TEAM FAST

FORMIC ACID AS A HYDROGEN STORAGE MEDIUM

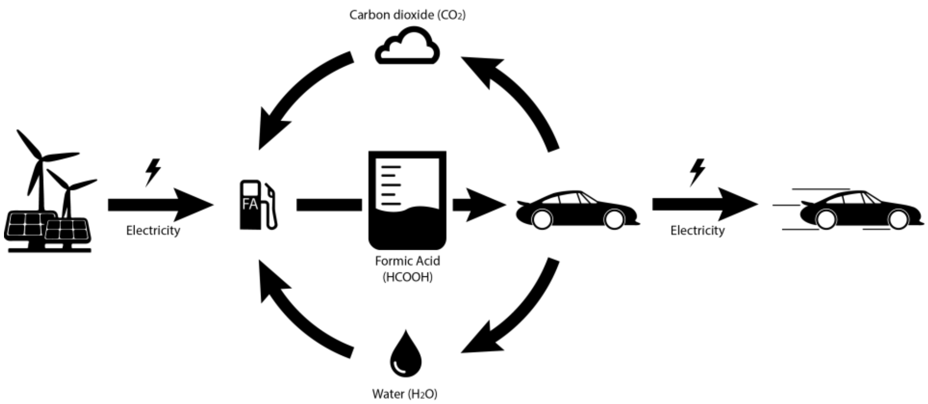
The storage of hydrogen gas in liquid formic acid for long term, energy dense and safe storage.

CONTEXT

In a transition towards a sustainable society the challenge will not be the production of sustainable energy. Renewable energy production has been proven possible with several technologies, such as solar panels and windmills. The challenge currently faced is storing this energy, to provide a stable grid and enable us to use the energy at any given place and time Producing hydrogen gas from sustainable power is one of the ways to store larger quantities of energy. Hydrogen gas storage and transport in pressurized vessels however remains a challenge and is therefore an inhibitory factor in the transition in the rollout of this technology. The storage of hydrogen in formic acid, a liquid at room temperature, can be done without these inhibitory factors and therefore has the capability to make storage of power in hydrogen more feasible. The most important advantages for storage of hydrogen in formic acid versus storage in pressure vessels are described below on the levels of practicality, safety and infrastructure. Also the functioning of the methodology of the system will be highlighted.

STORAGE METHOD

Hydrogen can be stored as formic acid (HCOOH) by binding the hydrogen molecule with a carbon dioxide molecule ($H_2 + CO_2 \rightarrow HCOOH$). Besides this way of formic acid production, it can also be produced directly from water and carbon dioxide, so that the extra hydrogen step is bypassed. When this formic acid is fueled, in for instance a vehicle, the formic acid is being converted back into hydrogen and carbon dioxide. The hydrogen will be turned into water vapor in a fuel cell which produces electrical power in the process. Both water vaper as carbon dioxide are the exhaust fumes which are released in the atmosphere. Despite the fact that the vehicle does emit carbon dioxide at its tail pipe, it is a carbon neutral fuel. During the production of formic acid just as much carbon dioxide is used as the system emits, making it carbon neutral. As seen in the picture below, carbon dioxide and water are merely temporary used to get the power from production to usage for a vast range of applications.



PRACTICALITY

Formic acid is a liquid and therefore inherently more energy dense, easier to store and easier to handle than a gas. The energy density of formic acid at atmospheric pressure 7,6MJ/L which is almost 70% much as hydrogen gas at 700 bar of pressure (4,5 MJ/L at 700 bar (Car standard) – 3,2 MJ/L at 350 bar (Bus and Trucks standard)). This implies that within the same volume more energy can be stored. The energy density per kilo is more difficult to compare since the storage method must be considered. Storage of hydrogen gas must be done in reinforced pressure vessels which are very heavy, while the weight of the hydrogen itself is nearly negligible. The storage of formic acid can be done in a light tank such as a plastic (HDPE) or a stainless steel (316L) tank, most of the weight is the fuel itself. On average both storage methods have the same energy density per kilo when taking the storage method into account. Due to this way of convenient storage the handling and transportation of formic acid has large advantages over the pressurized hydrogen since it can be transported in conventional IBC's, trucks and ships. In short; by storing hydrogen in formic acid it is possible to store more energy in a smaller volume at atmospheric pressure that can be handled like we are used to with liquid fuels as diesel or gasoline.

SAFETY

Hydrogen is a highly flammable gas which must be stored under high pressure. Even though this can be done in a safe manner from a technical point of view, the risk and consequences should be considered. Due to these safety aspects, it will not be advisable to build many hydrogen fueling stations in urban or high populated areas. When hydrogen is stored as formic acid, it is no longer flammable or explosive, which results into a safety risk that is even lower that the current fueling stations for gasoline or diesel. The only drawback that should be considered with formic acid is the corrosiveness that can occur when formic acid is dissolved in water. Pure formic acid is not corrosive (99%+), only when it is dissolved in water it will ionize ($HCOOH + H_2O \rightarrow HCOO^- + H_3O^+$), creating the corrosive H_3O^+ part. Still contact with the skin must be avoided, water from the skin or the atmosphere will ionize the formic acid making it corrosive. When contact with the skin does occur it should be washed off with diphoterine or large quantities of water to dilute the formic acid and reduce its corrosiveness. These safety aspects are not in relation of those of pressurized hydrogen, therefore having formic acid fueling stations in urban or high populated areas will not have any drawbacks.

INFRASTRUCTURE

Due to the liquid characteristic of Formic acid, it can be implemented in the current infrastructure with some minor adaptations. An instant pop-up fueling station, like used for AdBlue, can be installed for less than €10K[1] and will hold roughly 5000 liters of Formic acid. Rebuilding an operational fueling station for diesel and gasoline can also be done. The fuel tanks that are currently installed will need to be (re)coated and the hoses must be replaced. The rebuilding cost are estimated to be less than €100K[1]. Building a new fueling station for formic acid will be comparable with a diesel fueling station. When this type of infrastructure for formic acid is compared to that of pressurized hydrogen the investment costs are significantly lower, since hydrogen stations range from 1,5M to 6M.

[1] Hamer installatietechniek