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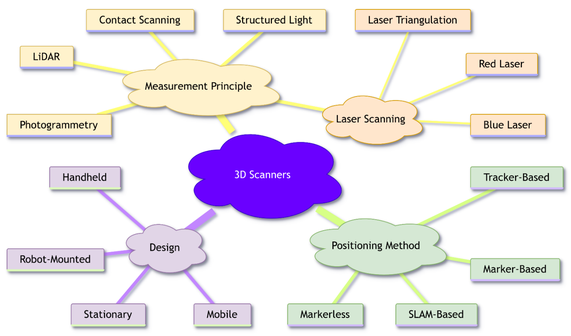
ITA Institut für Textiltechnik und Lehrstuhl für Textilmaschinenbau
RWTH AACHEN UNIVERSITY

Digital Quality Assessment of Composite Structures Using 3D Surface Scanning

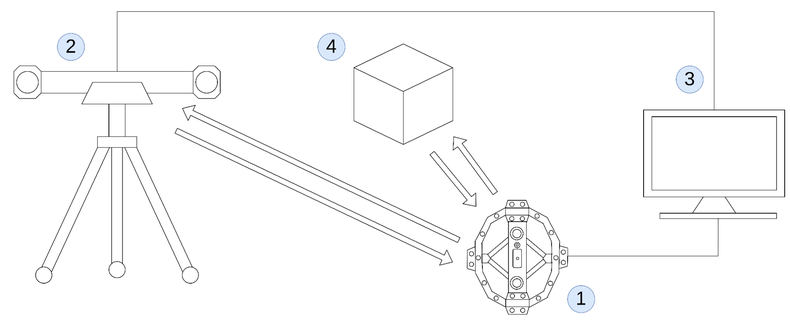
INTRODUCTION

Composite materials are increasingly used in engineering due to their high strength-to-weight ratio, making reliable quality assessment essential for ensuring structural integrity and detecting surface defects. Portable optical 3D scanning offers a non-contact method for capturing surface geometry and identifying dimensional deviations. This study investigates its applicability to the geometric assessment of composite structures, focusing on impact-induced deformation in sandwich panels and dimensional deviations in composite overwrapped pressure vessels (COPVs).

CLASSIFICATION OF 3D SCANNING SYSTEMS



SCANNING SYSTEM



The Revopoint Trackit is a portable optical 3D scanning system using blue laser scanning and infrared optical tracking. The setup includes (1) the scanner, (2) the optical tracker, (3) the computer, and (4) the scanned object. The tracker follows reflective markers to determine the scanner's position and orientation in 3D space.

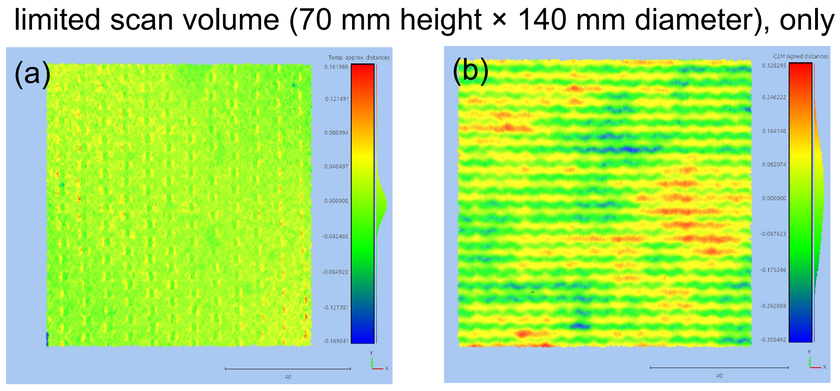
MATERIALS & METHODS

Two types of composite structures were investigated: multilayer carbon-fibre-reinforced sandwich panels (undamaged and impact-damaged) and a Type IV composite overwrapped pressure vessel (COPV), comprising a polymer liner, carbon-fibre composite overwrap, and integrated fibre-optic sensors.

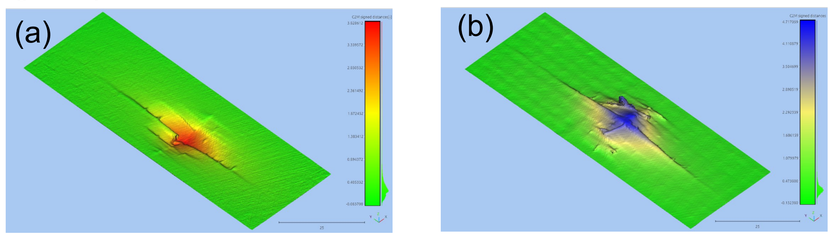
The acquired point clouds were used to establish reference geometries and quantify surface deviations. Planar surfaces were fitted using least-squares methods or Principal Component Analysis (PCA), while RANSAC enabled robust identification of dominant geometric features in the presence of outliers. Cylindrical surfaces were reconstructed through least-squares optimization, supported by local surface normal estimation. For complex structures such as COPVs, point clouds can be segmented into geometrically consistent regions using clustering or region-growing methods. Individual geometric primitives are then fitted to each region (e.g., a cylinder for the central section and suitable primitives for the end and transition regions), providing a piecewise reference geometry for subsequent deviation analysis.

RESULTS AND DISCUSSION

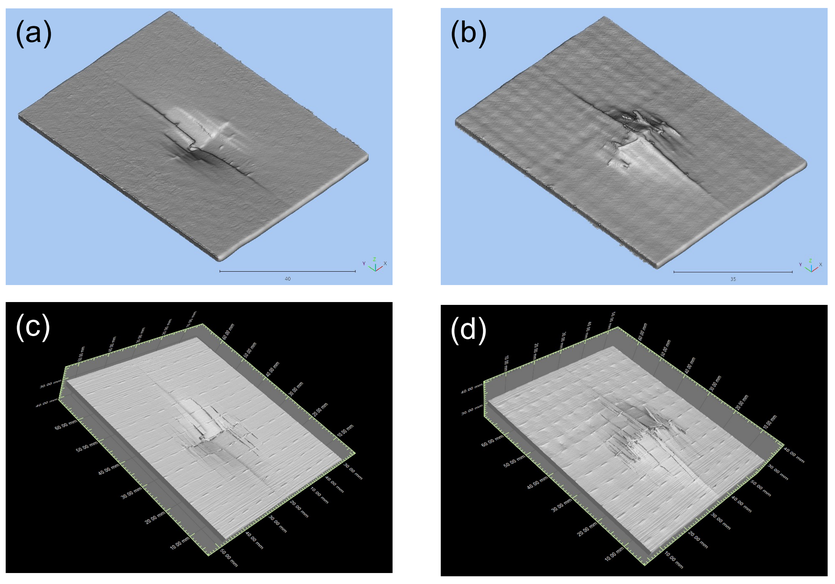
Optical 3D scanning (Revopoint Trackit; specified single-frame accuracy: 0.02 mm) was used for geometric inspection. Data were processed in Revo Track and CloudCompare. For selected impact-tested panels, X-ray CT (PROCON CT-ALPHA; specified detail resolution: 0.3 µm) was used to examine internal damage. Due to the limited scan volume (70 mm height × 140 mm diameter), only selected regions could be examined. CT data were visualized using VGSTUDIO MAX.



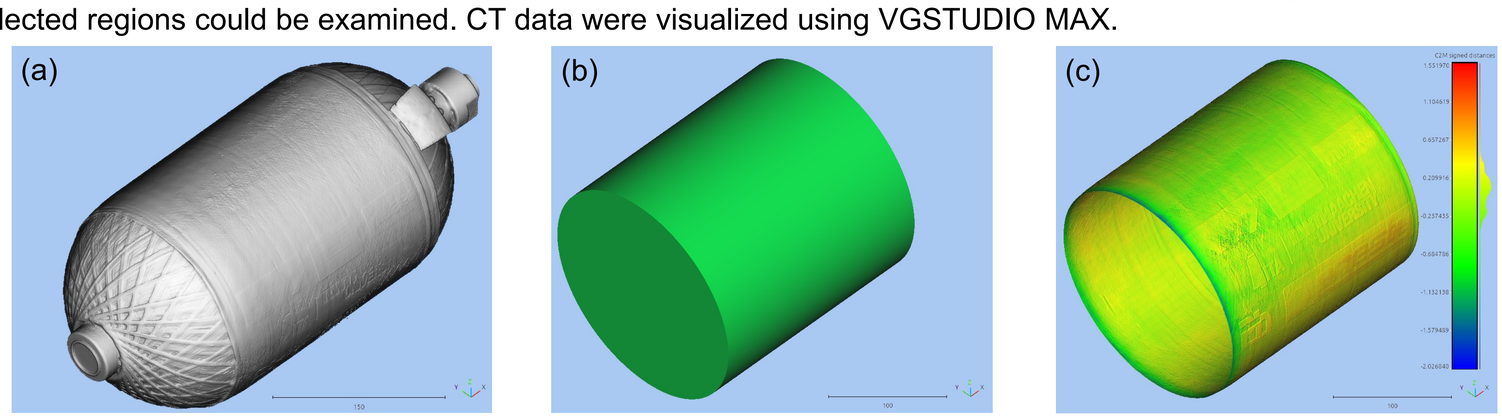
The deviation heatmaps, generated using fitted reference planes, reveal greater geometric variation on the back surface (b), which is shaped by the flexible vacuum bag, than on the front surface (a), formed against a rigid glass plate.



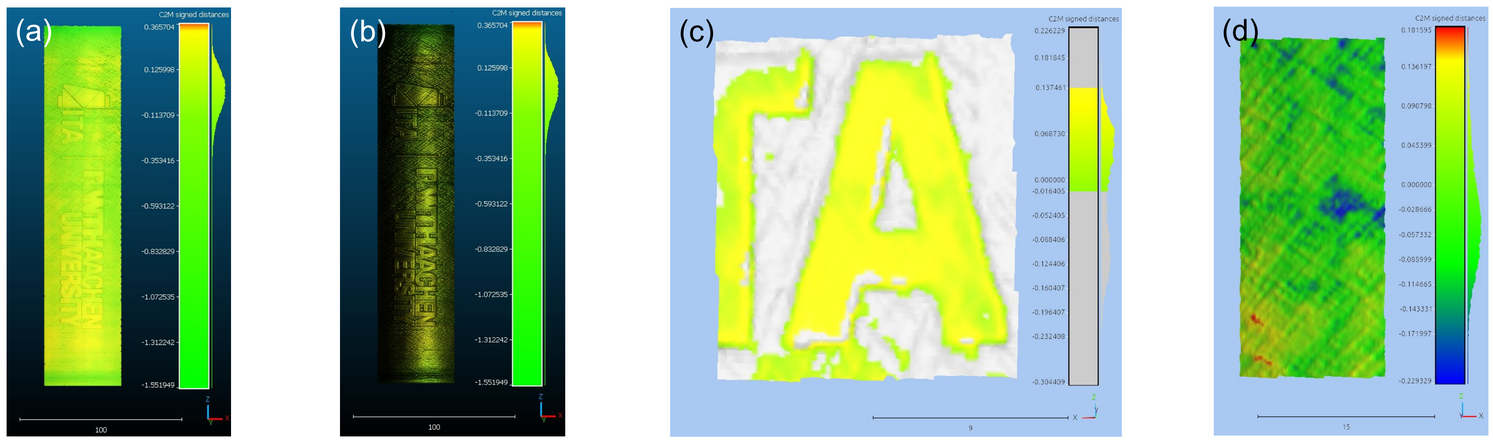
Following impact testing, front (a) and back (b) surface deviations can be assessed separately using heatmaps and histograms relative to their respective undamaged regions.



The optical 3D scans (a, b) capture the external geometry of the impact-damaged panel, while the corresponding CT images (c, d) provide a more detailed visualization. Portable 3D scanning provides sufficient detail for many inspections.



The scanned COPV (a) is used to fit a cylindrical reference surface to its central section (b). Radial deviations from this reference are visualized in a colour-coded deviation map (c), enabling the assessment of local geometric variations.



Localized radial-deviation analysis can be used to examine surface features that may be difficult to distinguish in an overall COPV scan. Colour-coded deviation maps and histograms support the assessment of identification markings relative to a fitted cylindrical reference (a), while enhanced shading facilitates the visual interpretation of local surface relief (b). A magnified view of the letter “A” (c) provides a more detailed assessment, while the same approach can be applied to the composite overwrap (d) to visualize cross-wound fibre patterns and characterize local protrusions and depressions.

CONCLUSIONS & OUTLOOK

Portable optical 3D scanning has demonstrated its applicability to the geometric assessment of composite structures with varying shapes and levels of complexity. Reference-based analysis can be adapted to characterize overall surface geometry, localized features, and deformation-related changes, including impact-induced damage.

Although CT provides more detailed visualization, portable optical 3D scanning offers a flexible and practical solution for external surface inspection, with potential for on-site assessment and industrial quality control.

Further work should focus on measurement repeatability, uncertainty evaluation, validation against independent metrological methods, and assessment of scanning performance under actual industrial production conditions.

ACKNOWLEDGEMENT

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