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A Green Engine Concept—Need Of The Hour

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ABSTRACT
The serious problems of pollution and global warming appear to be difficult to tackle. The solutions being offered are for containing both rather than eliminating. The real causes of these problems basically are combustion and fossil fuels. If we can tap energy from non-carbonaceous materials without involving combustion the problems will get eliminated. This paper discusses one such chemical reaction of decomposition, which can be made to produce kinetic energy. Such an approach will lead to a totally green engine which will give out useful gases rather than dangerous gases as in case of today's engines.
KEYWORDS: *green, ammonium nitrate, engine, pollution global warming, concept*

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I. INTRODUCTION

Today's scenario does not augur well for the future or even immediate future. Global warming is happening faster than what was predicted. Extreme weather conditions are hurting humanity animal world and crops alike. Dependence on fossil fuels like coal and petroleum products is not diminishing. Even if most of automobiles go electric way the problem is not going to diminish—it is only going to shift to a different place. Electricity is largely manufactured from fossil fuels. Therefore, the only solace would be that the areas where the automobiles ply would become clean. But what about the areas where electricity is produced? Those areas will become more polluted. In short the global warming and environmental pollution are not going to diminish unless a revolutionary energy source is found.

II. THE REAL PROBLEMS

If one tries to define the problem in short it would be: affordable clean, green mobility and also affordable clean energy. Affordable would necessarily mean that the common man should be able to utilize the means of transportation. The means should be clean—i.e. should not emit any harmful products. In energy production and / or utilization some by-products are generated which are damaging for the flora and fauna. Thus the affordable green mobility should—if at all—emit environment-friendly by-product. For example a hydrogen based engine would produce water as by-product which is environment-friendly and not harmful. However, a hydrogen based mobility solution is not affordable—at least as of now. At present the available clean energy sources are not convenient and efficient. Solar energy is practically free but tapping it for day-to-day use is not convenient. Electrical energy is plagued with storage problem. Therefore, even if we manage to produce electricity in environmentally clean manner storage becomes a hindrance as we are experiencing in electric cars. Charging batteries takes a long time and the range that an electric car can travel in a single charge is limited.

All these difficulties warrant a fresh look at how clean energy can be tapped which would be also useful for mobility.

III. WHY COMBUSTION?

Other than renewable energy common energy sources utilize internal or external combustion. The cause of all environmental issues is combustion. A chemical reaction is a must for most energy conversions. All IC engines produce mechanical energy through combustion of fossil fuels and release harmful exhaust gases. Are there any chemical reactions which do not involve combustion and still produce energy? Yes, there are. Some chemical reactions involve dissociation of compounds and are exothermic. This means that while dissociating into compounds they evolve energy. If we can tap energy from dissociation reaction we need not worry about combustion products. The only catch here is that the dissociation products should be clean from environment point of view.

IV. SOME DISSOCIATION CHEMICAL REACTIONS

One of the simplest dissociation reactions is dissociation or decomposition of calcium carbonate into calcium oxide and carbon dioxide:

¶ $CaCO_3 \rightarrow CaO + CO_2$ (1)

This reaction produces lime and carbon dioxide gas after dissociation. This is an endothermic reaction—meaning it *needs* energy for dissociation. Obviously such a reaction is not going to be useful for an engine.

Any electrovalent compound ionizes in an aqueous solution and dissociates in positive and negative ions such as:

$NaCl$ (solid) $\rightarrow Na^+$ (aqueous) + Cl^- (aqueous) (2)

These reactions may be endothermic or exothermic. However they too are not useful for consideration with respect to an engine.

Some ammonium compounds do dissociate and are interesting to study.

$NH_4Cl \rightarrow NH_3 + HCl$ (3)

This is a decomposition reaction which is reversible but endothermic. It also produces hydrochloric acid which is corrosive and harmful.

$(NH_4)_2CO_3 \rightarrow 2NH_3 + CO_2 + H_2O$ (4)

This reaction is endothermic and produces a harmful gas—ammonia.

However ammonium nitrite (NH_4NO_2) at 100^oC decomposes thus:

$NH_4NO_2 \rightarrow N_2 + 2H_2O$ (5)

In this exothermic reaction it releases nitrogen and water vapour. It produces energy equivalent to 224 kJ per mole of ammonium nitrite.

However, ammonium nitrite is highly unstable. Therefore, although the reaction produces harmless gases this substance cannot be considered for an engine.

Ammonium nitrate, on the other hand offers a number of decomposition reactions[1].

1. $NH_4NO_3 \rightarrow N_2O + 2H_2O$ (- 36 kJ/mole) (6)
2. $NH_4NO_3 \rightarrow NH_3 + HNO_3$ (176 kJ/mole) (7)
3. $NH_4NO_3 \rightarrow N_2 + 2H_2O + 1/2O_2$ (-602 kJ mol^{-1}) (8)

The first and the third reactions are exothermic and the third is the most attractive. It gives away maximum heat and gases which are harmless. In fact, this reaction which is complete dissociation of ammonium nitrate, gives pure oxygen too.

Decomposition of ammonium nitrate into nitrogen, water vapour and oxygen is the most suitable to run a complete green engine. This reaction normally takes place above 250^0C

V. COMPARISON OF ENERGY CONTENT OF VARIOUS SUBSTANCES

If we compare the energy content of various traditional fuels with that of ammonium nitrate it is noticed that the latter is the lowest in TABLE 1 given below.

Table 1[2]

Fuel	Energy Content kJ/gm
Natural Gas	54
Petrol (Gasoline)	48
Diesel	45
Black Coal	34
Brown Coal	16
Ammonium Nitrate	7.53

Though the enthalpy of ammonium nitrate is low it is nearer to brown coal. The question is whether this energy content is sufficient to run and sustain an engine.

VI. ENGINE POWER

Engine power has been often equated with the fuel enthalpy. In the ammonium nitrate decomposition reaction one more thing happens. A small volume of solid ammonium nitrate decomposes into large volumes of nitrogen, water vapour and oxygen.

Shalini Chaturvedi and Pragnesh N. Dave[3] investigating decomposition of ammonium nitrate show that its decomposition into nitrogen, water vapour and oxygen involves release of 354 calories/gm and the volume of gases released per gram is about 980 ml which is approximately 1 litre. At lower temperatures the volume may be lower—something like 350 ml but still quite significant. See TABLE 2 below:

Table 2: Modes of thermal decomposition of Ammonium Nitrate

Sr	Reaction	Heat evolved (cal/g)	Gas volume (ml/g)	Temp ^{0}C
1	$NH_4NO_3 \rightarrow NH_3 + HNO_3$	-521	-	-
2	$NH_4NO_3 \rightarrow N_2O + 2H_2O$	108	840	320
3	$NH_4NO_3 \rightarrow 3/4N_2 + 1/2NO_2 + 2H_2O$	316	910	860
4	$NH_4NO_3 \rightarrow N_2 + 2H_2O + 1/2O_2$	354	980	950
5	$8NH_4NO_3 \rightarrow 5N_2 + 4NO + 2NO_2 + 16H_2O$	201	945	560
6	$NH_4NO_3 \rightarrow 1/2N_2 + NO + 2H_2O$	86	980	260

The large volume of gases produced by decomposition can certainly offer sustainable mechanical power. For continuous decomposition reaction a temperature level above 250^{0}C needs to be maintained. Initial heating can be facilitated by a battery powered heater. As the decomposition reaction itself is exothermic it will not be difficult to maintain the temperature level once the reaction has been initiated.

VII.GREEN ENGINE CONCEPT

A conceptual design of ammonium nitrate engine may consist of a feeder unit to for continuous supply of Ammonium nitrate. Ammonium nitrate may have to be a mixture with some additives for safer handling. The nitrate would enter a reaction chamber where the decomposition will take place. As has been mentioned above,

the chamber will need heating initially to facilitate the complete decomposition to nitrogen, oxygen and water

vapour which takes place at 250^{0}C. Later the temperature would be sustained because of the exothermic nature of the reaction. See Fig.1.

It must be noted here that it is very essential to maintain the temperature above 2500C because at lower temperatures the decomposition may result in unwanted noxious and corrosive gases like nitrous and nitric oxides as well as nitric acid. A safety feature will have to be incorporated in the design of the engine to ensure that the reaction stops as soon as the temperature goes below 2500C.

A continuous decomposition resulting from uninterrupted supply of ammonium nitrate would build a large volume of nitrogen, oxygen and water vapour mixture. Water vapour may be condensed to water which can be used to cool parts other than the reaction chamber. The remaining gases would be stored in a sealed reservoir to build pressure. Valves would be fitted to the reservoir to control the pressure. A stream of gas under pressure would be released to rotate a turbine. This rotation would provide the mechanical drive.

Obviously the mechanical power can be used to drive vehicles as well as electricity generators and pumps.

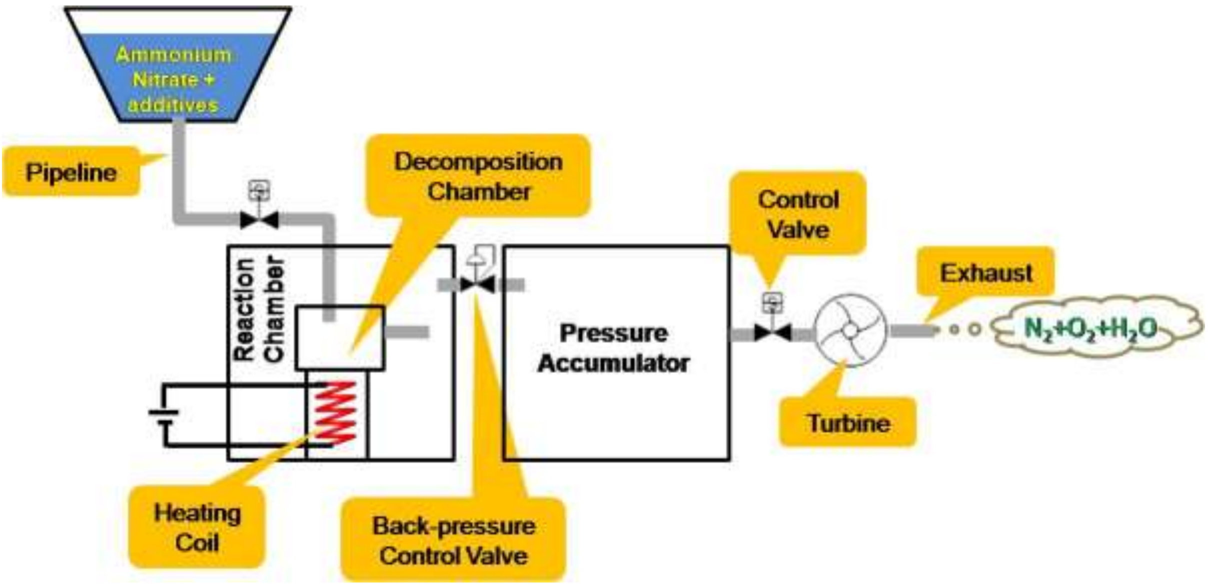

Fig. 1 **- Concept Diagram of an Ammonium Nitrate Engine**

VIII. CHALLENGES

The reaction looks very simple but it will need a great effort, investment and time before Ammonium Nitrate Engine can see the light of the day. The challenges in taking this concept to reality have many aspects. These may be listed as follows:

a. Safety: Ammonium nitrate is an explosive though its detonation needs some specific conditions. It would be necessary to keep the substance in the storage / engine tank safe from decomposing there itself. One idea would be to use a slurry with water which makes the substance secure from exploding. Besides it would also be easier to deliver the slurry to the reaction chamber.
b. Maintaining temperature level above 250^0C: To ensure optimum decomposition an external heat source such as a heating coil may be necessary. Whenever the temperature level goes below, a sensor would activate the coil to heat the chamber and maintain the temperature level.
c. Availability of ammonium nitrate: This should not be a great challenge since ammonium nitrate is used as a fertilizer too. For making it available as an engine fuel would need some kind of regulation.
d. Prototype: There could be several types of engines based on the principle of this concept. Even a reciprocating type of engine can be built which may one day open the possibilities of converting existing fossil fuel engines into ammonium nitrate engines. To build a prototype, however, may take years and a lot of financial investment.
e. Materials: Reaction chamber needs to be maintained at a temperature above 250^0C and if the exothermic reaction heats up the gases the materials for reaction chamber and turbine / reservoir need to be resistant to heat to those levels. Materials for engine construction also need to be corrosion resistant to nitrates.

IX. CONCLUSION

It appears that ammonium nitrate is a good candidate for a totally green engine. It offers exceptional advantages over existing engines in that it totally eliminates the emission of dangerous toxic gases. Developing ammonium nitrate engine will go a long way in getting rid of one of the biggest challenges in modern world. Institutions and industry must come forward to develop engines based on ammonium nitrate decomposition.

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