Data Article

Experimental flatwise tensile strength dataset of carbon fibre reinforced plastic sandwich panels with different core material preparations

Djarot Widagdo, Andi Kuswoyo, Taufiq O. Nurpratama, Bambang K. Hadi*

Faculty of Mechanical and Aerospace Engineering, Institut Teknologi Bandung, Jl. Ganesha 10, Bandung 40132, Indonesia

A R T I C L E  I N F O

Article history:
Received 21 September 2019
Received in revised form 20 November 2019
Accepted 17 December 2019
Available online 31 December 2019

Keywords:
Flatwise tension
Sandwich structures
ASTM C297
Composite material qualification

A B S T R A C T

Flatwise tension strength of sandwich structure is important for designing a sandwich construction since it provides failure mechanism and debonding strength between the skin faces and the core, as well as (i) core strength and (ii) face strength of the sandwich structures. The flatwise tension strength is affected by many factors: method of core preparation, test environment, testing speed, etc. In this paper, the ambient test temperature was 23 deg C and the humidity was 65%. The testing speed was 0.5 mm/min. Four different core preparations were investigated. ASTM C297 was used as a standard method to get the strength values. Two processes were employed to cure the adhesive during core-to-face bonding. It was found out that cleaning the core with Methyl-ethyl-ketone (MEK) and drying further in an oven gives maximum flatwise tension strength of the sandwich structures, with the value of 5.9 MPa. The data base is important for both the manufacturing and design engineers. For the manufacturing engineers, the data provides a value for process qualification, while for design engineers it gives a maximum allowable strength for designing sandwich construction for tensile loads.

© 2019 The Author(s). Published by Elsevier Inc. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/).

* Corresponding author.
E-mail addresses: bkhadi@ae.itb.ac.id, bambang.hadi60@gmail.com (B.K. Hadi).

https://doi.org/10.1016/j.dib.2019.105055
2352-3409/© 2019 The Author(s). Published by Elsevier Inc. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/).
1. Data

The data set provided herein was the result of experimental studies conducted to determine flatwise tensile strength of sandwich structures prepared using different methods of core material preparation and the core-to-face adhesive curing methods. The type of materials for sandwich structures is given in Table 1, while the core material preparation parameters are given in Table 2. A strength-deformation curves produced during the flatwise tensile tests were given in Fig. 4, while the complete maximum flatwise tensile load and strength was given in Table 3 for configuration parameters A, B, C and D. All specimens with different parameters were able to withstand above 5 MPa, with configuration B achieved the maximum flatwise tensile strength of 5.59 MPa. Fig. 5 provides failure surface of typical specimen configuration after test. The failure mode is a combination of adhesive, cohesive and core failure according to ASTM C297 [1]. The complete pictures of failure surfaces for each specimen is available from http://bit.ly/DIB-Data-Flatwise-Test. Table 4 gives summary of the failure modes of the specimens.

2. Experimental design, materials, and methods

2.1. Experimental design

The experiments were carried out according to ASTM C297 [1]. Typical experimental setup is given in Fig. 1 [1,2], while the current experimental configuration is given in Fig. 2.
### Table 1
List of materials.

| Parts                          | Type of materials used                                                                 |
|-------------------------------|----------------------------------------------------------------------------------------|
| Face                          | Hexcell W3T282-42°F593 carbon fibre epoxy fabric prepreg.                               |
| Core                          | Hexcell HRP-3/16-4.0 fibre glass honeycomb core with phenolic resin                    |
| Core-to-face adhesive         | Cytec FM-300 M.03 epoxy film adhesive                                                  |
| Aluminum-to-face adhesive     | Cytec FM-73 M.06 epoxy film adhesive                                                  |

### Table 2
Core material preparation parameters and the specimens numbering system.

| Spec Code | Core material preparation parameters                                                                 | Spec number | Table press process | Autoclave process |
|-----------|------------------------------------------------------------------------------------------------------|-------------|---------------------|-------------------|
| A         | Core material was cleaned using Methyl-Ethyl-Ketone (MEK) spray without drying process              | AT1 – AT5   | AA1 – AA5           |                   |
| B         | Core material was cleaned using Methyl-Ethyl-Ketone (MEK) spray with drying process in an oven      | BT1 – BT5   | BA1 – BA5           |                   |
| C         | Core material was cleaned using air spray without drying process                                     | CT1 – CT5   | CA1 – CA5           |                   |
| D         | Core material was cleaned using air spray with drying process in an oven                            | DT1 – DT5   | DA1 – DA5           |                   |

![Fig. 1. Typical flatwise tensile test ASTM C297 [1,2].](image-url)
Fig. 2. Schematic of specimens for flat-wise tensile test according to ASTM C297.

Fig. 3. Cell core used in the experiment.
Fig. 4. Strength-deformation results on flat-wise tensile test.
### 2.2. Materials

The materials used in the experimental was given in Table 1. The materials properties are as follows:

- **Core**: Fibreglass honeycomb core, HRP-3/16-4.0 Hexcell with the cell size of 3/16 inch and the density 0.064 g/cm³. The shear strength in L-direction is typically 4.07 MPa and the modulus 90 MPa; while in the W-direction, the strength is typically 1.10 MPa and the modulus is 45 MPa [3]. The thickness of the core was 12.7 mm.

- **Core-to-face adhesive**: FM-300 M.03 epoxy film adhesive Cytec Engineering Materials. The thickness of each ply was 0.13 mm with the density of 0.025 g/cm³. The service temperature was up to 135 deg C. Two plies of adhesive film was needed during the experiment.

- **Face**: carbon fibre fabric epoxy prepreg W3T282-42°-F593 Hexcell. The tensile strength was 3530 MPa and the modulus was 230 GPa. The thickness for each ply was 0.21 mm. Two plies of carbon/epoxy fabric was needed to produce the faces.

- **Aluminum-to-face adhesive**: FM-73 M.06, epoxy film adhesive Cytec Engineering Materials. The thickness of each ply was 0.25 mm and the density was 0.025 g/cm3. The service temperature was –55 to 80 deg C, while the curing temperature was 120–130 deg C.

### Table 3

Maximum load and flatwise tensile strength for different configurations.

| Spec code | Table press | Autoclave |
|-----------|-------------|-----------|
|           | Spec No     | Max load [N] | Flatwise strength [MPa] | Spec No | Max load [N] | Flatwise strength [MPa] |
| A         | AT1         | 14354.8     | 5.63                   | AA1     | 13475.3     | 5.29                   |
|           | AT2         | 13111.9     | 5.14                   | AA2     | 13480.6     | 5.29                   |
|           | AT3         | 14131.6     | 5.54                   | AA3     | 13736.7     | 5.39                   |
|           | AT4         | 14527.3     | 5.7                    | AA4     | 12568.4     | 4.93                   |
|           | AT5         | 14312.5     | 5.61                   | AA5     | 12793.1     | 5.02                   |
| Mean      |             | 14087.6     | 5.52                   |          | 13210.8     | 5.18                   |
| Standard deviation (%) |             | 563.3       | 0.22                   |          | 501.6       | 0.19                   |
| Coefficient of variation (%) |             | 3.98        | 3.67                   |          | 3.67        | 2.14                   |
| B         | BT1         | 15182.1     | 5.96                   | BA1     | 12841.8     | 5.04                   |
|           | BT2         | 14294.0     | 5.61                   | BA2     | 13236.2     | 5.19                   |
|           | BT3         | 14154.0     | 5.55                   | BA3     | 13497.2     | 5.29                   |
|           | BT4         | 13450.6     | 5.28                   | BA4     | 12860.4     | 5.04                   |
|           | BT5         | 14257.2     | 5.59                   | BA5     | 13047.2     | 5.12                   |
| Mean      |             | 14267.6     | 5.59                   |          | 13096.5     | 5.14                   |
| Standard deviation (%) |             | 615.9       | 0.24                   |          | 275.2       | 0.11                   |
| Coefficient of variation (%) |             | 4.29        | 2.14                   |          | 4.29        | 2.14                   |
| C         | CT1         | 14129.7     | 5.54                   | CA1     | 13561.6     | 5.32                   |
|           | CT2         | 12249.8     | 4.81                   | CA2     | 12896.7     | 5.06                   |
|           | CT3         | 14880.5     | 5.84                   | CA3     | 13206.5     | 5.18                   |
|           | CT4         | 14052.4     | 5.51                   | CA4     | 12815.6     | 5.03                   |
|           | CT5         | 12520.4     | 4.91                   | CA5     | 13477.3     | 5.29                   |
| Mean      |             | 13566.6     | 5.32                   |          | 13191.5     | 5.18                   |
| Standard deviation (%) |             | 1130.7      | 0.44                   |          | 334.3       | 0.13                   |
| Coefficient of variation (%) |             | 8.27        | 2.51                   |          | 8.27        | 2.51                   |
| D         | DT1         | 15035.2     | 5.90                   | DA1     | 14193.0     | 5.57                   |
|           | DT2         | 13468.9     | 5.28                   | DA2     | 13083.1     | 5.13                   |
|           | DT3         | 14255.6     | 5.59                   | DA3     | 13708.5     | 5.38                   |
|           | DT4         | 13747.1     | 5.39                   | DA4     | 13304.2     | 5.22                   |
|           | DT5         | 13292.6     | 5.21                   | DA5     | 13304.0     | 5.22                   |
| Mean      |             | 13959.8     | 5.47                   |          | 13518.5     | 5.30                   |
| Standard deviation (%) |             | 702.7       | 0.27                   |          | 439.4       | 0.17                   |
| Coefficient of variation (%) |             | 4.93        | 3.21                   |          | 4.93        | 3.21                   |
2.2.1. Manufacturing

The specimens manufacturing are the followings:

1) The carbon composite skin facing was manufactured using 2 plies Hexcell W3T282-42°-F593 Carbon fibre epoxy fabric prepreg and cured in an autoclave with temperature of 180 ± 5 deg C and

| Spec No | Failure Mode                  | Spec No | Failure Mode                           |
|--------|-------------------------------|--------|---------------------------------------|
| AT1    | Cohesive failure              | AA1    | Core failure and adhesive failure     |
| AT2    | Adhesive failure              | AA2    | Core failure and adhesive failure     |
| AT3    | Cohesive failure              | AA3    | Adhesive failure                      |
| AT4    | Adhesive failure              | AA4    | Adhesive failure                      |
| AT5    | Cohesive failure              | AA5    | Cohesive failure                      |
| BT1    | Cohesive failure              | BA1    | Core failure                          |
| BT2    | Core failure and cohesive failure | BA2   | Adhesive failure                      |
| BT3    | Core failure and cohesive failure | BA3   | Cohesive failure                      |
| BT4    | Core failure and cohesive failure | BA4   | Core failure and cohesive failure     |
| BT5    | Core failure                  | BA5    | Cohesive failure                      |
| CT1    | Cohesive failure              | CA1    | Cohesive failure                      |
| CT2    | Core failure and cohesive failure | CA2   | Adhesive failure                      |
| CT3    | Core failure and cohesive failure | CA3   | Cohesive failure                      |
| CT4    | Adhesive failure              | CA4    | Adhesive failure                      |
| CT5    | Adhesive failure              | CA5    | Adhesive failure                      |
| DT1    | Core failure and cohesive failure | DA1   | Core failure and cohesive failure     |
| DT2    | Core failure and cohesive failure | DA2   | Core failure and cohesive failure     |
| DT3    | Core failure and cohesive failure | DA3   | Core failure and cohesive failure     |
| DT4    | Core failure                  | DA4    | Core failure and cohesive failure     |
| DT5    | Core failure                  | DA5    | Core failure and cohesive failure     |

Fig. 5. Typical failure surface of specimens after test.
hold for 2 hours at the pressure of 3 bars. The heating up rate was kept between 1 and 3 deg C/min, while the cooling rate was kept below 3 deg C.

2) The core material was Hexcell HRP-3/16-4.0 Fibre glass honeycomb core with phenolic resin. Fig. 3 shows core material used in the experiments. The core material was prepared using different parameters as given in Table 2. The cleaning process with MEK was carried for 1 minute. The cleaning process with air gun was also done in 1 minute. The drying process was done using oven for 2 hours with temperature of 100 deg C.

3) The skin face and the core were bonded together using adhesive film Cytec FM-300 M.03 Epoxy film adhesive and cured. The curing process used two methods: using hot table press and autoclave. The curing was done at the temperature of 120 deg C. In the table press, the specimens was vacuumed to 200–250 mmHg (0.266–0.333 bar); with a pressure of 1.70 bar for 2 hours. The same parameters were done in the autoclave process.

4) The resulted sandwich structures are then bonded to the aluminium block using Cytec FM-73 M.06 Epoxy film adhesive and cured once again in table press at the temperature of 120 deg C for 2 hours. The aluminum block was sandblasted before bonded was carried out to the faces. The resulting sandwich structures were ready for flatwise tension tests.

2.3. Flatwise tensile test methods

The specimen was put into the Universal Testing Machine and given the tensile load. Fig. 1 shows typical flatwise tensile experimental setup. The specimens dimension was 50 × 50 mm and the overall thickness is 94 mm. The tensile machine was Instron with the maximum capacity of 100 kN. The displacement rate was set to be in the order of 0.5 mm/minute. Fig. 1 shows the experimental setup. The maximum load and the load-displacement curve were obtained after the test.

The ultimate flatwise tensile strength was determined using the Eq. (1):

$$F_{ftu}^z = \frac{P_{\text{max}}}{A}$$

where:

- $F_{ftu}^z$: flatwise tensile strength
- $P_{\text{max}}$: ultimate tensile load
- $A$: area of the specimen. In this case 50 × 50 mm.

It was known that the flatwise tensile strength was affected by the environment [4] and discoloration occurred when using Cytec FM-200 adhesive [5]. The environment affects the bondline strength of core-to-face adhesive. Cocoated sandwich structures provided more consistent data than precured [6]. In this paper, the tests were done with the room temperature of 23 deg C and the humidity was 65%. The faces were precured before adhesively bonded to the core.

Acknowledgments

The work was supported financially by Institut Teknologi Bandung through Faculty of Mechanical and Aerospace Engineering using P3MI Project in the year 2018. The authors wish to thank the Institut for providing the research grant.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] ASTM C297, Standard Test Method for Flatwise Tensile Strength of Sandwich Construction, ASTM International, 2010.
[2] Composite test fixtures: flatwise tensile strength, ASTM C297, downloaded on, https://www.instron.us/-/media/literature-library/products/2011/06/composite-test-fixture-astmc297.pdf?la=en-US. (Accessed 18 November 2019).
[3] Core data sheet, downloaded on, https://www.hexcel.com/user_area/content_media/raw/HRP_eu.pdf. (Accessed 18 November 2019).

[4] T.C. Radtke, A. Charon, R. Vodicka, Hot/Wet Environmental Degradation of Honeycomb Sandwich Structure Representative of F/A-18: Flatwise Tension Strength. Technical Report, DSTO Aeronautical and Maritime Research Laboratory, DSTO-TR-0908, Australia, 1999.

[5] A. Charon, Hot/Wet Environment Degradation of Honeycomb Sandwich Structure Representative of F/A-18: Discolouration of Cytec FM-300 Adhesive. Flatwise Tension Strength. Technical Report, DSTO Aeronautical and Maritime Research Laboratory, DSTO-TN-0263, Australia, 2000.

[6] H.S. Choi, Y.H. Jang, Bondline strength evaluation of cocure/precured honeycomb sandwich structures under aircraft hygro and repair environments, Compos. Part A (2010) 1138–1147.