How 'Christmas trees' can help improve hydrogen refuelling technologies

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How can we ensure safe, fast and efficient refuelling of hydrogen-powered cars, all at the same time? This brain teaser, key to the successful deployment of hydrogen technology in our future green economies, is being mulled over thanks to sensor technologies and a prediction model developed under the HYTRANSFER project.

When discussing the market potential of hydrogen, the sceptics often have refuelling at the top of their list of cons. Not only will it take decades to build the necessary infrastructure, but the refuelling operation itself is challenging to say the least.

Let's pretend that you have a 'Fuel cell vehicle' (FCV) and need to fill the tank up before a long trip. With a 'standard' fuel car, the operation would be completed in about a minute, whereas the latest FCVs require about three minutes for the whole operation. And getting to this result hasn't exactly been a sinecure for engineers: unlike petrol or diesel, hydrogen tends to heat up as it is being compressed into the fuel tank, and the composite materials used to create these tanks while keeping their weight as low as possible cannot withstand temperatures above 85 °C. In order to make the three-minute fast-filling operation possible, current refuelling stations pre-cool the hydrogen to -40 °C.

Improving this process to bring more efficient fuelling and even defuelling is the core objective of the HYTRANSFER (Pre-Normative Research for Thermodynamic Optimization of Fast Hydrogen Transfer) project, which started in June 2013 and will end in November 2015. Should it achieve its objectives, the project would help in reducing investment and operating costs, increase the reliability of refuelling stations and reduce maximum refuelling time, which would be a huge step forward in the successful rollout of the technology.

Sofia Capito, coordinator of the project, tells us more about HYTRANSFER's achievements so far, and how close it is to the ultimate goal of providing new recommendations for implementation into international standards and refuelling protocols.

What are the main objectives of the project?

In the HYTRANSFER project we develop methods and processes to adapt and reduce pre-cooling requirements, thus also reducing the capital and operating expenditure of refuelling stations. Experiments show that the heat transfer between hydrogen gas and the tank wall is rather ineffective. As a result, even when the hydrogen inside the tank reaches 85 °C—the maximum temperature composite-based tanks can be exposed to—the tank wall temperature will be significantly lower. Experiments conducted with nitrogen show a difference of 27 °C! Using thermodynamics to determine the relation between injected hydrogen, filling parameters such as hydrogen flow rate, and ambient temperature, can lead to a hydrogen transfer process which is optimised for the real boundary conditions.

What were the main difficulties you faced during the project and how did you resolve them?

Fortunately we are pretty much on track and many of the drawbacks we could have experienced just did not happen. The challenge for the two tank manufacturers involved, including project partner Hexagon Lincoln, are the particular requirements associated with the experiments: we need temperature sensors in the tank walls! And we don't need just one or two of them, but 30 sensors per tank. Positioning them during the manufacturing process is rather tricky, but both manufacturers put a lot of effort into it and eventually succeeded. With these sensors we can measure the temperature inside the tank walls. But we also need sensors to measure the temperature of the gas itself at various points in the tanks. As the tank openings are just a few millimetres in diameter, we introduce sensor arrangements nicknamed 'Christmas trees', narrow enough to fit through the tank orifices before they unfold themselves, similar to putting a ship in a bottle.

Where do you stand with the project? Have you achieved a satisfying level of temperature control yet?

At the moment three different laboratories are conducting experiments on three different kinds of tanks, as examining tanks in several labs ensures reliability and reproducibility of the results. Many of the experiments take place at the Joint Research Centre (JRC) of the European Commission which is a project partner. In parallel, accompanying 'Computational fluid dynamics' (CFD) simulations are further developed to be consistent with the results of the experiments. The project partner TesTneT is currently pre-checking initial experiment results, while the PPRIME institute (French research institute, CNRS/ENSMA/Univ. Poitiers) has already produced detailed measurements of the actual thermal properties of the tanks used. A simplified model with significantly reduced computation time—seconds to minutes instead of days to weeks—has been validated as well. So far, our experiments and modelling exercises support our assumption that there is significant room for improvement in pre-cooling requirements.

Are you optimistic about your approach impacting international standards?

As one of the first steps in HYTRANSFER, we analysed optimisation opportunities for the hydrogen transfer process within existing international 'Regulations, codes and standards' (RCS) and state-of-the-art of hydrogen technology. Based on this and the results obtained so far, we are quite confident that the project will produce test results and validation of these results leading to strong recommendations for RCS.

The CCS Global Group (CCS), with its decades of leadership in RCS development and compliance in the FCH and electrical sectors, is monitoring the relevant RCS activities and test results of the project so that we will be able to identify and extract RCS recommendations and develop a path forward for them to international bodies (e.g. CEN/ISO).

How do you expect your conclusions to help boost the hydrogen car market?

Car efficiency as such will not be boosted, but the interplay between refuelling stations and fuel cell vehicles will be improved. For the customers, this will result in reduced maximum refuelling time, increased reliability of the station and even reduced hydrogen prices. Ludwig-Bölkow-Systemtechnik (LBST) will conduct a detailed techno-economic analysis to identify the impact of the improved processes.

What are the next steps for the project, and do you have any follow-up plans after its end?

Current vehicles typically have not just one, but two or three connected tanks, so we need to find a viable refuelling approach for both single tanks and tank systems. The next step for us is to conclude our experiments on single tanks and further develop our simulations based on what we learn, after which a new, detailed refuelling protocol will be developed and tested on tank systems supplied by FCV manufacturer and project partner Honda.

HYTRANSFER will be considered as successful when the newly developed refuelling approach is published as a recommendation to international RCS bodies, and when our recommendations related to defueling are published.

We don't have any specific follow-up plans yet, but when HYTRANSFER is concluded and eventually finds its way into international RCS, further validation and an even a broader spectrum of experiments will have to be conducted.

More information: HYTRANSFER: www.hytransfer.eu

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