Data Article

Experimental data on fracture of open-hole composite laminates subjected to tension loading

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A B S T R A C T

In this data article, we present detailed failure process of big open-hole carbon fibre reinforced polymer (CFRP) composite laminates subjected to tension loading, which are tested by digital image correlation (DIC) system and electrical strain gauge system. In experiments, three different lay-ups are applied tension loading until specimens’ failure. Several strain gages are distributed in different locations of specimens to measure strains during loading, at the same time, DIC is adopted to obtain field strains of specimens. The maximum force and failure modes of different lay-ups composite laminates are tested. The failure process is displayed by strain field images, and final failure images are also supplied in this article. Detailed numerical analysis are reported in [1].

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Specifications Table

| Subject                  | Engineering, Composite laminates                                      |
|--------------------------|------------------------------------------------------------------------|
| Specific subject area    | Failures of composite laminates                                        |
| Type of data             | Table, Image, Graph                                                    |
| How data were acquired   | Tensile testing machine (Changchun Kexin WDW-200); Digital Image Correlation (DIC) system (PMLAB 3D); Electrical measurement (TST3826) |
| Data format              | Raw, analyzed, Filtered                                                |
| Parameters for data collection | The loading force accuracy of tensile testing machine: 0.5%; Tensile loading speed in experiments: 0.5 mm/min; Loading increment of taking speckle images: 1 kN; The camera pixels: 2048 × 2048; Length of pixel: 0.08 mm; DIC relevant criteria: ZNSSD; Sub pixel interpolation order: Optimized 4-tap; ZNCC threshold: 0.8; The size of strain gauges: 3 mm × 2 mm; |
| Description of data collection | The deformation information are tested by DIC and electrical strain gauges. Field of displacement and strain at surface of specimens can be obtained by processing images. Strains of special points can be tested by gauges accurately. The loading force is obtained from tensile testing machine. |
| Data source location     | College of Engineering, Peking University, Beijing 100,871, PR China    |
| Data accessibility       | Data are available with this article and the Mendeley Data repository at [2] |
| Related research article | Zhaoyang Ma, Jianlin Chen, Qingda Yang, Zheng Li, Xianyue Su, Progressive fracture analysis of the open-hole composite laminates: experiment and simulation, Composite Structures, (2021): 113,628. In Press. |

Value of the Data

- The data corresponding to failure process of big open-hole composite laminates are seldom reported in other literature, and field strains tested by DIC are supplied to describe the detailed failure process, which is meaningful for exploring failure mechanisms of composite laminates.
- The data could be valuable for scholars or engineers who (1) investigate failure mechanisms of composite laminates, (2) develop failure criterions or numerical methods, and (3) design composite structures.
- The local buckling phenomenon is observed in experiments, which is very interesting in specimens subjected to tension loading. The data obtained by DIC can be recalculated to investigate this point.

1. Data Description

The data comprises tension failure of different lay-ups CFRP composite laminates (T700/9368) with big open hole, which include unidirectional-ply ([0]_8), cross-ply ([0/90]_2z) and quasi-isotropic-ply ([0/90/45/−45]_s). Table 1 gives the max bearing force of this three lay-up composite laminates. Specimens of [0/90]_2z and [0/90/45/−45]_s composite laminates fracture at one band of the open hole, and shear fractures appear in [0]_8 specimen.

Fig. 1 displays deformation-load curves of this three lay-ups composite laminates. Fig. 1(a) displays strain-load curve of [0]_8 composite laminates, and the strain is tested by strain gauge

| Specimen               | Fracture force (kN) |
|------------------------|---------------------|
| [0]_8                  | 43.96               |
| [0/90]_2z              | 31.53               |
| [0/90/45/−45]_s        | 24.81               |
Fig. 1. Results of (a) strain-load curve of [0]_8 composite laminates, displacement-load curves of (b) [0/90]_2s composite laminate and (c) [0/90/45/-45]_s composite laminate.

Fig. 2. Crack propagation contour of strain ε_{22} obtained by DIC ([0]_8) [1].

Fig. 3. Final cracks of (a) [0]_8, (b) [0/90]_2s, and (c) [0/90/45/-45]_s [1].

located at orange block (A-5) (see Fig. 4(b) and (c)). Along with cracks’ initiation and propagation, the load’s sudden drops appear in strain-load curve. The deformation of the other two lay-ups composite laminates is represented by relative displacements between green points (A-B, C-D in Fig. 4(b)).

Fig. 2 gives the surface strain field of [0]_8 composite laminate tested by DIC, which can represent the crack propagating process in detail. In Fig. 2(a), at beginning, matrix cracks initiate and propagate at one bound along with fibre direction, then another shear cracks appears in the later fracture process shown in Fig. 2(b) and (c). Finally, the “H” shape is formed, as Fig. 2(d) shows.

Fig. 3 gives the final fracture images of three lay-ups composite laminates. For the [0]_8 specimen (Fig. 3(a)), several shear cracks initiate from the edge of open hole and propagate to the
clamp ends. In this experiment, fibre does not fracture at the end of loading. For the other two lay-ups composite laminates, one band of specimens fails completely, and failures of matrix and fibre are all appear in these two tests. In cross-ply composite laminate ([0/90]_2s), cracks of fibre and matrix at different layers are all perpendicular to the loading direction. For[0/90/45/−45]_s composite laminates (Fig. 3(c)), complicated failure modes occur, which include delamination, fibre rupture, matrix cracking and split.

The data of tension machine and strain gauges can be accessed at the Mendeley Data repository at [2]. Three sheets are included in this excel, and one shows data list of the load and displacement applied by the clamp of tension machine; the second one shows strains tested by different strain gauges, which are distributed as Fig. 4(c) shown; and the last one is the data table of Fig. 1.

2. Experimental Design, Materials and Methods

2.1. Specimens design

T700/9368 composite materials are adopted in experiments of failure, and three different lay-ups composite laminates are tested in this experiment, which include unidirectional-ply [0]_8, quasi-isotropic-ply [0/90/45/−45]_s and orthotropic-ply [0/90]_2s. As Fig. 4(b) shows, the geometry size of specimens is 180 mm × 160 mm with a 100-mm-diameter open hole, and the thickness of composite laminates is 1.2 mm. Two rows bolt holes are designed at the ends of specimens for clamping during tension loading.
2.2. Loading and testing systems

As Fig. 4(a) shows, the tensile testing machine (Changchun Kexin, WDW-200) was applied tensile load to specimens, and two measuring systems, 3D DIC (PMLAB) and electrical strain gauge measurement (TST3826) are used to test the deformation. In DIC testing, Speckles are painted at one side surface of specimens as shown in Fig. 3, and the PMLAB DIC system with two cameras are used to take the speckle images per 1 kN increment when the specimen is under tensile loading. Through data processing of the speckle images, the 3D strain field of three lay-ups composite laminates are obtained.

Another test system is the electrical testing setup. Strain gauges are used in this experiment and they are distributed at two sides of specimens, shown in Fig. 4(c).

2.3. Data acquisition and processing

The loading speed of tension testing is 0.5 mm/min, and the tension force is provided by the sensor in WDW-200. When the load of tension machine increases 1 kN-force, speckle images are taken by DIC cameras. At the same time, strains are captured by strain gauges. The testing will be stopped when the force drops suddenly, and the tension machine can record the maximum bearing force.

Based on speckle pictures taken during experiment, strain field at the surface of composite laminates can be obtained by PMLAB DIC software, shown in Fig. 2. The relative displacement between two points (average of A-B and C-D) at surface can also be extracted from DIC deformation results. After that, the relative displacement-force curves can be obtained in [0/90]_2s and [0/90/45/-45]_s composite laminates. In the [0]_8 specimen, the strain of tension direction are used as deformation quality, and the strain-load curve are obtained.

CRediT Author Statement

Zhaoyang Ma: Data collection & analyse, writing original draft preparation; Jianlin Chen: Methodology, prepare and implement experiments; Zheng Li & Xianyue Su: Supervision and Reviewing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships, which have or could be perceived to have influenced the work reported in this article.

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Supplementary Materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.dib.2021.106876.
References

[1] Zhaoyang Ma, Jianlin Chen, Qingda Yang, Zheng Li, Xianyue Su, Progressive fracture analysis of the open-hole composite laminates: experiment and simulation, Compos. Struct. 262 (2021) 113628, doi:10.1016/j.compstruct.2021.113628.

[2] https://data.mendeley.com/datasets/bxrwgtpn6/1.