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SOME CHALLENGES OF THE USE OF HYDROGEN IN THE INTERNAL COMBUSTION ENGINES OF VEHICLES

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Abstract:*In the immediate future, the internal combustion engine will remain the main power-generating equipment of motor transport, making it urgent to find a new source of heat. Hydrogen energy is particularly important among alternative energy sources, since, environmentally and economically, it is one of the most promising types of fuel, a renewable energy source and is the most common element in the world. However, its introduction in vehicle manufacturing is subject to a number of challenges presented in this article.*

In the modern era, the intense development of the energy and transport sectors places mankind before serious energy and environmental problems. A rapid increase in the number of vehicles leads to a reduction in the existing fossil fuel resources, whose world reserves might become scarce in the near future. At the same time, technological advances based on traditional energy impact negatively on the environment and cause changes in the global climate.

In this context, a search for a new non-traditional energy source is an important task for both the power industry and the domestic sector. Of particular importance among the alternative energy sources is hydrogen energy, whose advantage over petroleum products high heat stability and environmental safety, the possibility of using in the internal combustion engines, transportability and the practically inexhaustible reserves.

At the present time, the discussions on the improvements in such technologies and on their further introduction in practice are on a very high level. The popularity of the issue stems from the rise in oil prices, forcing many countries to look for real and affordable alternatives. The idea of a hydrogen-powered engine has not only been taken up in practice, but also been given life by popular manufacturers such as Honda Motors, General Motors, Ford, BMW, etc.

Specialists agree that in 30-40 years, hydrogen will completely cover humanity's demand for fuel.

In addition to a number of positive indicators, hydrogen is also characterized by a number of negative sides, which are currently the determining factor preventing its extensive use in the internal combustion engines of vehicles.

Despite the fact that hydrogen is the Earth's most abundant element, it is virtually impossible to find it in its free gaseous form. Due to its low density (0.09 kg /m³) it moves freely in the upper layers of the atmosphere and passes through the air-free space. Therefore, hydrogen on the Earth is in a bound state of in the composition of water (H_2O) and methane (CH_4). It can also be obtained from a chemically poisonous compound such as hydrogen sulfide (the Black Sea is the largest reservoir of hydrogen on Earth), because in the area with excess oxygen, hydrogen sulfide burns, and along with hydrogen, there is also released very poisonous sulfur dioxide. However, by respecting the relevant regulations governing the environmental safety, hydrogen can be decomposed into sulfur and hydrogen, since hydrogen energy offers mutual economic and and environmental benefits.

Therefore, in the case of using hydrogen as a fuel, it is necessary to separate it from these compounds and store in special containers under certain conditions.

Due to the above negative features, mass consumption of hydrogen in the internal combustion engines is prevented because of the following major problems:

- A low density of the mixture of hydrogen and air, the engine power drops significantly as compared to the base power (the fresh charge mass is reduced), but with a slight change in the ignition system settings, the power losses are compensable and furthermore, it can be increased by 15-18%.
- At moving the vehicle at a specified distance, it is necessary to place the large-volume cyllinders on it, which entails certain difficulties, and that is why it is essential to develop the efficient and safe technological process for storing and using hydrogen on board of the vehicle.
- An important problem is the absence of a chain of hydrogen filling stations, which is due to higher cost of such filling stations as compared to conventional stations. Equally problematic is the maintenance and equipment of these stations, knowledge of methods and standards of vehicle operation (personnel training), promotion of safety, and so on. However, with the use of modern technologies and complete compliance with safety requirements, these problems would be resolvable.

The question is: how safe is the operation and maintenance of such stations? Of course, keeping any amount of hydrogen in the liquid state is safe, but when dealing with air during the maintenance, it is an explosive mixture. In addition, when using hydrogen fas a fuel in the internal combustion engines, there is a danger that the interaction with oxidant increases the risk of ignition, or even explosion. The carried out studies have shown that, 1/10 of the energy needed for igniting the gasoline and air mixture is enough for ignition of the mixture of hydrogen and air, that is, aven a static spark is enough for ignition of hydrogen.

Furthermore, the danger is also that the torch flame is not actually visible during the combustion of the mixture, which makes it difficult to undertake measures to ensure safety of the process. It should be noted that although hydrogen is not poisonous itself, the accumulation of certain amounts of it in the environment leads to asphyxiation due to oxygen deficiency. The danger also is that it is impossible to detect its presence of this gas in the environment, because it has no specific smell and is virtually invisible to human visual organ. However, there is no problem with hydrogen leakage (for example, in the garage) from the elements of the vehicle's fuel feed system in the open space, as its concentration in the environment is low and safe for life.

It is also noteworthy that, as in the case of any gas in a liquid state, hydrogen has also a low temperature (-253˚C), which poses a certain danger that in case of its leakage from the elements of the cylinder or system , the contact with them causes serious frostbite of the human body.

The negative sides of hydrogen as a motor fuel are the high burning rate and a premature ignition. It should be noted that the burning rate of the mixture of hydrogen and air

is much higher than the burning rates of the other mixtures. Consequently, the high burning rate (especially for the stoichiometric mixture) causes an increase in pressure in the cylinder, that is, an increase in engine rigidity ($dP/d\varphi$), which is the reason for the increase in the engine noise.

Premature ignition is problematic for engines running on the mixture of hydrogen and air, as compared to other engines. Premature ignition before the spark is delivered, may occur if the gas temperature at the end of the compression is higher than the temperature of fuel self-ignition. Premature ignition can be caused by the heated parts existing in the compression chamber (such as the candle, valve, etc.), as well as by large amounts of sludge. Premature ignition in the hydrogen-powered engines is caused by a small amount of ignition energy - 0.02 MJ (70 times less than methane and 12 times less than the gasoline rate), as well as by a wide ignition range, which is determined the ignition limit, that is, the ignition limit of the air and fuel ratio. This limit is estimated by the fuel content by volume in the mixture and the excess air coefficient (α). In the case of hydrogen, $\alpha = 0.15\text{-}10$, for gasoline - $\alpha = 0.27\text{-}1.7$ and for methane - $\alpha = 0.05\text{-}2.0$. Although, this problem can be solved by a certain change in the composition of the mixture of fuel and air.

As of today, many unsolved problems remain along the path of hydrogen energy development that hinder its wide use in practice:

- The cost of the hydrogen thermal element is still high, which makes the whole transport cost higher. The use of a hydrogen thermal element leads to an increased risk of fire and explosion;
- There are some difficulties with the hydrogen storage containers;
- Difficulties in developing equipment that can deliver hydrogen quickly and cheaply;
- Problems with long-distance hydrogen transportation;
- The explosibility of hydrogen. Hydrogen is known to be more dangerous than classic fuel (gasoline) with its characteristics. This is explained by its ability to burn with the air in a wider range. For example, gasoline is not dangerous when the excess air coefficient is greater than 0.5 and less than 2. As to hydrogen, its combustion is problematic with these numbers;
- The rapid evaporation. In the case of long-term storage, the risk of hydrogen evaporation (damage of the cylinder or pipeline) is high. This is why scientists are looking for special (safe) places to store the hydrogen thermal element. A reliable container should have the multi-layer wall made of special-purpose materials. One of the options is a tank made of nanomaterials, which is filled with hydrogen.
- Difficulty of maintenance. Specialists believe that the maintenance of the hydrogen-powered engines is more challenging than the engines running on petroleum-products. The reports show that the value of services can may to 50%;
- Insufficient experience in operating the hydrogen-powered engines and difficulty filling them with fuel.

Europe, America and Japan have expressed their concerns regarding the development of transport infrastructure working on the hydrogen thermal elements. It is expected that by 2025, the number of hydrogen filling will reach 1680. Seven car manufacturers (BMW-Toyota, Daimler-Ford-Nissan and Honda-GM) have announced joint plans to create and sell on the market, or to lease the cars running on the thermal elements [2]. This has given rise to a need for establishing common standards of fueling vehicles with hydrogen. These standards, developed and practiced in the research laboratories in recent decades, are the basis for the creation of the hydrogen fueling infrastructure in the world. At present, there are four standards developed by the SAE: Hydrogen Fuel Quality (SAE J2719); Hydrogen fueling (SAE J2601); Communication between the car and the hydrogen fueling station (SAE J2799);

The designs of nozzles and receptacles (SAE J2600);

- For servicing vehicles running on hydrogen, it is necessary to create the entire network of hydrogen fueling stations, and this requires huge investments. The cost of equipment for the hydrogen fueling station is much higher than the cost of a conventional petrol station. In this case, very few investors are trying to invest in this area;
- High hydrogen prices. The cost of one liter of hydrogen is on average 6-8 euros, which is quite expensive as compared to petroleum products. That is why the main task of scientists working today in this field is to minimize the hydrogen price;
- High evaporation capacity. It is difficult to store and transport hydrogen in a liquid form. Due to the rapid evaporation, even half the volume of hydrogen transported can be lost within a few days.

The leading car makers have already started production of hydrogen-powered vehicles, but many of them still continue to carry out theoretical and experimental research in this area. However, based on current trends, researchers working in the field of hydrogen energy are suited to the existing challenges. In addition, worth noting is that, that today, there is every reason to believe that hydrogen engines are our future. The remainder is just a matter of time.

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НЕКОТОРЫЕ ПРОБЛЕМЫ ИСПОЛЬЗОВАНИЯ ВОДОРОДА В ДВИГАТЕЛЯХ ВНУТРЕННЕГО СГОРАНИЯ ТРАНСПОРТНЫХ СРЕДСТВ

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Ключевые слова: *альтернативное топливо, взрывоопасность, водород.*

Аннотация: *В ближайшем будущем двигатель внутреннего сгорания останется основным энергетическим оборудованием автотранспорта, поэтому необходимо срочно найти новый источник тепла. Водородная энергия особенно важна среди альтернативных источников энергии, поскольку с экологической и экономической точек зрения она является одним из наиболее перспективных видов топлива, возобновляемым источником энергии и наиболее распространенным элементом в мире. Тем не менее, его внедрение в производство связано с рядом проблем, представленных в этой статье.*