Application 2038

R&D of high pressure hydrogen storage system with increased fire resistance rating

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Scientific/Technological Excellence

The Warwick-Hexagon-Ulster user group applies for Transnational Access to HyKA research facility at KIT (Germany) aiming to address the key unresolved technological safety issues for hydrogen-powered vehicles, i.e. the increase of fire resistance rating of onboard high pressure hydrogen storage from about 10-15 minutes to 1-2 hours.

The objectives of the proposed R&D project are:

- Demonstrate experimentally the potential of substantial increase of fire resistance rating using innovative thermal protection solutions;
- Obtain data for validation of numerical models and simulations.

The applicants expect to achieve fire resistance rating of hydrogen onboard storage system of an order of magnitude higher compared to current unprotected tanks. This will allow to use thermally activated pressure relief device (TPRD) with smaller release rate. As a result of increased fire resistance rating and smaller TPRD diameter, a destruction of enclosure like a garage due to pressure peaking phenomenon will be excluded, and separation distances that are proportional to the TPRD diameter will be reduced accordingly. Moreover, self-evacuation and rescue operations at accident scene will be enabled as flame will be decrease from 10-15 m to about 1 m. It is expected that the research findings of this project would potentially feed relevant regulations, codes and standards, e.g. GTR. Results of this R&D work will be published in peer reviewed journals and presented at relevant meetings, including ISO TC 197 "Hydrogen technologies", and conferences, including ICHS.

Research Programme

Potentially from four to seven thermally protected high presser hydrogen storage systems will be tested to determine the upper limit of fire resistance rating. Storage systems will be thermally protected using various combination of different intumescent paint and/or other thermal protection (to be discussed during meetings of involved parties). The user group will formulate requirements to the design and manufacturing of equipment (except tank) and needed measurement instrumentation (for validation of models) in collaboration with KIT at the first meeting planned on 23rd of January 2014 at KIT. Equipment for this R&D study should be designed and manufactured at KIT to meet connectivity requirements between type 4 tank boss (will be supplied by the user group) and HyKA instrumentation. These series of tests does plan to determine the maximum possible fire resistance rating for available thermally protected storage systems but is not aimed at optimization of all parameters like space between vessels, thickness of the external shell, thermal insulation parameters.

Experimental fire procedure should follow general requirements of GTR 2013 bonfire protocol on instrumentation and temperature. However, the expected duration of the test should be expanded to at least two hours and special arrangements of the test in HyKA should be discussed such as continuous supply of nitrogen into the test vessel where premixed flame heats the storage system. Temperature in the space of HyKA should be controlled during the experiment and not exceed atmospheric temperature.

Container specification ("The Hexagon Composites Group"): capacity 36 litres (external diameter 325 mm and length 913 mm). The storage system should be filled with compressed hydrogen 350 bar or 700 bar. To experimentally determine a conservative fire resistance rating no TPRD will be installed on the storage system (simulation of blockage or failure of TPRD at an accident scene) and the test should continue until the catastrophic failure of the system. Safety plan should include appropriate measures for explosive rupture of the container pressurised up to 700 bar.

To obtain experimental data for model validation, the exterior contained surface temperature and temperature within/under protection coating could be monitored in key locations such as on top, bottom and side surfaces (measurement instrumentation for each of experiments should be planned in advance; the first experiment should probably have no external thermocouples to reduce heat transfer through the expanded intumescent paint). Thermocouples, if applied, should be isolated up to the area outside of the flame and probably covered by intumescent paint as well. Video records of the process are desired. Fuel flow rate should be recorded for the duration of the test as necessary input parameter for validation of CFD simulations.

Mineral wool is potential candidate to fill in space between the hydrogen tank and external shell (dual tank system). It is planned that separate series of experiments will be performed on propagation/extinction of premixed hydrogen-air flame through the tube filled with mineral wool. Intumescent paint after expansion in fire should not be destroyed (eroded) by bonfire jet flows. Support system should be painted as well to exclude heat transfer in areas of contact with the system. Internal tank should be installed within external metallic tank/shell (made of pipe) through thermo-isolating (low heat conductivity material) supports, e.g. basalt rings. Space between internal tank and the shell (external tank) should be sufficient for expansion of two layers of intumescent paint (in configuration when three layers of paint are applied - outer surface of internal tank type 4, and both internal and external surfaces of external tank/shell).

Space between tanks should be filled in by nitrogen to exclude potential of combustion of permeated hydrogen and air present from the beginning between two tanks (i.e. type 4 and shell). External tank could have small "check valve" (able to operate in fire conditions) to release expanding gas from the heated space between vessels and exclude entrance of hot gases from external environment. External tank/shell thickness should be such that release of pressure from internal tank would destroy external tank that will be registered as catastrophic failure (e.g. by pressure gauges installed in HyKA and by video records). First experiment could be with a minimum measurement instrumentation such as thermocouples to exclude any potential heat transfer and to assess the time to the tank failure (fire resistance rating).

Preliminary thermal protection configurations for tests (from 4 to 7) include in order of importance:

- type 4 tank with intumescent paint only;
- type 4 tank with intumescent paint and external tank with intumescent paint both on inside and outside surfaces;
- type 4 tank with intumescent paint and external tank with intumescent paint both on inside and outside surfaces and mineral wool in between the tanks;
- type 4 tank without intumescent paint and external tank with intumescent paint only outside and mineral wool in between the tanks;
- type 4 tank and external tank without any thermal protection (reference case);
- type 4 tank without intumescent paint, mineral wool in space between tanks, external tank with intumescent paint outside and radiation reflecting cover above it;
- type 4 tank with intumescent paint, thermo-isolating material "X" in space between tanks, external tank with intumescent paint outside.

User group

All user group members are outside of Germany, where HyKA facility is located. Two users - the University of Warwick (UW) and the University of Ulster (UU) - are from a member state (UK), one user (Hexagon) is from an associated member state (Norway). Majority of the user group (UW, HXG) are not partners in EC FP7 H2FC project.