PROPELLANT IN ROCKET MODELING: APPLICATIONS IN THE LAST FIVE YEARS

Ana Carolina dos Santos Deovalino[a] , Tiago Lima da Silva[b] , Bernardo Mattos Tavares [a]

[a], Universidade Federal do Rio de Janeiro-UFRJ-Centro Multidisciplinar de Macaé-Instituto Politécnico – Macaé-RJ-Brazil

[b] Universidade Federal do Rio de Janeiro-UFRJ-Centro Multidisciplinar de Macaé-Instituto Multidisciplinar de Química – Macaé-RJ-Brazil

Abstract: This document is intended to group the most common methods of manufacturing propellants for model rockets in recent years, for information purposes. The study methodology of publications, books and other research avenues was used. At the end of the reading, it will be possible to understand what each propellant provides according to the necessary perspective.

Keywords: Propellant; rocket model; rocket fuel.

PROPELENTES EM FOGUETEMODELISMO: APLICAÇÕES NOS ULTIMOS CINCO

Resumo: O presente documento tem o intuito de agrupar os mais usuais métodos de fabricação de propelentes para foguetemodelismo dos últimos anos, para fins informativos. Foi utilizada a metodologia estudo de publicações, livros e outras vias de pesquisas. Ao final da leitura, será possível entender o que cada propelente proporciona de acordo com a finalidade requerida.

Palavras-chave: Propelente; Minifoguete; Combustível para Foguetes.

1. INTRODUCTION

The field of rocketry is very exciting, generating enthusiasm and curiosity in people of all ages. Rocket modeling is manufactured for both educational and professional means. The mixture of substances in combination with each other or by itself, develop burning, generating a large volume of gases in a short time, instantly, offering thrust in one direction. The amount of mass supplied must be studied both in theory and in practice, to obtain data on the gases generated in order to assess the risk involved with insalubrity, dangerousness and impacts on the environment.

2.0 -METHODOLOGY

A survey of the bibliography was carried out using the Google search engine, using the terms "sustainability in mini-rocket fuels", 'propellants for competitions", "propellant innovation", among others. The criteria of inclusion in this review was papers or texts from journal or websites where scientific information in the topic were familiar and we exclude journals or website where the space science was not usual or frequently discussed.

3.0 -RESULTS FROM LITERATURE REVIEW

3.1 -Solid Propellants

Most commonly used, solid propellant is most commonly used for its easy handling, application, storage, ordinary accident risk and excellent cost- benefit.

The solid propellant is a complex and stable mixture of oxidizing and reducing compounds. When these compounds are ignited they burn in a continuous and homogeneous manner, generating heat and forming gaseous molecules of low molecular mass [1].

In solid propellant systems, the oxidizer and fuel are mixed and packed in the combustion chamber itself, in the form of a grain, ready to combust after initiation by an igniter [2].

3.1.1 -KNSu

KNSu, which stands for Potassium Nitrate and Sucrose, is the most widely used of the solid propellants. The stoichiometry here is 3 of nitrate for 1 of sucrose. The prototype is composed of 65% Potassium Nitrate and 35% Sucrose. The Potassium Nitrate performs the function of the oxidizing element while the Sucrose operates as fuel and binder. The fuel is the reactant that will be consumed in contact with oxygen, while the oxidizer is responsible for releasing more oxygen and intensifying combustion [1]. When its composition is not in balance, its burning has a high presence of carbon dioxide and monoxide, reflecting negatively on the environment.

3.1.2 -Aluminum and Water

Recently Laureen Morueh, Ph.D., mechanical engineer, along with her professors Douglas P. Hart and Thomas W. Eagar developed a sustainable fuel by manipulating scrap aluminum and water, modifying them into aluminum hydroxide and hydrogen, through metallic aluminum reacting with water at room temperature. The idea arose after the realization that nowadays the production of hydrogen in its plurality is produced based on fossil fuels, generating more than 2% of all global greenhouse gas emissions. Using the aluminum-water reaction to generate hydrogen produces no greenhouse gas emissions [3]. Using aluminum as a source, we can 'store' hydrogen at a density 10 times greater than if we just store it as a compressed gas, says Douglas P. Hart, professor of mechanical engineering [3].

The elaboration of the fuel was tempting, since the aluminum scrap underwent changes in its properties, such as the addition of silicon and magnesium in order to decrease melting temperature and increase corrosion resistance, called alloying elements. On the other hand, there was a need to modify the oxide layer of the scrap, so that aluminum would react with water, another essential point was the passivation of the metal, so that the chances of corrosion became minimal, it is a phenomenon in which a sufficiently solid oxide layer is formed and strongly attached to the metal surface.

In an oxireduction reaction, the more noble metal reduces and the less noble metal oxidizes. In other words, the less noble metal undergoes corrosion. Thus, although the oxide decreases the propensity of aluminum to corrosion, there are still metals that will be more noble than passivated aluminum. If in contact with any of these materials, directly or through some electrolyte, aluminum will therefore suffer galvanic corrosion [4]

3.1.3 -Alice

Originated from the junction aluminum and ice, due to the fact that it is composed of aluminum nanoparticles and ice, it is a propellant that was developed in collaboration with NASA, used in a test rocket measuring 2.7 meters long, at 400 meters altitude[5].

Despite the similarity in composition, compared to the aluminum and water propellant mentioned above, however, nano-aluminum is more efficient because it has a differential, it reacts instantly with oxygen forming a layer of aluminum oxide, blocking other reactions, removing all air from the water molecules, then generating hydrogen gas.

Its burning generates aluminum oxide and hydrogen gas, both non- toxic chemical compounds, until then being the usual propellant less aggressive to the environment today, containing stoichiometry equal to. $2Al + 3H_2O \rightarrow Al_2O_3 + 3H_2$.

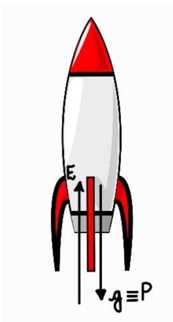
Hydrogen can combine with oxygen in the air, generating water as a product and releasing another amount of energy to propel the rocket [6]. Alice could one day replace some of the liquid or solid propellants and, when perfected, could outperform conventional propellants, and it is extremely safe when frozen because it is very difficult to ignite accidentally [5].

3.2 Liquid Propellants

It presents several challenges, the biggest of which is the cost-benefit and risk of explosion, on the other hand they have higher thrust and impulse values than the others. Its composition can be categorized as monopropellant, when only a single liquid is used, bipropellant, using two types of propellants or even tripropellant [2].

Liquid rockets tend to be heavier and more complex because of the pumps used to move the fuel and oxidizer. It is necessary to pay attention to this issue, because the lower its weight, the lower its thrust force, therefore, the choice of propellant has a lot of influence on the mini-rocket, for a better understanding we can reflect from Newton's third law, since for its launch, the rocket produces a thrust force that is contrary to the gravitational force, this thrust force is generated by the production of combustion gases expelled by the nozzles of the rocket, overcoming its weight force driving it upwards.

Figure 1- presenting some forces involved in rocket launch



$$E - P = m.a$$

E= empuxo ; P = peso ; m=massa ; a= aceleração

3.3. -Cryogenic

Cryogenics can be seen as liquid fuels: although they are made of gases, they are stored at temperatures low enough to be liquefied. They provide 30% to 40% higher specific impulse than most other fuels [7] .

3.3.1 -Liquid oxygen (LOX) and liquid methane (CH4, liquefied natural gas, LNG)

Produces clean combustion and high performance with water vapor as the product generated. Used on Origin's New Shepard. Developed by SpaceX, leaving a little of the traditional methods combining oxygen and liquid hydrogen, due to the benefits provided by methane compared to hydrogen, being the cost- benefit, storage, less explosive and its greater density providing greater thrust. As a counterpart, according to the UN the gas generated by methane is one of the biggest causes of the greenhouse effect [8].

3.4. Semi-cryogenic

3.4.1 Nell

Composed of liquid oxygen and gasoline, it was the first liquid propellant, developed by Robert Goddard that initially rose 41 feet during 2.5 seconds of flight.

It later played an important role in World War II, with Wernher von Braun designing V-2 rockets for the Nazis [8].

3.4.2 Liquid Oxygen and Carbon Monoxide (LO2, CO)

It has a specific impulse of around 250s, and was developed for a Mars funnel vehicle. The gases produced are odorless, colorless, flammable and toxic [8].

3.5 Hypergolic

These are fuels and oxidizers that ignite spontaneously on contact with each other, requiring no ignition to start the reaction. They are great for spacecraft maneuvering systems, for example, and remain liquid at normal temperatures [7].

3.5.1 Hydrazine (N_2H_4)

It is a bipropellant that only combusts on contact. Its chemical properties are similar to those of ammonia, which already implies that it is a highly toxic chemical and difficult to handle. Enjoyed in the orbital control of the 56 satellites of the HS line [9].

3.6 - Hybrid propellant

Between solid and liquid propellant, hybrid propellant has intermediate characteristics featuring safety, low cost and reliability, making it difficult to mix and react spontaneously before the combustion chamber.

It is done by supplementing the solid propellant in grain form by injecting the liquid or gaseous oxidizer into the combustion chamber, in general the fuel is in the solid state and the oxidizer in the liquid state.

3.6.1 LOX.

Developed by the Pacific Rocket Society, employing liquid oxygen (LO2) in conjunction with other combustible materials such as wood, wax loaded with carbon black, and rubber-based fuel [10].

4 -FINAL CONSIDERATIONS

For the realization of the study in question, a survey was carried out with an average of 4 articles, making it possible to better probe and interpret which categories of propellants are most common today. Dividing into topics such as solid, liquid and hybrid propellants, it was possible to understand the purpose of each one.

Although there is a wide variety of propellants, the KNSu type is the most used in competitions and educational means for its easy handling, storage and excellent performance. Although very promising, a series of improvements can be made so that KNSu becomes even more functional and has its use at a higher level of functionality, such as the addition of nano aluminum to remove any remnants of moisture, thus prolonging and preserving its storage.

The area of propellant manufacturing is very promising precisely because it has an enclosure where creativity has potential at high levels, enabling the creation of several types of propellants even more functional than those that exist today according to the need in question.

Acknowledgments

The authors would like to thank FAPERJ for financial support in the form of scholarships and financial resources for the development of the project.

5. REFERENCES

[1] ALVES, André Luíz et al. Minifoguete a propelente sólido: aspectos teóricos e propostas experimentais para o ensino de física. **Revista Brasileira de Ensino de Física**, v. 42, p.e 20200390, 2020.

[2] ARNONI, Vinicius Leonardo. **Investigação Experimental de um propulsor híbrido usando polietileno e tetróxido de nitrogênio**, 2014. Dissertação de Mestrado. (Dissertação de Mestrado do curso de Pos-Graduação em Engenharia e Tecnologia Espaciais/Combustão e Propulsão), INPE, p160. 2014.

[3] STAUFFER, Nancy W. Using aluminum and water to make clean hydrogen fuel — when and where it's needed. **Mit**, 2021. Disponível em: <https://energy.mit.edu/news/using-aluminum-and-water-to-make-clean-hydrogen-fuel-when-and-where-its-needed/>. Acesso em: 15 de jun. de 2023

[4] MARTENDAL, P. C.; FERNANDES, K. V. Alumínio tem problemas com corrosão?. **Engenheiro de materiais**, 2016. Disponível em: <https://engenheirodemateriais.com.br/2016/10/12/aluminio-nao-tem-problemas-com-corrosao-certo-ou-errado/>. Acesso em 1 de julho de 2023.

[5] STEWART, Alan. O novo propelente de foguetes recebeu o nome de ALICE - ALuminum ICE. **Moraisvinna**, 2010. Disponível em: <https://moraisvinna.blogspot.com/2010/01/o-novo-propelente-de-foguetes-recebeu-o.html>. Acesso em: 22 de jun. de 2023.

[6] BALDISSERA, Rafaela; GABRIEL, Larissa; POLETTO, Matheus. Propelentes sólidos para foguetes-Avaliação da geração de gases tóxicos com base nas reações de combustão. In: **5º Congresso Internacional de Tecnologias para o Meio Ambiente, Bento Gonçalves**. 2016.

[7] CAVALCANTE, Daniela. De que são feito os combustíveis dos foguetes?. **Canaltech**, 2022. Disponível em: <https://canaltech.com.br/espaco/de-que-sao-feitos-os-combustiveis-dos-foguetes-228363/>. Acesso em: 22 de jun. de 2023.

[8] FOGUETE de combustível líquido. **Wikipédia**, 2020. Disponível em: <https://pt.m.wikipedia.org/wiki/Foguete_de_combust%C3%ADvel_l%C3%ADquido>. Acesso em 24 de jun. de 2023.

[9] HIDRAZINA composto químico. **Wikipédia**, 2020. Disponível em: <https://pt.m.wikipedia.org/wiki/Hidrazina>. Acesso em 24 de jun. de 2023.

[10] BERTOLDI, Artur Elias de Morais. **Estudo de instabilidade de combustão em motor foguete a propelente híbrido**.Tese (Doutorado em Ciências Mecânicas)-Universidade de Brasília, 2018.