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THE DEVELOPMENT OF A CRYOGENIC PROPELLANT TANK FULLY MADE OF COMPOSITE MATERIALS

Abstract

Space technologies are aiming at load-bearing structures with a much lighter weight in future. This concerns fuel tanks in particular since they make up the major part of the weight. Composites have the highest specific density among other materials, and using them in fuel tanks therefore enables the lighter weight of a launch vehicle and a larger payload to orbit. This paper discusses the objective of developing and testing a fully composite superlight fuel tank for use in future space rockets and reusable aerial vehicles. Yuzhnoye State Design Office has been first to develop carbon fiber-reinforced, fully composite tanks for oxidizer and fuel, including the cryogenic propellants. The tank structure was designed in accordance with the analysis of the stress-strain behavior under the specified inner pressure (7.5 to 130 kgf/cm2). Strength computations were done to prove the performance of the tank of the selected geometry. To verify the obtained results, Yuzhnoye has manufactured and tested 40-liter tank prototypes that had the walls 1 to 3 mm thick and weighed 2.4 to 3 kg. For increasing the specific strength of carbon fiber reinforced plastic, Yuzhnoye has developed the method of carbon fiber surface modification with atmospheric plasma in acrylic acid. It has been determined that plasma treatment can make fibers 18–26The higher adhesion strength of the boundary between the filler and the binder was ensured by using infrared radiation for the winding and solidification of the carbon fiber-reinforced pressure shell due to the modified mechanism of binder polymerization. Infrared radiation was used to reduce the time and money required for making a fully composite fuel tank and to increase the adhesion strength between the binder and the filler. The use of infrared radiation for making the fuel tank pressure shell has made it possible to shorten the time of solidification by 4–5 times and reduce the cost of consumed electricity accordingly. To prove the adequacy of the scientific and engineering solutions selected for designing and making fully composite fuel tanks, experiments were run to determine the tightness and strength of tank prototypes. Water and liquid nitrogen were used to produce and increase the inner pressure up to the level of burst pressure. The tanks have burst at the expected values of pressure. The burst inner pressure has reached the value of 185 kgf/cm2 in water tests for a fully composite, high-modular high-density carbon fiber fuel tank with a 3-mm thick pressure shell. The developed fully composite tank for cryogenic propellants is three times as effective as a traditional aluminum tank, which enables the considerably lighter liftoff weight of launch vehicles.