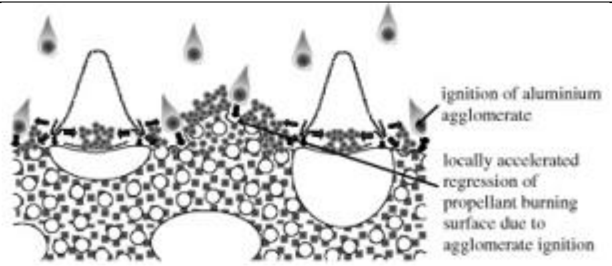
Use of metal (fuel) in this study do not appear to give effect if only seen from the burning rate only. The addition of metallic Al of which are used to increase the temperature of combustion and burning rate. The high combustion temperatures will certainly help increase the pressure in the combustion chamber, which will also affect the overall parameters of the burning propellant. In addition, the function of metal-fuel is as a combustion stabilizer, so the selection should really appropriate3). Metal fuel to the propellant used in this study is aluminum powder, with a specific particle size.



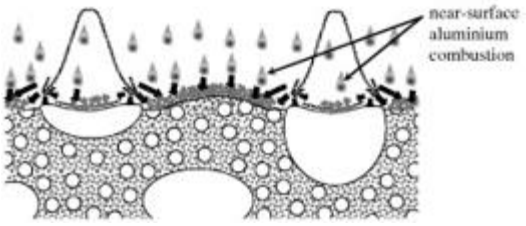
a. The addition of Al in the rough AP causes a decrease in the burn rate



b. Accumulation of Al on the burning surface to act as a thermal sink and cause a reduction in the burning rate.



c. Al bonds got ignition and rolled into lumps of burning causing pockets of localization of surface regression accelerated



d. ignition and combustion of Al accumulates around the surface of the propellant increases the burning rate.

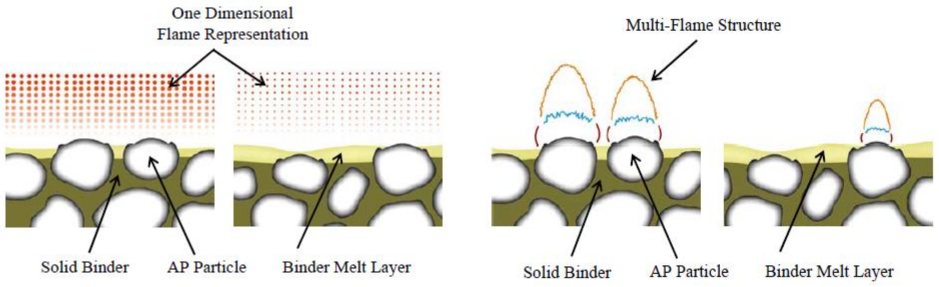
Fig 4.2.1.1. Effect of the addition of Al on the burn rate[17)].

Ide (2002) suggests that the overall Al content varies between 5% - 25% by weight, with 15% of the value of the most commonly used, with a particle size of 80-120 µm. Thus the composition of the AP/Al in propellant must be balanced and appropriate in order to ballistic and mechanical properties of propellant as expected. One theory to determine the specific impulse for the specific composition of the base polybutadiene propellant presented by Bac[18)].

The position of Al in propellant compounds can be illustrated in Fig. 4.2.1.1 above. The addition of Al can increase the burn rate, but also can reduce the value of the burn srate. Fig. a and b show a decline in the burn rate, while images c and d, the increased burning rate scheme.

In the second composition, wherein the content of oxidizer lowered, but with the same number of AP content of the composition I, shows the lowest burn rate. This can be caused by two things, a decrease in the content of oxidizing agents, or additions to the content of the binder. In this case, the molten layer of binder can affect the decrease in burn rate.

Combustion of composite propellant occurs in different phases, oxidizer particles decompose in the middle of the fuel matrix decomposition, AP does not melt, but rather decompose isotherms (see Fig. 4.2.1.2). Adjacent gas stream (oxidant and fuel) arising from the surface, and the immediate reaction is not possible until the mixing is complete diffusion. The combustion process occurs in three distinct zones, foam, fizz, and flame. On the surface of the combustion, the gas velocity is are relatively small and have little energy. In the flame zone (flame) in the which the final reaction occurs and the majority of the heat and the gases evolved.



(a) (b)

Fig. 4.2.1.2. Diagram 1-dimensional melting binder layer on the composite propellant[16)].

In the left picture (a), the molten layer is shown nearing the surface of the AP produced in the normal combustion. In the picture to the right (a), molten layer appears higher than the particle positions AP causes flow molten binder cover a part or all of the AP and other particles. Fig. 4.2.1.2(b) shows the molten binder layer is illustrated with models flame. The left image shows normal combustion when the molten layer at or below the surface of the particles of AP. In the picture to the right of (b) shows a scenario in which the surface of the AP is lower than the molten binder layer resulting flow covers part or all AP particles, resulting in reduced flame structure, and can extinguish the flame of the other[16)].

4.2.2. Normalization of burn rate

When the sample propellant burns with pressure on the strand burner, the transition phase of solid reactant transform into liquid on the burn surface, then to a gas as a result of combustion that will increase the pressure. The increased pressure varies during the measurement process, this is a weakness of the instrument used. The increase in pressure ranges from 10-20%. Ideally, samples should be burnt in an environment of constant pressure, this increase can be considered to have little effect during characterization testing**.** Carro (2011), giving the equation to normalize the burn rate as a result of this error[7)].

$$r_{normalisasi} = r_{ukur}\left[\frac{P_{av}}{P}\right]^{n} \qquad (3.)$$

Normalization calculation results are given in Table 4.1.2 (the rightmost column).

5. Conclusion

From the tests and calculations have been done, be concluded that changes in the content of the AP have an impact on changes in the burn rate of propellant obtained. Propellant of omposition III has the highest burning rate value, while the composition II has the lowest burn rate. This is caused by the content of the AP on the composition III highest. Increased content of fuel-binder in this study can not be concluded with a perfect, still needs further research.

Reducing the Al content in the composition III than composition II does not look significantly. This is caused by the reduction of the number of Al slightly, accompanied by increasing in oxidizer, so it is possible role of oxidizer is very dominant in an increased of burn rate even though the content of Al is lowered.

The addition of binder content to 20% by weight, but coupled with the decrease in AP content in the propellant of composition II clearly decrease the value of the burn rate, but which one is more dominant needed more detailed research.

From these results, the local HTPB shown to bind oxidizer of propellant with several different compositions, thus, it is feasible used for rocket motor design.

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