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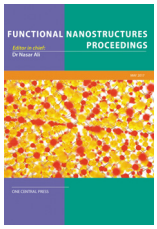

On the Use of Hydrogen in the Automotive Sector

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ABSTRACT

According to studies promoted by the United Nations over the last hundred years, the average temperature of the atmosphere increased by 0.5 °C. The trend has been almost exponential since the 1960s, years of world industrial development and economic boom. Hydrogen offers an alternative to the fuels used today and proposes itself as a possible interesting solution for our future. After showing the benefits that hydrogen can offer, the attention is then focused on its use in the automotive sector. The number of vehicles is expected to increase following the recent massive motorization in India and China. It is therefore necessary to find a transport means that allows to drastically cut the emissions. Various studies on the possibility of hydrogen propulsion are currently underway, many of them at the level of experimentation. The easiest way to use hydrogen in the vehicular context is in current internal combustion engines with the addition of appropriate modifications, just as it happens for methane or LPG conversion to cars. The advantages over normal engines and other solutions are considered.

I. INTRODUCTION

Since ancient times, human society has developed on the basis of the available energy resources. From 1900 to today the primary energy requirement has increased by more than 10 times; in last forty years it has almost doubled. The increase in energy needs is due to the continuous increase of population and to the improvement of living conditions. At present, transport and heating, corresponding to two-thirds of primary energy, require petroleum, coal and natural gas as fuel; these fuels are favored by being quite simple to extract.

The production of harmful gases during combustion of petroleum products has led to the search for cleaner alternative sources. Over past 40 years, environmentalists and various industrial organizations have promoted hydrogen as a solution to global pollution and global warming, considering that it is a pure, inexhaustible and abundant source. Hydrogen has proved to be the best candidate for replacing diesel, heating oil, natural gas and many other fuels used for transport and not only.

Like electricity, hydrogen is a high-quality energy carrier that can be used to get high efficiency with virtually zero emissions. Production increases every year by about 10% and in 2005 the total value of produced hydrogen was around 135 billion $ [1].

The annual global hydrogen production is of order of 500 billion Nm^3, equivalent to 44 million tons. These are obtained:

- 60% by the chemical reforming process of light hydrocarbons, mainly methane;
- 30% by the cracking of heaviest hydrocarbons (petroleum);
- 7% by coal gasification;
- 3% by electrolysis.

More than 90% of the produced hydrogen results directly or indirectly from processes involving the use of hydrocarbons, although production systems based on clean and renewable energy sources are spreading everywhere. In the foreseeable future it is expected a substantial increase in demand for hydrogen, a great use for both electricity production and vehicular use. The use of hydrogen is considered to be exploitable also for other purposes, such as aircraft, boats, laptops, mobile phones [2].

II. VEHICLE APPLICATIONS OF HYDROGEN

a) *Hydrogen thermal motors*: the easiest way to use hydrogen for a vehicle is in existing internal combustion engines with the addition of appropriate modifications, just as it does for methane or LPG conversions for cars. Advantages compared to normal engines are in particular:

- the wide range of flammability;
- a low ignition energy that allows a rapid kindling;
- a very high self-ignition temperature that increases the compression ratio of the motor, increasing the efficiency of the theoretical and real cycle;
- a very high combustion flame velocity as well as the thermal conductivity, approaching the transformation to the isochore combustion of ideal cycle;
- a high diffusivity, which implies a greater mixing with combustion air.

b) *The fuel cell solution*: vehicles may be powered with the electricity produced by the fuel cells installed on board. This is the evolution of battery technology where, in the presence of hybrid traction, using fuel cells it is possible to increase the vehicles autonomy. With this solution we obtain hydrogen vehicles that are very compact and well fit with the urban use, cars able to have similar autonomy to the present fuel-powered ones, buses, freight transport vehicles.
c) *Hydrogen fuel cell vehicles*: for some years, the tendency is to produce vehicles of this type designed and conceived solely to accommodate hydrogen traction systems. They are innovative "concept cars" that take advantage on the ability of fuel cells to be able to place the various components with the resulting benefits, such as increased living space and innovative driving characteristics.
Electric motor: we have DC and AC motors. The generated power ranges from a few hundred watts to some kW; for cars designed for extraurban routes we have values between 15 and 90 kW, for buses between 100 and 250 kW.
DC motors normally operate between 48 and 192 V; to overcome this last value, a brushless motor is required. They are especially suited for indoor applications, such as forklifts that need little maintenance, simplicity, economy, and reduced control needs [3,4].

III. VEHICLES PRODUCED BY CAR MANUFACTURERS

In recent years numerous automakers have given commercial availability to some models of hydrogen-powered cars. Cars that use hydrogen in internal combustion engines can run both with fossil fuels and with hydrogen. This solution, less polluting than internal combustion engines fueled by fossil fuels, has been the first step towards adopting fuel cell cars.
- *Hydrogen: propellant in internal combustion engines*: interesting results have been achieved by the BMW home that has produced a V-12 engine powered both with fuel and hydrogen and the car "Hydrogen 7". Mazda has developed the RX8 model, which has a hydrogen autonomy of around 200 km, thus approaching the value of Hydrogen 7. The difference between the two cars is the storage of hydrogen. Ford has produced some bi-powered prototypes such as the hydrogen-powered Focus C-Max H2ICE, that has an online 4-cylinders motor of 2300 cc and 110 hp.
- *Fuel cell supply*: automotive homes have designed and realized prototypes of fuel cell vehicles, despite the higher complexity of the system and the higher cost. We particularly recall: Honda FCX Clarity, Mercedes F-CELL Class B, Fiat Panda Hydrogen, General Motors Hydrogen 4, Chevrolet Equinox Fuel Cells, General Motors Sequel, Ford Focus FCV Hybrid, Suzuki SX4-FCV, Hyundai Tucson IX FCEV [5].

IV. SUMMARY

The energy crisis is of great interest and oil, in addition to the well-known problems of atmospheric pollution, will be end. Hydrogen, among the various alternative sources, is a completely efficient solution, although unfortunately it will have to deal with the power of oil-holding states and with the initial costs factor (for launching a new marketplace as it is that of hydrogen, very substantial initial investments are needing).
Some hybrid cars are already on the market, with very low consumption but the purchase price is higher than that of similar fuel cars and this is why they are struggling to market themselves. It is necessary an increase of awareness for energy sources that allow, in addition to lower consumption, lower environmental pollution. There is also the competition with "full-electric" cars.

Car makers such as Mercedes and BMW are also pointing in this "full-electric" direction. An electric vehicle, however, suffers very long charging times and big limits in tems of weight and bulk relatively to the batteries. The hope and even the expectation is to obtain, through research and experimentation, more and more enticing products from the point of view of constructive simplicity, cost, autonomy, efficiency, reliability,

and operational flexibility; these are the important factors for the market, even more than environmental themes.

V. REFERENCES

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