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Scope of Pulverized Metal Fuel as an Alternative For Fossil Fuels

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Abstract: The availability of cheap fuel is a significant challenge for every economy. Many researchers are working on solving this problem, along with the concern of environmental degradation. The skyrocket fuel price, alarmingly severe air pollution level, and climate change due to global warming will be driving factors to change the current mode and method of transportation. The user fraternity is looking for the fuel that hasa high yield at low cost and is also environment-friendly. Pulverized Metal Fuel (PMF) or metal particles of nanometre-scale can be a promising alternative. This study finds that metal fuels have better combustion properties when compared to conventional fossil fuels, which are highly polluting in nature.

Keywords: Pulverised Metal Fuel, Alternative Fuel, global warming, combustion, energy

Introduction:

Nanomaterials are nanoparticles of metals, ceramics, polymers, etc. Preparing nanomaterial using nanotechnology is a technique to break solids into microscopic particles of size 1-100 nanometres (nm)[1]. PMF is based on the idea of oxidation of metals. Metal particles like iron or aluminum when exposed to oxygen, due to high reactivity they oxidize. Since the oxidation process is exothermic in nature, therefore some heat will be released. Although the energy produced by small quantity nanomaterials does not seem significant if used in correct proportions, it can generate sufficient energy to drive a vehicle [2]. Experiments stated that metal fuels (MF) could power a vehicle for three times the distance traveled by conventional fuel-powered vehicles [3]. Moreover, the combustion is smoke-free, and no environmental pollution is caused [4]. The characteristic which makes MF the most suitable fuel is the ability to be recycled. Unlike their counterparts, MF does not get consumed during the combustion. These metal oxides (residual after oxidation) can be treated with hydrogen to remove the oxide layer and can be reused again for combustion. The advantages of PMF over macro-sized MF are listed in Table 1.

Table 1: Advantages of PMFs.

S. No.	*Advantage*
1	Improved combustion efficiency
2	No agglomeration
3	Reduced slag formation
4	Complete oxidation
5	No or very less smoke generation
6	Reusability

Metal combustion is a difficult task but has vast areas of application,mainly in space applications. As these fuels have a high energy density, these fuels are used for solid-propellant rocket engines. These nanomaterials originated at NASA (National Aeronautical Space Agency), U.S., in the late ’60s. Further, due to safety concerns caused by liquid fuels,

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the complete focus was shifted towards solid metal fuels in 1974 [5]. Dreizin et al.[6] conducted research on the combustion of metal fuels in microgravity conditions for space applications. Since then, the development of various metal, i.e., Mg, Al, and Ti and their alloys, as metal fuels are underway.

Literature review:

If we compare the MF like iron or boron to petrol, then iron can release twice the energy compared to petrol, and boron releases almost five times the energy released by petrol [7]. At initial stages, the MF was not considered as fuels because achieving high enthalpies in time was very difficult to achieve. Agglomeration, slow combustion rate, and incomplete combustion were some challenges faced by MFs [8]. With a revolution in the field of nanotechnology, most of the challenges faced by PMF have been taken care of. Properties of some metal fuels are given in Table 2 [9].

Table 2: Properties of Metal Oxides.

S. No.	Metal	Metal boiling point temperature at 1 atm (K)	Oxide	Volatization temperature (K)	$H_{T,vol}$-H_{298}+ΔH_{vol} (kJ/mol)
1	Al	2791	Al_2O_3	4000	2550
2	B	4139	B_2O_3	2340	640
3	Be	2741	BeO	4200	1060
4	Cr	2952	Cr_2O_3	3280	1700
5	Fe	3133	FeO	3400	830
6	Mg	1366	MgO	3430	920
7	Ti	3631	Ti_3O_5	4000	2970

Production of MF is done by metal alloying techniques. It is followed bya ball milling process to break the metals into nano-sized alloy particles. The ball milling process, although efficient and straight forward, can ignite the fuel due to sudden phase change. This problem can be avoided by using control agents like hexane or methanol. Also, an inert gas is filled in the chamber where the milling process takes place [10].

Combustion of nanoparticles primarily depends upon several parameters: oxidizer composition, rate of heating, ambient conditions [9]. The combustion temperature for Al-Mg alloy is measured to be 897^{0}C. Several burner designs have been developed to study the combustion technique of various PMF. The combustion takes place when air and nanoparticles are mixed in a mixing chamber in the presence of DC current, and a metal aerosol is produced [11]. The flame is usually 2-3 mm high for Mg and Al particles.The heating values of various metal fuels are listed in table 3.

PMF can easily be burnt in an internal combustion engine just like many other fuels. The major challenge faced is that the nanoparticles when oxidizes, it releases all its energy in one go. This is not good for application in engines as the energy has to be released in a controlled manner, i.e., energy release should last between 5-20 milliseconds to get maximum output [12]. To solve this problem, we can control the rate of heat release by controlling the diffusion of oxygen into the metal particles. If we can create clusters of nanoparticles (1-200

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mg), then the combustion rate can be controlled. Apart from the above-mentioned technique, these MF can be used as fuel in Stirling engines [8].

Table 3: Metal Fuel heating value [11].

S. No.	*Fuel*	*Heating value (Cal/g)*
1	Aluminum	7420
2	Magnesium	5910
3	Titanium	4716
4	Boron	13800
5	Carbon	7830
6	Zirconium	2877
7	Polystyrene	9931
8	JP5	10150
9	JP10	10014

Discussions:

Despite several advantages over conventional fossil fuels still, PMFs are not in use due to some significant disadvantages. The weight of the metals is one of the major concerns as metals are heavy; thus, it will increase the overall weight of the vehicle. If we compare this to the hydrogen fuel cell, then initially hydrogen fuel might seem to be a better choice, but the challenge with a hydrogen fuel cell is that it releases water vapor as a by-product into the environment. Millions of vehicles emitting water vapor will lead to increased global warming effect because water vapor is the dominant gas for causing global warming.

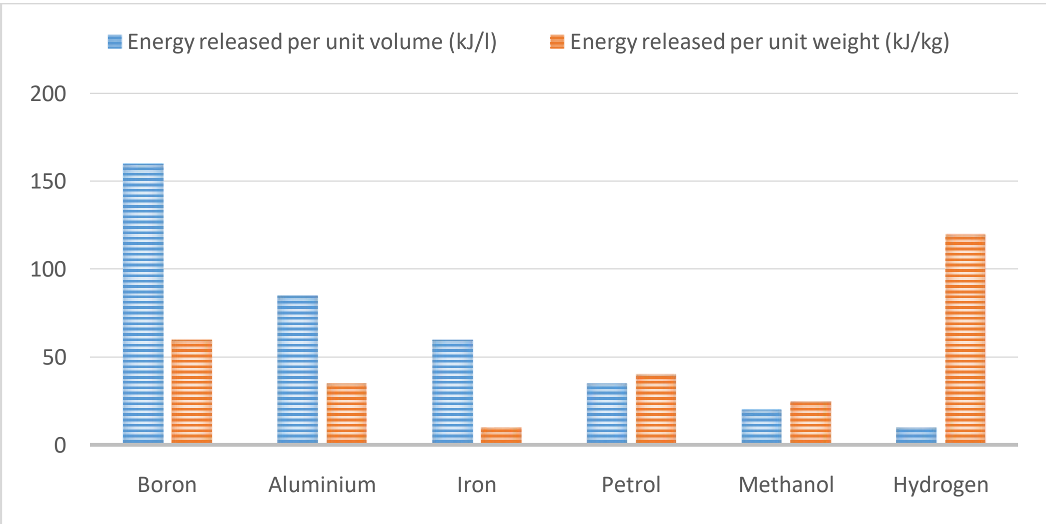

Figure 1: Comparison of energy release by various fuels.

In order to curb the weight problem, some light metals like aluminum or boron can be used instead of iron. They are light in weight as well as can release more energy as compared to iron and many other conventional fuels. Figure 1 gives a comparison of the energy released by various fuels [11]. Although aluminum and boron are light in weight and release more energy, they are expensive when compared to the iron. Currently, research is going to build an engine and test it with fuels to identify the best of it.

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Conclusion:

Metal fuelled engines have a very high potential of replacing conventional auto fuels from the market. In fact, the companies that dominate the fossil fuel sector will soon shift to metal scrap, which will be generated by old vehicles and convert it into potential fuel, which can be reused again and again. PMF needs to be studied for various combustion characteristics by not only developed countries but by developing countries like India too. This will result in a slightly modified engine producing very fewer emissions,i.e., carbon dioxide, particulate matter, and NO_x.

References:

[1] Bharat Bhushan, *Springer Handbook of Nanotechnology*. Springer Berlin Heidelberg, 2007.

[2] M. A. Schroeder, "Possible chemical mechanisms for boron hydride acceleration of nitramine decomposition: Literature review," *Journal of Propulsion and Power*, vol. 14, no. 6. American Institute of Aeronautics and Astronautics Inc., pp. 981–990, 1998.

[3] T. Sell, S. Vyazovkin, and C. A. Wight, "Thermal decomposition kinetics of PBAN-binder and composite solid rocket propellants," *Combust. Flame*, vol. 119, no. 1–2, pp. 174–181, Oct. 1999.

[4] R. Friedman and A. Maček, "Ignition and combustion of aluminum particles in hot ambient gases," *Combust. Flame*, vol. 6, no. C, pp. 9–19, 1962.

[5] M. K. King and H. D. Ross, "Overview of the NASA microgravity combustion program," *AIAA Journal*, vol. 36, no. 8. American Institute of Aeronautics and Astronautics Inc., pp. 1337–1345, 1998.

[6] E. L. Dreizin, "On the mechanism of asymmetric aluminum particle combustion," *Combust. Flame*, vol. 117, no. 4, pp. 841–850, Jun. 1999.

[7] C. L. Yeh and K. K. Kuo, "Ignition and combustion of boron particles," *Progress in Energy and Combustion Science*, vol. 22, no. 6. Elsevier Ltd, pp. 511–541, 1996.

[8] D. S. Sundaram, V. Yang, and V. E. Zarko, "Combustion of nano aluminum particles (Review)," *Combustion, Explosion and Shock Waves*, vol. 51, no. 2. Springer New York LLC, pp. 173–196, 01-Mar-2015.

[9] T. E. Glassman, G. Bhandari, and T. H. Baum, "Evidence for cooperative oxidation of MOCVD precursors used in BaxSr1-xTiO3 film growth," in *Materials Research Society Symposium - Proceedings*, 1997, vol. 446, pp. 321–326.

[10] G. Young, K. Sullivan, M. R. Zachariah, and K. Yu, "Combustion characteristics of boron nanoparticles," *Combust. Flame*, vol. 156, no. 2, pp. 322–333, Feb. 2009.

[11] S. S. Thipse, *Alternative Fuels*. 2010.

[12] I. Glassman and P. Papas, "Combustion thermodynamics of metal-complex oxidizer mixtures," *J. Propuls. Power*, vol. 15, no. 6, pp. 801–805, 1999.