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ELECTRICAL MEASURMENTS FOR CRACK LENGTH MEASURMENT IN FIBRE REINFORCED POLYMERS

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ABSTRACT

Due to their outstanding mechanical properties, fibre composites already have a wide range of applications in the mobility sector. With the transition of the economy away from fossil fuels towards renewable energies, hydrogen is set to play a central role in many applications. Concepts are currently being developed to power aircraft or lorries with hydrogen. This requires tanks made of lightweight materials that meet the high requirements of the mobility sector. Due to its comparatively high energy density, liquid hydrogen is to be used as an energy carrier in aviation [1]. However, this must be stored at - 253°C, which places enormous demands on the tank and its insulation. When a liquid hydrogen tank is filled, the tank walls cool down very quickly. Tanks made of carbon fibre reinforced plastics (CFRP) are subject to high thermal stresses during cooling. The brittle fracture behaviour of the epoxy matrix, which is exacerbated by low temperatures, results in microcracks in the matrix [2]. The microcracks accumulate in the material over the number of cooling and heating cycles. If a continuous path has been created through the tank wall, the hydrogen can penetrate from the inside to the outside and deteriorate the vacuum insulation of the tank. This leads to so-called boil-off losses and a poorer storage capability of the hydrogen in the tank. One way to prevent microcracks in the matrix is to increase the fracture toughness of the matrix. A high fracture toughness requires a higher energy and therefore a higher load to cause cracks to form or grow in the material. Common systems for increasing fracture toughness are toughening modifiers or flexibilisers made from thermoplastic polymers or elastomers, which extend the path of a crack by adding a second phase to the matrix. For use in a hydrogen tank, these systems must also lead to an increase in toughness at low temperatures in order to prevent thermally induced cracks.

This work focuses on the development of toughening modifiers to increase the fracture toughness of the matrix, which can also be used at low temperatures. For this purpose, chemical toughening modifiers and carbon nanoparticles are added to the resin as additives and processed together with glass fibres in an impregnating roller mill to form prepreg material. The material is cured in an autoclave and specimens for double-cantilever beam (DCB) and end-notched fibre (ENF) tests are cut from the sheets.

The tests at room temperature are carried out in accordance with ASTM 5528. The ‘Modified Compliance Calibration’ method is used to calculate the energy release rate. With this method, markings are usually applied to the side of the samples to enable the crack length to be read off during the test. This method cannot be used at low temperatures, as the samples can freeze and the markings are not recognisable. To solve this problem, a method from the field of structural health monitoring is adapted, which is based on capacitance measurement [3]. Capacitance measurement is used to determine the crack length during the test without visual observation of the markings. For this purpose, two electrodes are glued to the outside of the sample and the capacitance is continuously measured with a multimeter during the test. Due to an air gap that grows as the crack lengthens, the measured capacitance decreases during the test. This method makes it possible to determine the crack length in closed systems. The influence of various environmental properties such as temperatures, liquids or special pressure conditions on the sample can be tested. Mode II fracture toughness is also

tested at room temperature and at low temperatures using the ENF test in accordance with ASTM 7905 (see also Fig. 1 and Fig. 2).

Figure 1: Simplified representation of DCB measurement at low temperatures using capacitance measurement.

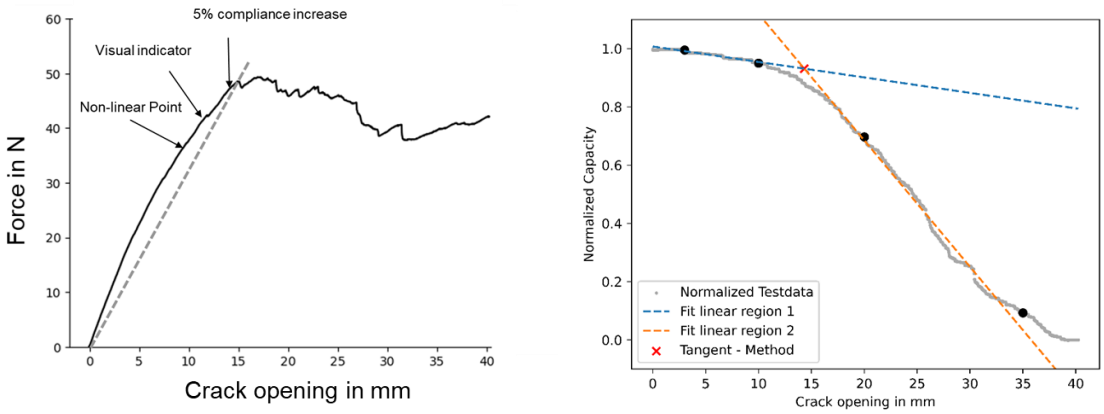

Figure 2: Determination of the critical energy release rate G_{Ic} based on electrical capacitance. Determination of the initiation point by: Visual inspection; Non- linear Point; 5% Compliance increase; 5% Capacity decrease; Capacity tangent.

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