Contribution ID: **508** Type: **Regular Oral (15m)**

Structural and thermal design of cryogen-free mechanical property testing cryostat

Thursday 25 July 2024 09:45 (15 minutes)

In-situ mechanical property testing of materials at cryogenic temperatures is critical for the advancement of cryogenic engineering. Liquid hydrogen is emerging as a promising hydrogen storage and transportation medium to ensure the global decarbonization process. The development of liquid hydrogen infrastructure to meet the anticipated surge in demand necessitates a thorough exploration of novel materials and material properties, in both existing and novel materials such as composites, at cryogenic temperatures. Mechanical properties of materials that are pivotal in the designing process of infrastructure systems, therefore, need to be accurately quantified within the in-situ cryogenic environment to ensure the reliability and validity of the properties.

Historically, in-situ cryogenic mechanical property testing cryostats have primarily relied on the use of liquid cryogens such as liquid nitrogen (77K) or liquid helium (4K) to establish cryogenic conditions. Up to now, most of the testings were conducted using liquid nitrogen, a low-cost cryogen compared to liquid helium, and that limits the availability of the material property dataset at 77K, in which properties up to 20K are required for liquid hydrogen system designs. Considering the limitations of available material property datasets and the difficulty and cost of handling cryogens, this study introduces a novel approach by presenting the structural and thermal design of a cutting-edge cryogen-free cryostat tailored for conducting tensile and compression testing of materials at cryogenic temperatures. This cryostat has been carefully engineered in compliance with industry standards such as ASTM D638, ASTM E8/E8M, and ASTM D3039/D3039M, catering to the specific requirements of tensile testing for plastics, metals, and polymer composites. Notably, the system possesses a tensile loading capacity of 50 kN. The cryostat consists of a two-stage Gifford-McMahon (GM) cryocooler integrated into a customized self-reaction tensile testing jig system. The heating system incorporated at the second stage of the cryocooler provides the capability to control the temperatures of the system and to establish the system temperature at 20 K, ensuring material testing at the liquid hydrogen storage temperature range.

Structural integrity and performance of the testing jig system were rigorously assessed using Finite Element Analysis (FEA) to ascertain proper load-transferring mechanisms during mechanical testing. Components of the jig system were comprehensively evaluated for yield and buckling failure considerations, accounting for variations in room and cryogenic temperatures. Furthermore, the thermal design of the cryostat was carefully conducted, taking into account various heat transfer mechanisms such as heat conduction, convection, radiation, and free molecular heat transfer inherent during equipment operation. Both numerical analysis and FEA were utilized for thermal design to calculate the heat losses. Notably, heat conduction emerged as the primary source of heat loss, predominantly due to the loading rod that gets exposed to both room and cryogenic temperatures. This comprehensive approach of structural and thermal analysis ensures the efficacy and reliability of the cryostat in facilitating accurate mechanical property testing at cryogenic temperatures. Also, it lays a foundation to design and develop other mechanical property testing cryostats with minimal error. The cryogenic mechanical testing set up capable of carrying out stress and thermal fatigue testing. Furthermore, the testing set-up is equipped with two observation windows, enabling monitoring of specimen deformation using Digital Image Correlation (DIC) techniques. It will allow capturing of stress versus strain behaviour, which is vital to characterise the materials' fracture toughness, plasticity, ductility, and fracture behaviour. Also, composite fracture can be monitored using microscopic cameras so that micro-crack generation and propagation can be monitored for composites, which is vital to evaluate the leak and permeation of LH2 composite storage tanks.

Submitters Country

Australia

Author: BADUGE, Shanaka (The University of Melbourne)

Co-authors: Mr COSTA, Susiri (The University of Melbourne); Mr PREMAKUMARA, Amila (The University of Melbourne); Mr SAKVITHI, Hasala (The University of Melbourne)

Presenter: BADUGE, Shanaka (The University of Melbourne)

Session Classification: Thu-Or15

Track Classification: Tracks ICMC Geneva 2024: ICMC 15: Cryogenic materials and devices testing, methods and standards