The experimental and finite element analysis data of Cu-UV glue composite materials

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**Abstract**
Five different layered-fiber reinforced Cu-UV glue composite structures were prepared, with Cu plate and wire as the reinforcing phase, and UV glue as the substrate. The volume ratio of Cu and UV glue of these structures is the same, but the difference lies in the number and diameter of Cu wires. Three-point bending tests were performed on these structures, and the bending stress-bending strain curves of different structures were measured. At the same time, the finite element method is used to simulate the three-point bending test process of different structures, and the bending stress-bending strain curves of different structures were calculated. Then the experimental and simulated strengths corresponding to different structures were obtained from the stress-strain curves obtained by experiment and simulation. These data are supplementary material for the associated research article [1].

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Specifications Table

| Subject | Materials Science - Structural Analysis and Behavior |
|---------|-------------------------------------------------------|
| Specific subject area | Experimental and finite element analysis of the strength of layered-fiber reinforced composite |
| Type of data | Table, Image, Graph, Figure |
| How data were acquired | Experiment data was acquired by electronic universal material testing machine (WDW3020, Instrument Institute of Changchun Kexin Company). Simulation data was acquired by ABAQUS 2016. |
| Data format | Analyzed |
| Parameters for data collection | Three-point bending test |
| Description of data collection | Take pictures to record the sample preparation process and the three-point bending experiment process. The data obtained from experiments and simulations are drawn into graphs with GraphPad Prism 8 or recorded in tables. |
| Data source location | Institution: Department of Mechanical Engineering, Tsinghua University City/Town/Region: Beijing Country: China |
| Data accessibility | With the article |
| Related research article | Chen, X. and Z. Hao. Biomimetic layered fiber-reinforced Ti-Al composites: Effects of various parameters on their strength and ductility through finite element analysis. Materials & Design, 2021. 209: p. 109989. https://doi.org/10.1016/j.matdes.2021.109989 |

Value of the Data

- These data verify the effectiveness of the finite element method for analysing the plastic deformation and strength of Cu-UV glue composites. At the same time, these data also show the influence of fiber diameter on the strength of the layered-fiber reinforced structure.
- For those researchers who want to use the finite element method to carry out plastic simulation and strength checking of composite materials and want to further study the performance of the layered-fiber reinforced structure, this article has certain reference value.
- These data verify the effectiveness of the finite element method for plastic analysis and strength calculation to a certain extent. Therefore, researchers can perform finite element analysis on other composite materials on the basis of these data and do not have to conduct experimental tests, thereby saving research costs.

1. Data Description

XXX.

2. Experimental Design, Materials and Methods

2.1. Sample structure

The copper plate used in this article was purchased from Jingdong Hongwang Building Materials and Hardware Specialty Store, and the copper wire was purchased from Jingdong Shierya Hardware Tools Specialty Store, and it is assumed that the mechanical properties of the copper wire are consistent with the mechanical properties of the copper plate. UV glue was purchased from Ausbond Jingdong’s self-operated flagship store.

The structure and size of 7 samples designed for three-point bending experiment are shown in Table 1. The overall dimensions of these 7 samples are the same, named Str1 ~ Str7, where
Table 1
The structure and size of 7 samples used for three-point bending experiment.

| Structure number | Structure | Copper plate thickness | Copper wire diameter | Copper plate, copper wire content | Total measurement |
|------------------|-----------|------------------------|----------------------|-----------------------------------|-------------------|
| Str1             | ![Structure Image] | 1.0                    | 0                    | 0.2, 0                            |                   |
| Str2             | ![Structure Image] | 0.5                    | 1.0                  | 0.1, 0.1                          |                   |
| Str3             | ![Structure Image] | 0.5                    | 1.5                  | 0.1, 0.1                          |                   |
| Str4             | ![Structure Image] | 0.5                    | 2.0                  | 0.1, 0.1                          |                   |
| Str5             | ![Structure Image] | 0.0                    | 3.0                  | 0, 0.2                            |                   |
| Str6             | ![Structure Image] | 0.0                    | 0                    | 0, 0                              |                   |
| Str7             | ![Structure Image] | 5.0                    | 0                    | 1, 0                              |                   |

Note: The unit of dimensions in the table is mm, and the direction of length L is perpendicular to the paper surface.
Str2 ~ Str4 are layered-fiber reinforced composite structures, and the number of fibers is 12, 6, and 3 in order. Str1 is a layered structure, and Str5 is a fiber reinforced structure. The volume ratio of Cu/UV glue of Str1 ~ Str5 is the same, both are 1/4. Str6 and Str7 are pure UV glue and pure Cu, respectively, used to obtain the stress-strain curve of pure UV glue and pure Cu.

2.2. Sample preparation

For the 6 structures of Str1 ~ Str6 in Table 1, prepare 5 samples for each structure. Str7 is a pure copper plate purchased and does not need to be made. A total of $7 \times 5 = 35$ samples. The sample preparation method of Str1 ~ Str6 is as follows:

1) Fix the copper wire in the mold covered with transparent tape as shown in Fig. 1(a).
2) Prepare two transparent acrylic boards about 120 mm × 40 mm × 1 mm, and cover one side of the board with transparent glue.
3) Use double-sided tape to paste the copper plate on the transparent adhesive surface of one of the acrylic plates.
4) Place the acrylic plate without copper plate and the acrylic plate with copper plate on the front and back sides of the mold, with the transparent glue facing inward, while ensuring that the copper plate is in the proper position.

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**Fig. 1.** The mold for making samples (a) and the mold with copper wires and copper plates (b).
5) Fix the mold and the acrylic plate together with a long tail ticket holder, so that there is a certain contact pressure between the mold and the acrylic plate, so as to ensure that the UV glue will not leak from the gap between the two, as shown in Fig. 1(b).

6) Fill the mold with UV glue.

7) Use a 365 nm UV flashlight (purchased from Jingdong Bill Sports Outdoor Store) to irradiate the UV glue in the mold from bottom to top, and irradiate each sample for 1 to 2 h to ensure that the UV glue is completely cured. During this period, the UV glue needs to be supplemented appropriately to make up for the shrinkage generated when the UV glue is cured.

8) After fully curing, remove the long tail ticket holder and acrylic board, and take the sample out of the mold.

9) Due to the size error of the mold and the production process, the final overall size of the sample will deviate from the ideal size, so the actual overall size b, h and L of the sample should be recorded.

3. Three-point bending test

According to the national standard for bending performance measurement, the sample is loaded with upper and lower indenters with a radius of 5 mm. As shown in Fig. 2, the span between the axis of the lower indenter is 80 mm, and the loading speed is 2 mm/min. Stop loading when the loading force reaches the maximum value or the loading displacement reaches about 15 mm. Record the loading force-loading displacement data of each sample. The experimental equipment used is an electronic universal material testing machine (WDW3020, Instrument Institute of Changchun Kexin Company).
4. Material property calculation

Through the three-point bending experiment on the two structures of Str6 and Str7 in Table 1, the stress-strain curves of pure UV glue and pure Cu can be obtained. Then use the isotropic plastic material constitutive model shown in Fig. 3 to fit the stress-strain curves of the pure UV glue and pure Cu obtained from the three-point bending test to obtain the elastic modulus $E$, plastic deformation curve and yield strength $\sigma_M$. The Poisson’s ratio of pure Cu is 0.34. Cured UV glue is plastic, and Poisson’s ratio is assumed to be 0.4.

5. Finite element modeling and analysis

In Abaqus, finite element models of five structures of Str1 ~ Str5 are established and analyzed according to the process shown in Fig. 4. After obtaining the reaction force and displacement data of the upper indenter, the bending stress-bending strain curves of the five models are calculated according to formulas (1) and (2).

$$\sigma_f = \frac{3Fl}{2bh^2} \quad (1)$$

$$\varepsilon_f = \frac{6sh}{l^2} \quad (2)$$

Where $\sigma_f$ is the bending stress, $F$ is the force applied to the upper indenter, $l$ is the span between the lower indenters, $b$ is the width of the sample, $h$ is the thickness of the sample, $\varepsilon_f$ is the bending strain, and $s$ is the displacement of the upper indenter.

6. The elastic modulus and plastic deformation curve of pure UV glue and pure Cu

In order to obtain the elastic modulus and plastic deformation curve of pure UV glue and pure Cu, the experimental data need to be processed as follows:

1) Curve correction. Since the upper indenter of the electronic universal material testing machine (as shown in Fig. 2) is not consolidated with the testing machine, it can have a small relative displacement with the testing machine in the vertical direction, which makes the force-displacement curve obtained in the experiment have a small initial section with a slope close to 0; in addition, because the sample surface is not flat, it is only in point contact with

![Fig. 3. Stress-strain curve of isotropic plastic material.](image)
the indenter at the beginning. At this time, a small section with a slope close to 0 will appear when the load is loaded, as shown in Fig. 5. Therefore, it is necessary to find out the part where the slope of the force-displacement curve is close to 0 at the initial stage, and remove it to obtain the corrected force-displacement curve. Using the modified force-displacement curve, formula (1) and formula (2), the bending stress-bending strain curve can be obtained.

2) Calculate the true stress-true strain curve. Because the Abaqus plastic model requires the input of the true stress-true strain curve of the material, it is necessary to convert the nominal stress-nominal strain curve to the true stress-real strain curve, and the conversion formulas are as shown in formula (3) and formula (4).

\[
\sigma = \sigma_{\text{nom}} (1 + \varepsilon_{\text{nom}}) \tag{3}
\]

\[
\varepsilon = \ln(1 + \varepsilon_{\text{nom}}) \tag{4}
\]

Where \( \sigma \) is the true stress, \( \sigma_{\text{nom}} \) is the nominal stress, \( \varepsilon \) is the true strain, and \( \varepsilon_{\text{nom}} \) is the nominal strain.

3) Calculate the average value of 5 samples of Str6 and Str7, respectively. Take a point every 0.001 strain from the obtained true stress-true strain curve, and the maximum strain is about
Fig. 5. Correction of force-displacement experiment curve. (The raw data of this figure is in the supplementary material named “Raw data of Fig 5. xlsx”).

Fig. 6. The true stress-true strain curve, elastic deformation limit, elastic modulus and bending strength of pure UV glue (a) and pure Cu (b). (The raw data of this figure is in the supplementary material named “Raw data of Fig 6. xlsx”).

0.06, which means reducing the number of points on each curve to about 70 (more than 50,000 points measured in the experiment). The true stress-true strain curves of all samples of Str6 and Str7 are averaged, and the true stress-true strain curves of pure UV glue and pure Cu can be obtained.

4) Fit the true stress-true strain curve with the isotropic plastic material constitutive model. According to the plastic constitutive model shown in Fig. 3, a straight line passing through the origin and the i-th point is used to fit the elastic modulus $E$ of the real stress-real strain, and the fitting error is calculated according to formula (5), and the point with the smallest error $er$ is taken as the elastic deformation limit, the following part is regarded as the plastic deformation curve.

$$
er = \left( \sum_{k=1}^{i} \left( \frac{\sigma_k - \varepsilon_k \sigma_i}{\varepsilon_i} \right) \right) / i \tag{5}$$

Where $er$ is the fitting error, $i = 1, 2, 3...i_{max}$, $i_{max}$ is the total number of points on the true stress-true strain curve, $\sigma_k$ is the true stress at the $k$-th point, $\varepsilon_k$ is the true strain at the $k$-th point, and $\sigma_i$ is the true stress at point $i$, and $\varepsilon_i$ is the true strain at at the $i$-th point.
Table 2
Experimental and calculated values of the bending strength of Str1 ~ Str5.

| Structure number | Str1  | Str2  | Str3  | Str4  | Str5  |
|------------------|-------|-------|-------|-------|-------|
| Bending strength (MPa) | Experimental value | 75 ± 2 | 137 ± 7 | 119 ± 4 | 127 ± 4 | 84 ± 1 |
|                  | Simulated value   | 77    | 171    | 160    | 163    | 88    |

Fig. 7. Representative sample after loading, where (a), (b), (c), and (d) are show four different perspectives. The yellow circle marks the necking of the sample, and the blue circle marks the bubble defect.

The elastic modulus and plastic deformation curves of the pure UV glue and pure Cu finally obtained are shown in Fig. 6. These parameters are taken as the material properties of the finite element analysis of five structures Str1 ~ Str5.

7. Comparison of bending experiment and simulation results of Cu-UV glue composite materials

The experimental curve of Str1 ~ Str5 modified according to the method shown in Fig. 5 and the calculation curve obtained by simulation according to the process shown in Fig. 4 are shown in the research article [1]. From the curves, the experimental and calculated values of the bending strength of Str1 ~ Str5 can be obtained, and the results are shown in Table 2. Fig. 7 shows a representative sample after loading.

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.
CRediT Author Statement

Xiaoyong Chen: Conceptualization, Methodology, Software, Writing – original draft, Visualization; Zhixiu Hao: Writing – review & editing.

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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.2021.107389.

Reference

[1] X. Chen, Z. Hao, . Associated research article, . Biomimetic layered fiber-reinforced Ti–Al composites: effects of various parameters on their strength and ductility through finite element analysis, Mater. Des. 209 (2021) 109989, doi:10.1016/j.matdes.2021.109989.