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Application News

inspeXio™ SMX™-225CT FPD HR Plus Shimadzu Microfocus X-ray CT System

Observation of Crimped Terminals Using X-Ray CT System

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User Benefits

- 3D observation of the condition of electrical wires in the interior of crimped terminals is possible.
- Measurement of the terminal shape and internal dimensions can provide feedback to the design and manufacturing processes.
- Cycle testing of the same product is possible, enabling analysis of the product failure process.

■ Introduction

Methods for connecting electrical wiring to machinery and boards include direct connection, fixing with solder, and the use of terminals. Circular and Y-shaped terminals are available, and are widely used because they are easily connected and disconnected. Wires are attached to terminals by compressing part of the terminal around the wires in a process called crimping. Since the quality of crimping affects the stable operation and reliability of the machine concerned, inspection and analysis of the shape and strength of crimped terminals are frequently required. Although the external shape can be inspected visually or with a magnifying glass, X-ray CT (computed tomography) is effective for inspection and analysis of the interior of crimped terminals. This article introduces an example of nondestructive observation and analysis of the interior of terminals using a Shimadzu inspeXio SMX-225CT FPD HR Plus microfocus X-ray CT system (Fig. 1).

Fig. 1 inspeXio™ SMX™-225CT FPD HR Plus Microfocus X-Ray CT System

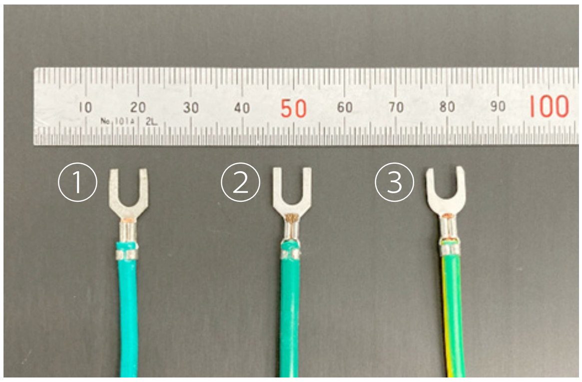

Fig. 2 Photographed External Appearance of Work:
① Strong Crimping Force, ② Weak Crimping Force, ③ Correct Crimping Force

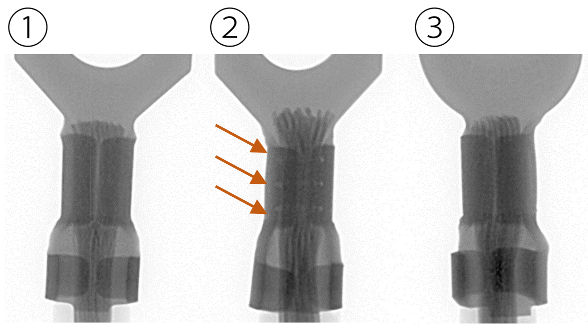

Fig. 3-a Fluoroscopic Images of Crimped Terminals from Front:
① Strong Crimping Force, ② Weak Crimping Force, ③ Correct Crimping Force

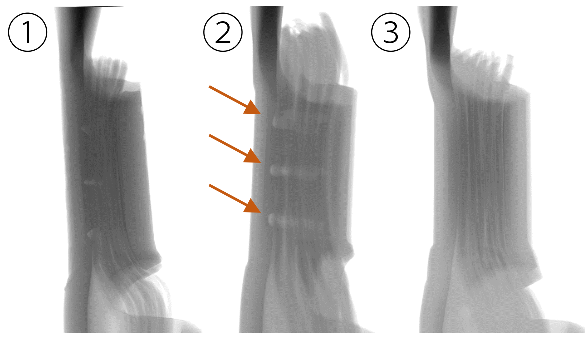

Fig. 3-b Fluoroscopic Images from Side:
① Strong Crimping Force, ② Weak Crimping Force, ③ Correct Crimping Force

■ Fluoroscopic Observation of Crimped Terminals

When crimping a terminal, it is important to use the correct amount of crimping force, since the wire inside the terminal may be broken if excessive force is applied, and may pull out of the terminal if the crimping force is inadequate. Fig. 2 shows the external appearance of the terminals observed in this experiment. From the left, these samples were prepared using excessive (strong) crimping force, inadequate (weak) crimping force, and correct crimping force. No large differences can be detected from their external appearance. Next, Fig. 3-a and 3-b show fluoroscopic images from the front and side of the same terminals. From Fig. 3-b ①, it can be understood the height of the strongly-crimped terminal ① is lower than that of the other terminals. On the other hand, in the weakly-crimped terminal ②, it is clear that there are differences in the internal shape. For example, as indicated by the arrows in Fig. 3, there are grooves in the interior of the terminal.

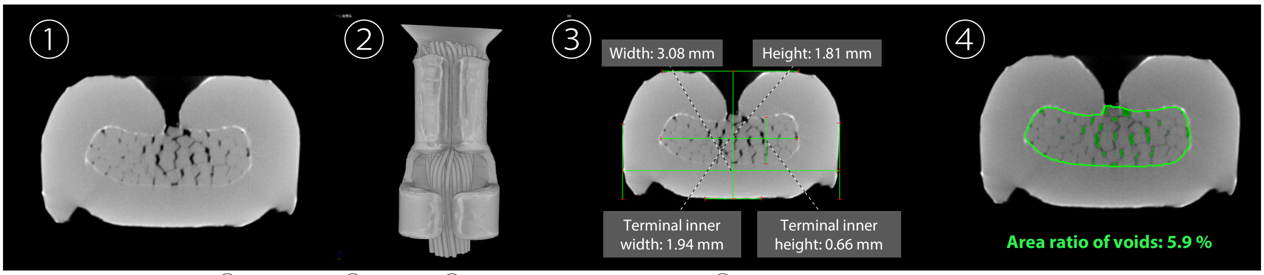

Fig. 4 Crimping Force: Strong ① Cross Section, ② 3D Image, ③ Width and Height Measurements, ④ Internal Cross-Sectional Area of Terminal and Area Ratio of Voids in Wiring

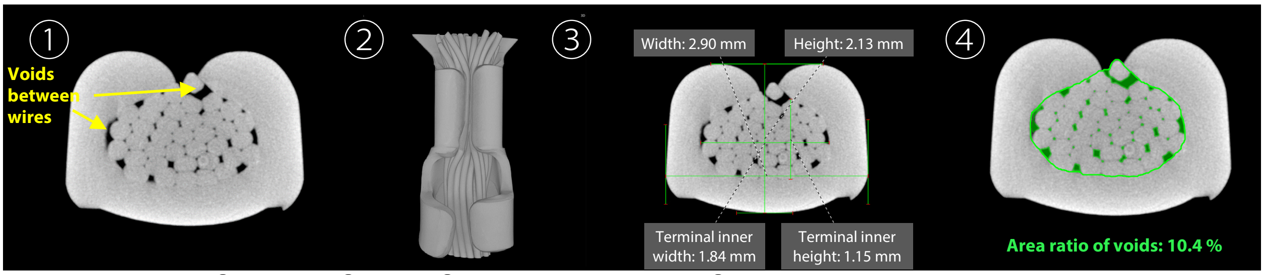

Fig. 5 Crimping Force: Weak ① Cross Section, ② 3D Image, ③ Width and Height Measurements, ④ Internal Cross-Sectional Area of Terminal and Area Ratio of Voids in Wiring

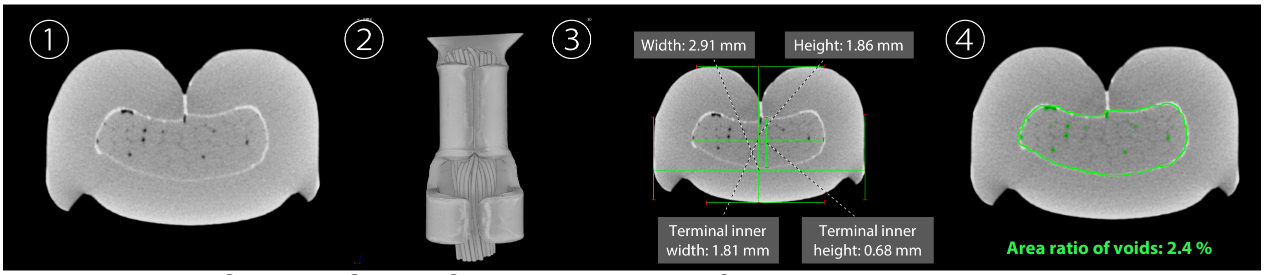

Fig. 6 Crimping Force: Correct ① Cross Section, ② 3D Image, ③ Width and Height Measurements, ④ Internal Cross-Sectional Area of Terminal and Area Ratio of Voids in Wiring

■ CT Observation of Crimped Terminals

Next, CT scan of the respective work pieces was conducted based on the captured data using the VR (volume rendering) software VGSTUDIO MAX*1 (Volume Graphics GmbH). Figs. 4, 5, and 6 show the cross-sectional and 3D images of the terminals prepared with strong, weak, and correct crimping force, respectively. Because more force than necessary was applied when crimping the strongly-crimped terminal in Fig. 4, crushing of the wires inside the terminal can be observed. In the weakly-crimped terminal in Fig. 5, the wires are not crushed and have retained their round shape, but voids can be seen between the wires, as shown by the arrows in Fig. 5 ①. The correctly-crimped terminal in Fig. 6 displays moderate crushing of the wires, and almost no voids can be observed inside the terminal.

The various dimensions of the terminals were measured, as summarized in Table 1. Among these dimensions, the strongly-crimped terminal displayed the lowest height (1.81 mm) and the widest width (3.08 mm). This is inferred to be the result of spreading of the terminal in the width direction when strongly compressed during crimping. Because the interior of the terminal also spread, many voids can be observed between the wires. On the other hand, the width of the weakly-crimped terminal is almost identical to that of the satisfactory terminal (2.90 mm vs. 2.91 mm), but the height (2.13 mm) is higher than that of the other two terminals, and numerous voids can be observed between the wires inside the terminal. As the cause of weak crimping, it is conjectured that one of the wires protruded from the space between the two tabs of the terminal, and the effect of this protruding wire prevented complete crimping. The internal void areas of the three samples were measured by using the 2D image processing software HADI-S*2 (3DII: 3D Industrial Imaging Co., Ltd.).

The measurement results indicated that the void ratios of both the strongly-crimped terminal (5.9 %) and the weakly-crimped terminal (10.4 %) were larger than that of the satisfactory terminal (2.4 %). In explaining the high void ratio measured in the strongly-crimped terminal, it can be inferred that the internal area in this sample was reduced by the heavy crimping force, which should reduce the void ratio, but the lateral spread of the terminal under this excessive crimping force allowed voids to form between the wires.

*1 Optional software: using VGSTUDIO MAX
*2 Optional software: using HADI-S

Table 1 Dimensions and Internal Void Area Ratio of Terminals

Crimping force	Terminal height	Terminal width	Internal height	Internal width	Void area ratio
Strong	1.81 mm	3.08 mm	0.66 mm	1.94 mm	5.9 %
Weak	2.13 mm	2.90 mm	1.15 mm	1.84 mm	10.4 %
Correct	1.86 mm	2.91 mm	0.68 mm	1.81 mm	2.4 %

■ Conclusion

Although nondestructive observation of the condition of electrical wires in the interior of crimped terminals is possible by conventional X-ray fluoroscopy, X-ray CT (computed tomography) enables cross-sectional and 3D observation and measurement of the internal dimensions and cross-sectional area of products, which cannot be determined from external appearance. X-ray CT technology is not limited to nondestructive observation of the internal features of products, but can also be utilized to improve manufacturing quality by providing feedback on the optimum crimping condition to the manufacturing process based on analysis results.

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