Liquid Organic Hydrogen Carrier – a solution for storing and transporting hydrogen

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Hydrogen can be stored in many ways. Compressed hydrogen at different pressure levels is currently applied in most applications. In industrial grades it is available on a commercial basis in pressures from 200 bars up 700 bars. Due to its higher density liquefied hydrogen is used for hydrogen transport. Both options, the compressed as well as the liquefied state of hydrogen suffer from the fact that their volumetric energy densities are quite poor in comparison with the density of fossil fuels, such as diesel, which is well established as energy source.

Today industry is evaluating different options for hydrogen storage by converting it into synthetic fuels with higher storage densities, such as Ammonia, Methanol and LNG. They are produced in reactions of hydrogen either with nitrogen or carbon dioxide.

An alternate option are metal hydride storages which are most relevant for the power supply of air independent submarines. Here a metal alloy acts as the reversible carrier of hydrogen. In similar way certain organic compounds can pick up hydrogen into their chemical structure and release it under controlled conditions. These compounds are called Liquid Organic Hydrogen Carrier (LOHC) and known since decades without achieving a wider awareness.

During the last years LOHC systems were developed jointly by industry (BMW) and science (University of Erlangen). As a result of these efforts a new company, Hydrogenious LOHC Technologies, was established by the University of Erlangen. This company commercializes the LOHC technology in different fields, e.g., in combination with electrolyzers for storing wind energy or in hydrogen release process for fueling maritime and railway applications. The big advantage of the LOHC is the high level of safety considering the risk of ignition which are known from other fuels. Several different compounds have been tested for their hydrogen storage capacities. Most recently an oil which is used for storing thermal energy up to temperatures of 300 °C (Marlotherm) turned out the well suited for its hydrogen storage capacity. Since these thermal oils evaporate hardly, they have a rather low tendency to ignite. Another advantage is that they can be bunkered like diesel oil.

To release the hydrogen from the organic carrier the oil must be heated up to a certain temperature, which depends on its nature, and once sufficiently hot it is transferred over a catalytic bed. There the supplied heat allows a release of the bonded hydrogen, which can be used after passing a conditioning process as fuel for fuel cells and combustion engines. Even there the risk of ignition is limited only to the free volume of hydrogen between the release process and the energy converter, e.g., a fuel cell. The volume of free hydrogen can be controlled easily. The un-loaded carrier liquid is stored in an empty tank segment from where it can be returned to a land-based hydrogen loading installation. For hydrogen loading both the un-loaded carrier oil and hydrogen must pass through a catalyst bed. In an exothermic process hydrogen is bonded on the organic carrier.

Besides some other advantages the LOHC concept suffers from on major disadvantage, the large volume and weight of the carrier material. For storing 36 tons of hydrogen more than 600 tons of LOHC are necessary, but at a slightly smaller volume than the compressed hydrogen requires. For the transport of liquefied hydrogen, the required storage volume might be smaller. But here significant losses have to be expected by releasing evaporated hydrogen (boil-off).

Today the LOHC-technology is beginning to make its first steps out of its niche existence. In trials storage applications are tested in small and large scale. Most recently special importance achieved the transport of hydrogen loaded LOHC within the Japan – Brunei Project where Toluene is used as storage compound for large scale hydrogen transport to Japan. In a similar approach it is intended to convert the wind energy produced on Helgoland's wind fields into hydrogen by electrolyzes. To allow a safe transport from Helgoland the hydrogen shall be stored on LOHC.

The release of hydrogen from LOHC is evaluated in several applications. At Siemens Mobility the advantages of LOHC are inquired with the target to substitute compressed hydrogen storages on trains. Targeting on maritime applications it was announced in July 2021 that Hydrogenious LOHC and Johannes Østensjø dy AS have established the joint venture company Hydrogenious LOHC Maritime AS in Norway. The aim is to develop and commercialize emission-free propulsion systems for the global shipping market based on liquid organic hydrogen carrier (LOHC). The company is aiming to have a megawatt-scale commercial product ready by 2025. Siemens-Energy will be the integrator of the complete energy conversion process.

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