THE PROSPECTS FOR AN APPLICATION OF COMPOSITE MATERIALS IN THE HYDROGEN STORAGE AND TRANSPORT SYSTEMS

Koroteev A.S., Koshlakov V.V., Mironov V.V.
FSUE "Keldysh Research Center", Onezhskaya, 8, Moscow, 125438, Russia
Fax: (495) 456-82-28, E-mail: kerc@comcor.ru, kerc@elnet.msk.ru

For all practical purposes, the hydrogen storage and transport systems are forced to use pipelines and reservoirs (tanks and bottles) operating under great excessive pressures.

Reservoirs are structurally to comply with some requirements for the service safety, long-term storage, resistance to climatic effects, and above all, to provide a possibility to store a sufficiently big amount of hydrogen. To a certain extent, overall-dimensions and mass parameters of the reservoirs may be characterized by the "tank factor" that is the ratio of the storable hydrogen mass to the reservoir weight, K_t. From the practical point of view, the values of K_t equal to 0.1…0.2 may be considered acceptable, which can be achieved with using high-pressure bottles (the working pressure as high as 400 to 600 atm), manufactured from composites.

Basic parts of these bottles are: the inner sealing liner of metal (Al, Ti, steel) or polymeric material; the outer load-carrying shell from composite material reinforced by organic (Armos, Rusar) or carbon fibers (UKN-5000, Kulon, VMN), fillers and fasteners.

Composite materials offer a diversity of necessary properties of which the most important are high specific strength and specific stiffness, low density, high resistance to corrosion, long-term static and dynamic loads and vibratory loads, a possibility to be operated in the conditions of low and high temperatures, alternating loads, increased humidity etc. Along with a decrease in mass, the application of CM makes it possible to essentially raise the reliability of tanks and bottles, as well as the operational safety due to the nonshattering character of breakdown of the shell at great loads.

In the last years FSUE "Keldysh Research Center" is performing a complex of calculation-and-theoretical, design and experimental works on the fields of a rational application and manufacturing of tanks and high-pressure bottles of CM. The performed investigations resulted in the advisability of using the CM tanks and bottles for the hydrogen storage under high pressures.

The paper has to do with results of experimental investigations of the strength characteristics of a number of tanks and bottles manufactured from CM (Figs. 1 and 2). In the process of these experiments the limiting bursting pressures at the level of 880 atm were attained. Besides, the manufactured bottles were put through multicycle tests (up to 5000 cycles) for the working pressure up to 450 atm.

From the results of the performed calculation and experimental investigations it follows:

- the application of the CM tanks and bottles to the compressed hydrogen at the working pressures from 400 to 600 atm (the safety margin ~ 2 and 1.5) allows it to increase the tank factor up to the levels as ~ 0.07 and 0.11 (when using reinforced organic plastic);
- the optimization of the shape of the tanks (diameter, elongation), techniques of winding the load-carrying shell (band, braid) and of the reinforcement structure, allows extra increasing K_t from 0.09…0.11 to 0.12…0.13;
- the use of materials with increased amounts of the strength and stiffness, e.g. the substitution of carbon fiber for organic (the modulus of elasticity of carbon fiber is higher than that of organic fiber by a factor of 1.3…1.5) enables to enhance the mass efficiency of the reservoirs for the hydrogen storage to ~ 0.15…0.17.

The use of the nonmetallic CM in the high-pressure tanks and bottles has good prospects and offers several advantages over conventional technologies:

- the decrease in the construction mass by 50…70%;
- the increase in the safety margins by a factor of ~ 2;
- the increase in the service life due to a high corrosion stability;
- the increase in reliability due to the resistance to long-term static and dynamic loads, high vibratory resistance, a possibility to operate in the conditions of high and low temperatures, alternating loads, high humidity;
- the improvement of the explosion proofness due to the nonshattering character of the shell breakdown at great loads.

Fig. 1.

Fig. 2. The nonshattering character of the composite tanks and bottles breakdown.