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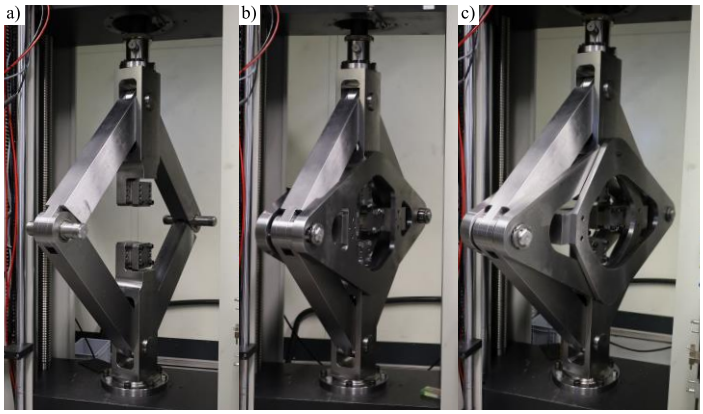
Development of validation tests for the simulation of leakage networks in cryogenic CFRP hydrogen tanks

Initial situation and objectives

Hydrogen is widely used as an energy carrier in space travel. The low volumetric energy density of hydrogen is increased by high pressures and very low temperatures. However, this results in high thermomechanical loads on the pressure tank.
Under these conditions, cracks form in the tanks made of carbon fiber reinforced plastic (CFRP). With sufficient damage, leakage networks are created through which the hydrogen can escape.
The aim of the joint project is to develop a calculation concept for the formation of these leakage networks and thus enable a prior assessment. The utg is responsible for the development and implementation of the validation tests. These require a permeation test of specimens under thermal and multi-axial mechanical load.

Approach

The special validation tests require simultaneous cryogenic cooling and multi-axis loading of samples with simultaneous permeation testing.
The permeation of the samples is determined via a leakage measurement using helium. A sample is subjected to a slight overpressure on one side and a strong underpressure on the opposite side. As soon as helium molecules can be detected on the opposite side, there is a leak. The quantity of molecules detected correlates with the size of the leakage.
This measurement method must then be linked to the thermomechanical load.
A mechanical test stand was developed for this purpose, which can be used in a universal testing machine. The kinematics used allow the uniaxial load to be transformed into a multiaxial load. This also eliminates the need to control independent axes, as used in biaxial tensile machines. The test rig allows access to the specimen from both sides. This allows simultaneous cooling and permeation measurement. Furthermore, the test stand was designed in such a way that several strain states are possible. In addition to a biaxial strain state, another attachment can also be used to achieve a plane strain state.



Test stand for multiaxial strain conditions
a) base; b) plane strain; c) biaxial strain

The cruciform specimens are cooled using contact cooling. Liquid nitrogen flows through a cooling device, causing the sample to cool down. The necessary connections for the permeation measurement are provided in the cooling device so that these two functions can be combined in one device.

Outlook

The developed and validated calculation concept will enable a more precise design of safety-relevant components for space technology in the future. In addition, the understanding of damage mechanisms will be increased. The knowledge gained in this way can also be extended to other industrial sectors and thus facilitate the commercialization of hydrogen as an energy carrier.

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