International Journal of Social Science Research and Review

http://ijssrr.com
editor@ijssrr.com
Volume 6, Issue 1
January, 2023
Pages: 153-159

Application Energetic Materials for Solid Composite Propellant to Support Defense Rocket Development

Khevinadya Ramadhani Runtu[1]; Wahyu Sri Setiani[1]; Mala Utami[2]

[1]Weaponry Technology Department, Faculty of Defense Technology, Indonesia

[2]Defense Industry Department, Faculty of Defense Technology, Republic of Indonesia Defense University, Indonesia

E-mail: khevinadya@gmail.com; wahyu.setiani@tp.idu.ac.id; mala.utami@tp.idu.ac.id

http://dx.doi.org/10.47814/ijssrr.v6i1.756

Abstract

In its application in space technology, solid composite propellants are often used as fuel in rockets for military purposes. Increasing the energy of the propellant is carried out by observing two stages, the use of energetic materials and improvements to the process technology. The current development of propellant technology makes it possible to use new energetic materials, simple formulations, high energy, and smokeless. The purpose of this research is to find out developments related to the use of highly energetic materials as raw materials for composite propellants for defense rockets at the Rocket Technology Research Center, ORPA-BRIN. This study uses qualitative analysis methods with research designs in the literature studies and simulation results. In the context of mastering rocket propellant technology in Indonesia, the application of highly energetic materials is expected to be able to solve the problem of rocket propulsion performance. Currently, the Rocket Technology Research Center, ORPA-BRIN is developing a smokeless propellant composite with a composition based on the energetic materials AP/HTPB/Al and an oxidizing agent RDX. From the results of the combustion simulation software ProPEP and RPA, it shows that the composition of the resulting combustion gaseous (Al2O3 and HCl) shows a decrease when using RDX energetic material-based propellant. It's known that RDX can significantly reduce smoke in propellant combustion products. The application of the new highly energetic materials compound is expected to significantly solve the problem of solid rocket propulsion performance.

Keywords: *Energetic Materials; Composite Propellant; RDX; Smokeless Propellant*

Introduction

One of the current developments in the defense industry refers to the development of defense rockets. In accordance with the Presidential Regulation of the Republic of Indonesia Number 8 of 2021 concerning the General Policy of State Defense for 2020-2024 (Jakumhanneg), where the rocket is one of the 10 strategic programs in the field of defense equipments for the Indonesian defense industry.

Rocket technology is a key technology of a country in national defense efforts that must always be developed and improved. Therefore, the development of rocket technology in Indonesia is very important, especially in the field of defense, rockets are very useful for securing the region and protecting national assets. The development of rockets in the defense sector is always undergoing renewal, especially in the field of propellants or rocket fuel. The current development of propellant technology makes it possible to use new energetic materials, simple formulations, high energy, and smokeless (Reese, 2014).

In general, rocket propulsion systems use composite propellants, which consist of main components such as fuel, binder, and oxidizing agent, and additive components such as metal fuel, adhesive agent, and plasticizer which are useful for obtaining characteristic properties and improving the quality of a propellant (Setyaningsih, 2010). In the context of mastering rocket propellant technology in Indonesia, propellant development at The Rocket Technology Research Center, ORPA-BRIN to date uses AP/HTPB/Al-based composite propellants.

When the rocket was first built, the range that the rocket could go was very limited. However, with the advancement of existing technology, the current distance can reach hundreds of kilometers. This is can't be separated from the role of propellants as fuel in rockets. To be able to reach long distances, a propellant containing energetic material is needed so that it can produce high thrust from the combustion products.

Besides being able to increase the range of the rocket, some energetic materials that are currently commonly used have some limitations. Ammonium Perchlorate (AP) as an oxidizing agent that is energetic produces Hydrochloric Acid (HCl) gas during the combustion process. With the humidity in the air, the products of combustion will become white smoke in the atmosphere. The combustion gases are highly corrosive and toxic in nature and then form clouds in humid conditions. This can cause acid rain and depletion of the ozone layer (Youssef, 2019). Therefore, smokeless technology is the focus of research that is currently being intensively developed. This isn't only aimed at reducing damage to the atmosphere but also aims to avoid detection by enemy radar.

The Rocket Technology Research Center, ORPA BRIN has problems in mastering propellant technology, including difficulties in procuring propellant raw materials, propellant reformulation, and constraints on process technology. In the procurement of propellant raw materials, ORPA-BRIN is experiencing difficulties because currently all propellant raw materials such as AP, HTPB, Al, and TDI are still imported. Difficulties are also increasing because the countries producing raw materials for propellant, members of the MTCR and non-MTCR members, limit the export of raw material for propellant with specifications for grade one. In addition, it does not yet have the ability to determine the grade of the propellant raw material.

The limited supply of propellant raw materials will certainly be a domino effect to the next stage, such as the propellant reformulation stage. The propellant reformulation only optimizes the propellant raw material which can be obtained with a solid loading content of a maximum of 85%. The limitation of raw materials has resulted in the propellant reformulation not being able to be carried out through optimization of shape and size as well as optimization of binders with high loading capacity. Furthermore, reformulation using highly energetic materials has never been carried out (Wibowo, 2018).

Research Method

The research was conducted by applying qualitative research methodology. Literature studies and simulation results were applied referring to the energetic raw materials of composite propellants and explore about it. This study aims to find out developments related to the use of highly energetic materials as raw materials for solid composite propellants for defense rocket development at the Rocket Technology Research Center, ORPA-BRIN, Indonesia.

In this study, simulation of the propellant combustion thermochemical balance approach can use ProPEP (Propellant Evaluation Program) and RPA (Rocket Propulsion Analysis) software. ProPEP and RPA are known as thermochemical software that is very useful for evaluating the theoretical performance of a propellant. The software can also obtain data on the composition of the combustion gaseous and their combustion energy values.

The results and discussion were obtained by collecting various data from references relevant journal reviews and simulation results. Furthermore, developments related to the use of highly energetic materials as raw materials for composite propellants for defense rockets development can be used in future research and development of solid composite propellant technology, especially in Rocket Technology Research Center, ORPA-BRIN, Indonesia.

Result and Discussion

Energetic Materials as Raw Material for Composite Propellants

In its application in space technology, solid composite propellants are often used as fuel in rockets for military purposes. In the context of mastering rocket propellant technology in Indonesia, propellant development at the Rocket Technology Research Center, ORPA-BRIN uses AP/HTPB/Al-based composite propellant compositions, its Ammonium Perchlorate (AP) as an oxidizing agent, Hydroxyl Terminated Polybutadiene (HTPB) as a binder, Aluminum (Al) as fuel which has a very high energy level, and Toluene Di Isocyanate (TDI) as a curing agent.

The characteristics of the reaction of the fuel binder with the curing agent will affect the quality of the propellant that will be produced. The oxidizing agent in solid composite propellants is used as a source of oxygen during the propellant combustion reaction. The type of oxidizer that is often used is AP. During the combustion process, the AP produces a lot of HCl gas as a source of air pollution and produces white smoke, so the trajectory and initial position of the missile can be easily observed. Some materials such as Mg and Al or sodium nitrate are added to reduce it. Currently, it's known that the addition of RDX compounds into the composition of AP improves combustion characteristics and reduced smoke in propellant combustion products (Wibowo, 2010).

Additive components such as plasticizers are useful for facilitating the process of mixing propellant constituent materials and the propellant molding process. The addition of energetic plasticizers can also affect the performance of solid composite propellants. Plasticizers that are commonly used are DOP, DOA, & DOS. In Table 1, it shows some characteristics of composite propellants in ORPA-BRIN using energetic materials based on AP/HTPB/Al.

Table 1. Characteristics of Propellant in Rocket Technology Research Center, ORPA-BRIN

Characteristics	Characteristics of Propellant in Rocket Technology Research Center, ORPA BRIN (AP/HTPB/Al)
Isp (s)	220
R (mm/s)	>0.7
Solid Content (%)	85
AP/HTPB/Al (%w/w)	80/15/5
AP Trimodal (mesh)	400/200/100
Density (gr/cm^3)	1.67
Homogenity (%)	98

Source: (Wibowo, 2018)

From the table 1, when viewed from the development of existing propellant, the propellant is expected to have much better characteristics than before. Propellant performance that is still low will provide rocket achievements with ranges, payloads, and dimensions that are not as expected in rocket development so mastery of rocket technology will be hampered. Therefore, it is necessary to make comprehensive efforts to improve the energetic characteristics of the propellant.

Currently, at Rocket Technology Research Center, ORPA-BRIN, a smokeless composite propellant with an oxidizing composition based on RDX is being developed. RDX itself has high energy and smokeless. The composition of Al and AP will be reduced and substituted with RDX. In the future, composite propellants are also expected to be able to use high-energy composite propellant compositions consisting of the Table 2.

Table 2. Energetic Raw Materials for Composite Propellant

Propellant Component	Energetic Raw Materials
Oxidizing	AND, CL-20, FOX-7, RDX
Fuel	AlH3, BeH3
Binder	GAP, NHTPB, NIMMO
Plasticizer	NG, BTTN

In the development of solid rocket propellants, the application of the new compound energetic material in Table 2 such as a new high-energy binder, oxidizing, fuel, and plasticizer systems have been developed, particularly in composite propellants based on RDX oxidizing agents. Therefore, it's expected to significantly solve the problem of solid rocket propulsion performance.

Smokeless Composite Propellants Based On Energetic Material Of RDX

High-performance composite propellants usually contain Ammonium Percholate (AP) as an oxidizing agent. The weakness of AP as an oxidizing agent that is energetic, which produces smoke or hydrochloric acid (HCl) gas in the form of white gas which is quite corrosive to the propellant combustion products. This can cause environmental pollution which will have a negative impact on health. In addition, the oxide compounds from the smoke generated from the military side of the rocket trajectory can be observed, so that it will be easier to detect by enemy radar (Selvaraj, 2012).

Currently, smokeless composite propellant technology or reduced smoke in propellant combustion products is being intensively developed. In addition to aiming to reduce environmental pollution, low-smoke propellants can eliminate the risk of giving the rocket a position to fire and avoid being detected by enemy radar. What needs to be done is by substituting AP with nitromine-based smokeless powder materials such as RDX and HMX (Sutton, 2016).

RDX (Cyclotrimethylene Trinitramine) as Research Department Explosive is a nitroamine explosive that is known as a high-performance energetic material and is widely used in national defense industry applications. Commercially, RDX is used for rocket propulsion and petroleum exploration. RDX itself has high energy and produces environmentally friendly combustion products with low smoke. The composition of the AP will be reduced and substituted with RDX. Substitution of RDX compounds into the composition of AP will also improve its combustion characteristics (Gnanaprakash, 2021). Where the value of heat of formation (ΔHf) of RDX is 62 kJ mol-1, and AP is -283 kJ mol-1 (Agrawal, 2010). Chemically, RDX belongs to the nitramide group of compounds, has similarities to HMX (Cyclotetramethylene Tetranitramine), and is more energetic than TNT (Trinitrotoluene).

The RDX energetic material-based propellants are known to bring several features required for advanced propulsion systems, including a better performance with large volumes of gaseous, high energy, high specific impulse, and environmentally friendly (low smoke) combustion products. It's known that the substitution of RDX compounds into the AP composition will improve its combustion characteristics [2]. In this study, its highly recommended to use an oxidizing agent based on energetic RDX material to be further researched and developed for rocket propellant technology in the future.

Reduced smoke propellant technology on propellant combustion products is the focus of research and development. To determine the level of the smoke of propellant combustion can be measured from the number of gases produced from the combustion of propellant such as HCl and Al_2O_3. The reduced smoke test on the propellant can be carried out by observing the smoke that comes out of the combustion propellant.

Simulation of the propellant combustion thermochemical balance approach can use ProPEP (Propellant Evaluation Program) and RPA (Rocket Propulsion Analysis) software. ProPEP and RPA are known as thermochemical software that is very useful for evaluating the theoretical performance of a propellant. The software can also be used to check possible propellant compositions, which can also be used to quickly determine the effective ratio of ingredients to achieve the desired performance.

ProPEP and RPA are also used to predict the energetic performance of propellant produced at the Rocket Technology Research Center, ORPA-BRIN. The software analysis of ProPEP and RPA can be shown in Figure 1 and Figure 2.

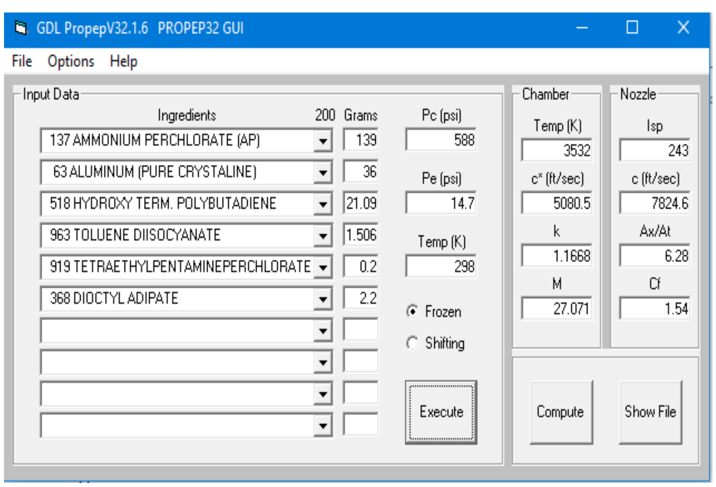

Figure 1. ProPEP Analysis

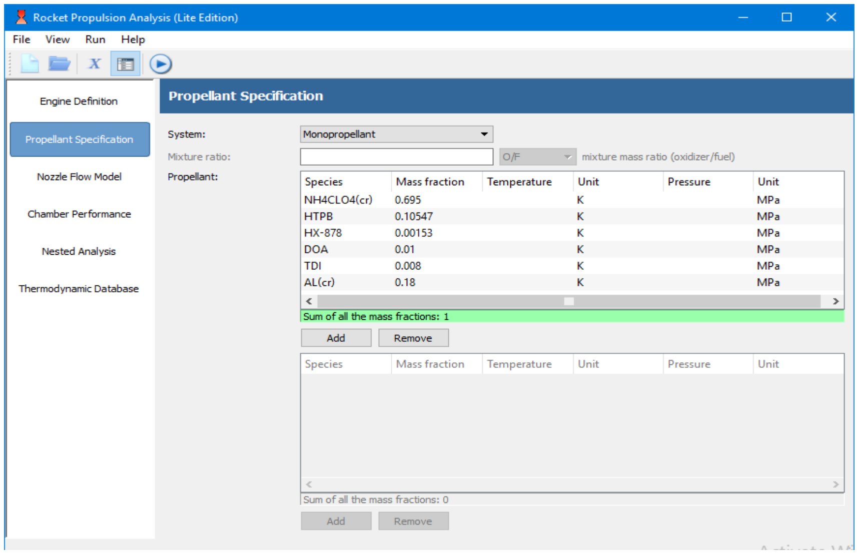

Figure 2. RPA Analysis

From the simulation results in ProPEP and RPA software, data on the composition of the combustion gaseous and the energy value of the combustion can be generated. The simulation results will be validated by combustion testing. The simulation results of the gas composition resulting from propellant combustion using ProPEP and RPA software can be seen in Table 3.

Table 3. The Simulation Propellant Results of the Gaseous Combustion Using ProPEP and RPA

Propellant Composition	% Combustion Gaseous			
	ProPEP		RPA	
	Al_2O_3	HCl	Al_2O_3	HCl
AP/HTPB/Al	0,66635	1.15728	0,25700	0,21151
AP/HTPB/Al/RDX	0,33353	1,17838	0,17004	0,21528

The results of the combustion simulation in both software in Table 3, it shows that the composition of the resulting combustion gaseous such as Al_2O_3 and HCl shows a decrease when using RDX energetic material-based propellant. It's known that RDX can significantly reduce smoke in propellant combustion products.

Conclusion

In the context of mastering rocket propellant technology in Indonesia, the application of high-energy energetic materials is expected to be able to solve the problem of rocket propulsion performance. Currently, ORPA-BRIN is developing a smokeless propellant composite with a composition based on the energetic material AP/HTPB/Al and an oxidizing agent RDX.

The results of the combustion simulation software ProPEP and RPA, it shows that the composition of the resulting combustion gaseous (Al_2O_3 and HCl) shows a decrease when using RDX energetic material-based propellant. It's known that RDX can significantly reduce smoke in propellant combustion products.

The application of the new high-energy compound is expected to significantly solve the problem of solid rocket propulsion performance. So that in future research, the use of RDX-based energetic materials can be an alternative in the development of solid composite propellant manufacturing technology as an effort to master rocket propellant technology in Indonesia.

References

Agrawal, J.P., 2010. High Energy Materials: Propellants, Explosives and Pyrotechnics. John Wiley & Sons.

Gnanaprakash, K., Chakravarthy, S.R., Jayaraman, K., Appu, H. and Singh, D., 2021. Combustion Behaviour of Composite Sandwich Propellants Containing RDX. Proceedings of the Combustion Institute, 38(3), pp.4451-4459.

Reese, D.A., Groven, L.J. and Son, S.F. (2014). Formulation and Characterization of a New Nitroglycerin-Free Double Base Propellant. Propellants, Explosives, Pyrotechnics, 39(2), pp.205-210.

Selvaraj, B., Masthiraj, N.V. and Dhinesh Kumar, S.R., 2012. Minimum-Signature (Minimum Smoke) Propellant. Inter. J. Emer. Tech. Adv. Eng, 2(4), pp.599-604.

Setyaningsih D., 2010. Propelan Padat Komposit. Berita Dirgantara, 8(4).

Sutton, G.P. and Biblarz, O., 2016. Rocket Propulsion Elements. John Wiley & Sons.

Wibowo, H.B., 2010. Material Eksplosif dan Penggunaannya. Berita Dirgantara, 11(1).

Wibowo, H.B., 2018, November. Current Solid Propellant Research and Development in Indonesia and Its Future Direction. In Journal of Physics: Conference Series (Vol. 1130, No. 1, p. 012027). IOP Publishing.

Youssef, E. M., Elshenawy, T., Mostafa, H. E., Radwan, M., Elbeih, A. 2019. Optimization of low signature base bleed propellant Formulations. IOP Conf. Series: Materials Science and Engineering.