Smart Sensor Network for Hydrogen Detection and Localisation in Aircraft Environments

Tim Hoff*, Simon Beckmann*, Kai Wicke*, Rebecca Rodeck* and Gerko Wende*
*German Aerospace Center (DLR), Institute of Maintenance, Repair and Overhaul, Hamburg, 21129, Germany

Hydrogen is often considered as one of the most promising power sources for meeting the aviation sector's long-term decarbonization goals. Practitioners and researchers are therefore actively investigating whether it is possible to use hydrogen as a power source for aircraft in order to create sustainable alternatives to conventional fossil fuels. One major challenge in doing so is its high explosiveness, as a hydrogen-air mixture is ignitable between 4 and 75% hydrogen in air by volume. This explosiveness leads to safety concerns especially regarding leakages of all hydrogen-carrying systems and is a major challenge in its use as an energy carrier in aviation.

Therefore, the goal of this ongoing study is to develop a new hydrogen sensor monitoring concept in such a way that not only safe operation of possible hydrogen systems in aircraft is guaranteed, but at the same time the leakage can be localized as quickly as possible in the event of uncontrolled hydrogen emissions. The measurement method should be flexible and adapt to the different environmental conditions to which aircraft are exposed.

To achieve this, a digital, bus-based smart sensor network was developed. It combines a multitude of sensors such as gas-, humidity-, temperature and air flow sensors, each of them extended with a dedicated computing unit. These controllers can be specifically programmed to the assigned sensor and their current status, operating conditions, measurement requirements and positioning and can be reconfigured by a master command control unit at any time. Each of these small computing units is linked to each other via a bus interface. Since data is almost exclusively sent on the bus communication line in the case of an event, there is a high degree of freedom and flexibility in the data communication. Such an event would primarily be the detection of a a hydrogen concentration exceeding a predefined limit. In case of an event, the master command control unit can request the raw data of the current measurement, as well as past recorded data.

The localization of a possible leakage is achieved by post-processing the generated data. Using time deviations of the hydrogen detection of each sensor and knowledge about its positioning, it is possible to use a number of methods to localize the leakage. Potential methods could include those rooted in machine learning or geometry-based approaches. Usage of additional data such as air speeds, generated by the air flow sensors, can be used to optimize the result.

The proposed concept has several advantageous use cases. For example, through local digitization, parameterisation and subsequent signal analysis, the status of all sensors can be monitored with a simple traffic light display. It also enables to utilize the maximum number of sensor nodes (125) per bus, adding flexibility to add or remove sensors. Furthermore, to avoid distorting recorded data, changes in the environment (e.g. change of flight phase) can be communicated to the smart sensors so that they re-calibrate themselves in a decentralized manner. The localization of the leakage decreases repair times, as manual search can be prevented.

These use cases make the proposed smart sensor network stand out from other state of the art hydrogen monitoring systems. However, additional work has to be performed in order to test the system, develop sophisticated post-processing methods and identify and challenge individual use cases. The main focus on further research will lay on the tests in a small scale labrotary environment as well as the implementation of the system in the "Hydrogen Aviation Labs" ground demonstrator in the midterm future. This is performed with the thought to develop a flexible but expedient system that enables a safe operation of hydrogen systems on board of aircraft, ultimately supporting the implementation of hydrogen in aviation in order to achieve more sustainable air flight.