Journal of Current Research in Engineering and Science
Bi-Annual Online Journal (ISSN : 2581 - 611X)

Volume 5- Issue 1, Paper 50 January 2022

Advanced Hybrid Solid PropellantFor Futuristic Missile Technology

A. Ganguly and A. Kumar

Department of Aerospace, SRM Institute of Science and Technology
Email: 1. abhigang2000@gmail.com **| 2.** kumar.apoorv123@gmail.com

In Today's time the rocket engines for the missiles generally depend on the cryogenic and liquid propellants because of their high Specific Impulses (ISP ~ 450s) and control. The cryogenics have a major issue of storage and handling. Over the past few years, the dependence on the cryogenic propellants {i.e., fuel-> Liquid Hydrogen (LH) and oxidizer- >Liquid Oxygen (LO2)} is increasing at a very high pace. Hybrid Solid propellants provide a good alternative to these. In this project, we aim to enhance the performance of rocket engine by increasing the ISP of the propellants by using various energetic materials {that are readily available}, and varying proportions of fuel & oxidizer to obtain a new composition that can be prepared in a room temperature to create a Hybrid Solid Propellant. Our work is driven by the need to reduce the over-dependency on liquid and cryogenic propellants, and find an alternative to these propellants. The performance is evaluated in terms of Specific impulses (Isp) and Characteristic velocity (C*) both of which are significant parameter.

Introduction

A missile is a guided airborne ranged weapon capable of self- propelled flight usually by a jet engine or rocket motor. The rocket engines for the missiles generally depend on high Specific Impulses (ISP ~ 450s) and control. This can only be provided by cryogenics and liquid propellent because they can be controlled and also the base Isp is above 350 seconds where and only keep increasing till as high as 540 seconds. That is why, over the past few years, the dependence on the cryogenic propellants {i.e., fuel-> Liquid Hydrogen(H)(L) and oxidizer- >Liquid Oxygen (O2) (L)} is increasing at a very high pace. Solid Propellants have been gradually pushed out of the centre stage of rocket propulsion. liquid and cryogenics have some disadvantages as they have their advantages. The Disadvantages are: -

1. They are very difficult to store as mostly very low surrounding temperature in order not to get damaged.
2. Require huge amount of money to research and develop new products in the line.
3. They cannot be made readily available as they have complex procedure to be manufactured and transported.

Journal of Current Research in Engineering and Science
Bi-Annual Online Journal (ISSN : 2581 - 611X)

Volume 5- Issue 1, Paper 50 January 2022

4. Transportation Hazard are big part of the propellants being hard to get as a small leak can be fatal.

In the future the price is only going to increase which means developing and under developed nations will find it very hard to make good, effective and economical missiles. For that matter even developed countries may face a challenge. However, in national security missile technology take the first place and cannot be ignored. That is why a cheap, viable and equally effective propellant has to be developed or discovered.

Results of Simulation

Base Composition

Base composition consisted of Aluminium (Al) in crystalline form was the fuel, Hydrogen Peroxide(H2O2) in liquid state was the binder and Ammonium Perchlorate (NH4ClO4) was the Oxidizer. As the CEA software does not have facility to enter any material as binder HP was entered in fuel selection and was treated as a fuel. The simulation carried out at the operating conditions given in procedure yielded the following results.

✓ Base composition Isp: 336.90 s

✓ Characteristic Velocity(c*): 1544.5 m/s

* Repeatability of Third Order is ensured for all the data presented

After the values for the base composition was found out different materials available in the CEA

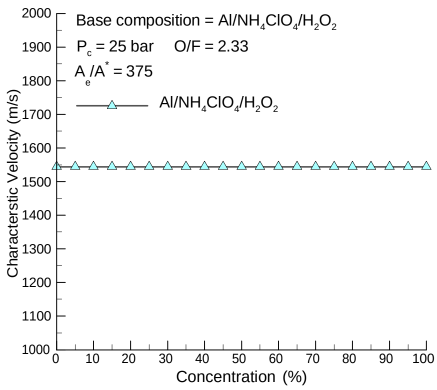

Figure 1: Variation of Isp in Base Composition

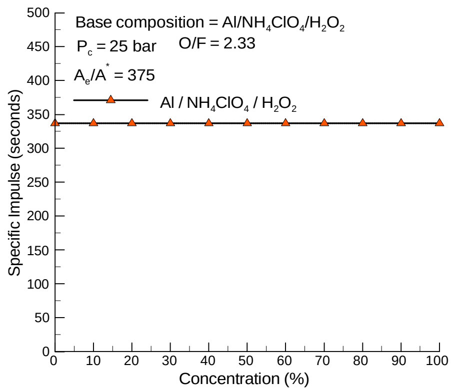

Figure 2: Variation Of C* in Basecomposition

Journal of Current Research in Engineering and Science
Bi-Annual Online Journal (ISSN : 2581 - 611X)

Volume 5- Issue 1, Paper 50 January 2022

Hydrocarbons in Oxidizer.

As the above plots show it can be inferred that when comparing Isp all three materials tested do not have much difference at peak values, due to the lines almost coinciding. This can be attributed to two factors, first the peak values of Isp occur at the same value of weight percentage which is 15% for all three materials, Second the values of maximum I_{sp} have very less difference between all three. However, in characteristic velocity the difference can be clearly seen with methane having the highest while the other two are relatively lower. At 100% by weight percentage both the Isp and characteristic velocity of all the three materials drop lower than that of base composition barring characteristic velocity of methane which manages to stay just above that of base composition. The lowest Isp and characteristic velocity were given by JP-5 when added 100% by weight in the oxidizer.

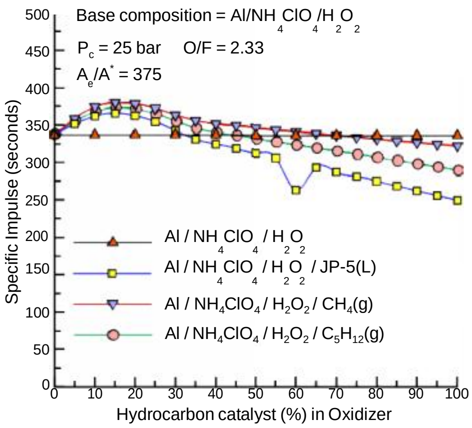

Figure 3: Variation of Isp due to additionof Hydrocarbons in Oxidizer

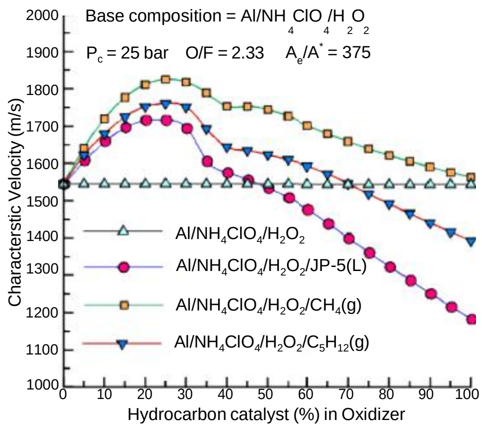

Figure 4: Variation of c* due to additionof Hydrocarbons in Oxidizer

Hydrides in Oxidizer

As visible in the combined plots the Isp of Lithium and Beryllium hydride are very close to each other albeit with beryllium giving a little higher at a higher percentage by weight mixed with the oxidizer. The lowest Isp is given by Magnesium and Beryllium hydride at between 80-90% concentration and 60% concentration respectively. The decrease At 100% substitution by weight the specific impulse and characteristic velocity of all the materials drops below that of base composition. In characteristic velocity potassium hydride is far lower than base composition compared to other materials and it also gives a gradual decrease in I_{sp} which is always lower than that of base composition.

Journal of Current Research in Engineering and Science
Bi-Annual Online Journal (ISSN : 2581 - 611X)

Volume 5- Issue 1, Paper 50 January 2022

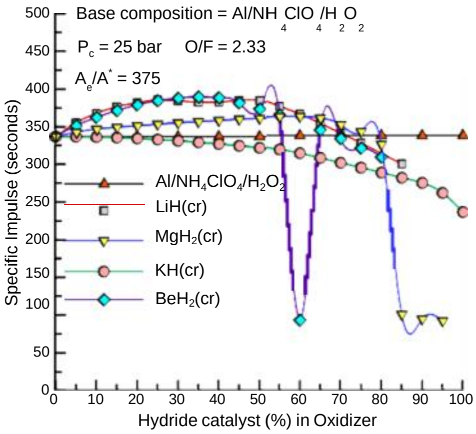

Figure 5: Variation of I_{sp} due to additionof Hydrides in Oxidiser

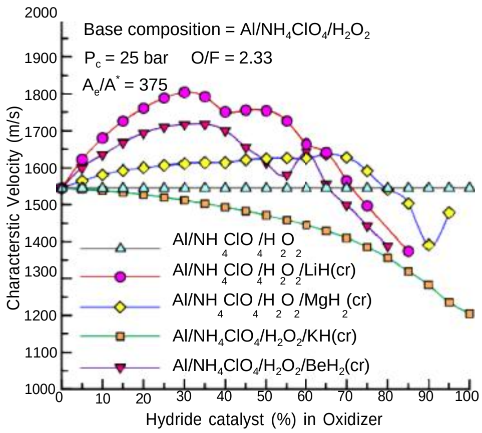

Figure 6: Variation of c* due to additionof Hydrides in Oxidiser

Hydrocarbons in Fuel

After combining all the hydrocarbons in one plot we observe that acetylene has an advantage in Isp over other two materials and all of the materials give highest specific impulse or characteristic velocity at 10 or 20 percent of Hydrogen Peroxide. The maximum increase in characteristic velocity is highest at 10% or 20% of Hydrogen Peroxide, and as can be seen in the plot is given by acetylene when around 80% of it is mixed in fuel. None of the materials have characteristic velocity that drop under that of base composition even at high concentrations. The Isp of Naphthalene and RP-1 do go below that of base composition and both materials do not have much difference between peak specific impulse, but acetylene is clearly better and has the highest Isp increase from base composition and even at high concentration of 80% does not go below it.

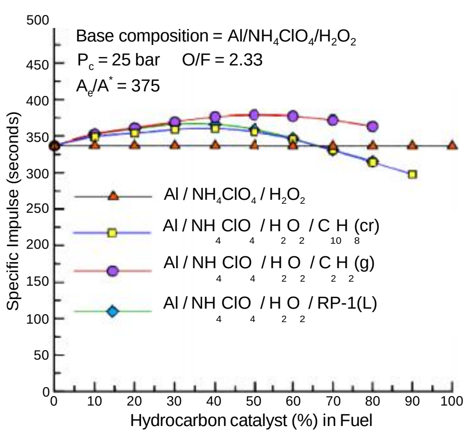

Figure 7: Variation of Isp due to addition of Hydrocarbons in fuel

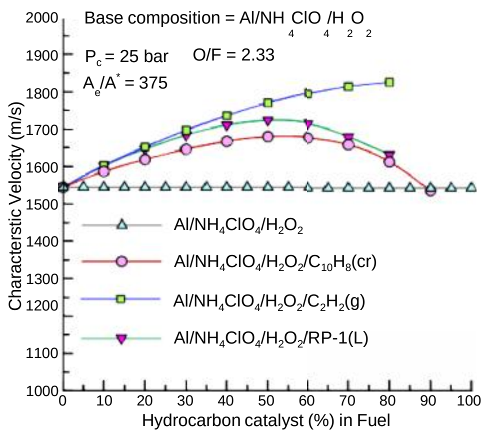

Figure 8: Variation of c* due to addition of Hydrocarbons in fuel

Journal of Current Research in Engineering and Science
Bi-Annual Online Journal (ISSN : 2581 - 611X)

Volume 5- Issue 1, Paper 50 January 2022

Hydrides in Fuel

In the combined plots of hydrides, it can be seen that hydride of beryllium gives much higher peak I_{sp} of 422 seconds at 70% concentration with fuel compared to lithium which gives a maximum of 386.23 seconds. The plot for lithium flattens after a point after 50% concentration of catalyst, but the plot for beryllium keeps climbing meaning beryllium will give a more rapid increase while lithium will give maximum I_{sp} at a point and drop from peak value after that as seen in the characteristic velocity graph. In the characteristic velocity plot also by the time peak value for beryllium is reached the values for lithium are already falling. However, both the parameters remain above the values of base composition, for both the hydride catalyst meaning they are useful for increment in performance. Here in both materials the Hydrogen Peroxide is 10% of the fuel section.

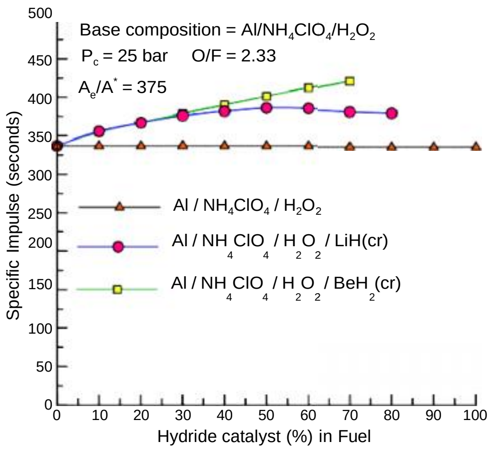

Figure 9: Variation of Isp due to additionof Hydrides in fuel

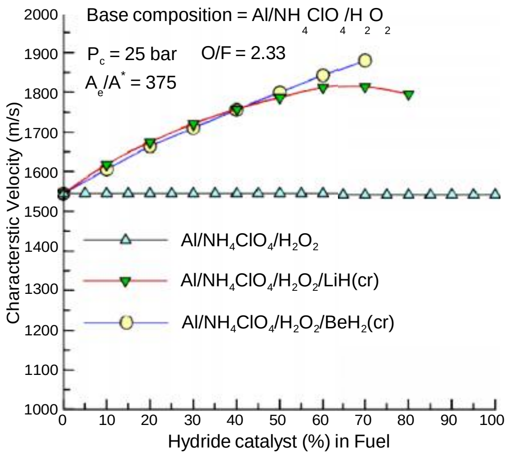

Figure 10: Variation of c* due to addition of Hydrocarbons in fuel

Summary of Results

After testing many compounds and noting the best results can be summarised as follows: -

1.) Hydrocarbon Energetic Catalysts in oxidizer of the Base Composition

- Methane is preferred for increasing Isp by mixing it in oxidizer as highest increase in given by it in hydrocarbons.
- Neo-Pentane can both increase or decrease depending on the weight percentage in which it is mixed in oxidizer, so gives the best overall performance.

2.) Hydrocarbon Energetic Catalysts in Fuel of the Base Composition

- Acetylene is also capable of increasing the Isp by nearly 50 seconds when mixed with fuel.

3) Hydride Energetic Catalysts in oxidizer of the Base Composition

- Hydrides of magnesium and beryllium for specific percentage by weight in oxidizer are capable of pulling down Isp very rapidly to below 100 seconds.
- Lithium and beryllium give highest Isp in this group with the latter giving a higher value.
- Potassium is useful for giving gradual decrement in Isp.

4) Hydride Energetic Catalysts in fuel of the Base Composition

- Beryllium and lithium give high value but beryllium is more preferable as Isp crosses 400 seconds.

Looking at the following results the common factor is the material beryllium hydride as it gives both a high increase and a good decrease. When the Isp is at 422.85 seconds, giving an increase of more than 25% from base composition, it is already in the category of most energetic chemical propellants and is looking like a good alternative to cryogenic and liquid propellant. When it reduces specific impulse below 100 seconds, giving a decrease of around 70% from base composition, it can be used to make a missile reusable as low Isp means it will not be able to easily gain velocity and so can be bought back for landing instead of carrying out self-destruct procedure. Another conclusion which can be drawn from this project work is that it is possible to increase the specific impulse of solid propellant and also to manipulate the performance of hybrid solid propellants by changing adding materials and changing the composition of the propellant.

Journal of Current Research in Engineering and Science
Bi-Annual Online Journal (ISSN : 2581 - 611X)

Volume 5- Issue 1, Paper 50 January 2022

Acknowledgement

We would like to express my deepest gratitude to our, professors for their valuable guidance, consistent encouragement, personal caring, timely help and providing us with an excellent atmosphere for doing research. All through the work in spite of their busy schedule, they have extended cheerful and cordial support to us for completing this research work.

References

1. Moore, G.E., and Burman, k., 'A Solid-Liquid Rocket Propellant System', International Telecommunications Convention, Article 8, par. 4 (3), 1956
2. Tormey, J.F., 'Liquid Rocket Propellants- Is There an Energy Limit?', VOL 49, No. 9, Rocketdyne, A Division of North American Aviation, Inc., Canoga Park, Calif, 1957
3. Ross, F.R., 'Space System Specific Impulse', Journal of Aerospace Sciences, 1961
4. Sollott, G.P., Alster, J., Gilbert, E.E., and Slagg, N., 'Research towards novel energetic materials. J. Energ. Mater., 4, 5-28, 1986
5. Robert L. Zurawski., 'Current Evaluation of the Tri propellant Concept'. NASA Technical Paper 2602, 1986
6. A. Palaszewski., 'Upper Stages Using Liquid Propulsion and Metallized Propellants', NASA Technical Paper 3191, February 1992
7. Borman, S., 'Advanced energetic materials emerge for military and space applications'. J. Chem. Eng. News, 18-22, 1994
8. Zandbergen, B.T.C., 'Modern liquid propellant rocket engines'. American Institute of Aeronautics & Astronautics, 2000
9. Robles, R.A., 'Thermochemical Analysis of Hydrogen Peroxide with Applications to Rocket Design', Project Report for 'Masters of Science', San Jos State University, May 2002.
10. S. Venkatachalam. G. Santhosh, K.N. Ninan 'High Energy Oxidisers for Advanced Solid Propellants and Explosives' Advances in Solid Propellant Technology, P1 International HEMS1 Workshop, Ranchi, India, 2002, 87-106.
11. Jain.S.R., 'Solid Propellant Binders', Journal of Scientific and Industrial Research, Vol61, November 2002
12. Muhalim, M. and Krishnan, S., 'Design of Nitrogen-Tetroxide/Monomethyl Hydrazine thruster for upper stage application', http://www.propulsion-skrishnan.com/pdf/N2O4-MMH%20Upper%20Stage%20Thruster.pdf, 2010

Journal of Current Research in Engineering and Science
Bi-Annual Online Journal (ISSN : 2581 - 611X)

Volume 5- Issue 1, Paper 50 January 2022

13. Potter, Christopher R., "Design of Economical Upper Stage Hybrid Rocket Engine". University of Tennessee Honors Thesis Projects.2013
14. Rufino, S.C., Silva, G. and Iha, K. ‘An Overview of the Technological Progress in Propellants Using Hydroxyl-Terminated Polybutadiene as Binder During 2002–2012’,J. 39 Aerosp. Technol. Manag., São José dos Campos, Vol.5, N° 3, pp.267-278, Jul.-Sep., 2013
15. Luigi, T. De Luca., Toru, Shimada. Valery, P. Sinditskii., Max, Calabro., ‘Chemical Rocket Propulsion: A Comprehensive Survey of Energetic Materials’, Springer Aerospace Technology, Springer International Publishing, 2016
16. Banerjee, S., Ramanan, V., Malhotra, V., ‘Energetic Composite Solid Propellants’, International Journal of Aerospace and Mechanical Engineering, Volume 4 – No.2, April 2017.
17. Gajjar, P., and Malhotra, V., ‘Advanced upper stage energetic propellants’,IEEE Aerospace Conference,2018
18. Ray, T., and Malhotra, V., ‘Advanced High Energy Materials for Futuristic Liquid Propellant Rocket Engine Propelled Space Missions’, Journal of Chengdu University, 2021