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# Experimental research on applying the copper-clad aluminum tube as connecting tubes of air conditioners

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ABSTRACT

This paper describes experimental investigation of copper-clad aluminum (CCA) tubing as a replacement for copper tubing to connect the indoor and outdoor units of split air conditioners. Experiments conducted on three specifications of CCA tubes ($\varphi 6.35 \times 0.6\,mm^2$, $\varphi 9.52 \times 0.7\,mm^2$, and $\varphi 12.7 \times 0.8\,mm^2$) indicate good performance in terms of mechanical properties, processing properties, corrosion resistance, and pressure resistance; this means CCA tubes meet the installation and operation safety requirements for connecting tubes of air conditioners. Additionally, experimental results under two specifications – air conditioners in cooling and heating conditions – reveal no obvious difference in cooling or heating performance when CCA tubes, instead of copper tubes, connect the indoor and outdoor units of air conditioners. Furthermore, compared to copper tubes, CCA tubes can reduce the weight by 36.5%–46.3% and the material cost by 23.0%–34.8%. There is great potential for weight and cost reduction in the widespread application of CCA tubing as the connecting tubes in air conditioners.



## 1. Introduction

The quantity of air conditioners in demand increases with the development of the world economy and the improvement of people's lives level with high energy efficiency ratio [1,2]. Many types of copper tube are used in evaporators, condensers, and as connecting pipes during the manufacture of air conditioners. As shown in Fig. 1, the copper tube is used as the present connecting pipe between indoor and outdoor units. The copper nuts are fixed in the pipe expander of the connecting pipes. Copper nuts and cut-off valves are connected when the air conditioner is installed. In recent years, the price of copper has risen substantially, so air conditioner manufacturers have a growing interest in the substitute of copper tubes [3]. For cost reduction, some manufacturers select aluminum to replace copper in connecting pipes. However, aluminum tubing, which is not as strong as copper tubing, can bend during installation. Furthermore, electrochemical corrosion occurs in the joint between the aluminum tube and copper nut [4–10]. For this reason, the copper-aluminum composite tube is proposed to increase the performance and decrease material cost [11–13].

There are two types of copper-aluminum composite tubing: one entails an aluminum outer and copper inner (aluminum-clad copper tube, or ACC), while the other involves a copper outer and aluminum inner (copper-clad aluminum tube, or CCA). The emergence of CCA tubing is relatively new to the air conditioning industry. The CCA tube is not a simple superposition between two materials; it is made by first sandwich rolling copper and aluminum tube billet. Secondly, the heat and pressure generated from the rolling cause change in the copper and aluminum tube billet, along with the formation of the fresh metal surface. Interdiffusion then occurs among the interface atoms of the copper and aluminum, leading to a metallurgical bonding course. Then there is an integrated copper-clad aluminum tube. Finally, the CCA tube is produced via a similar method to that used in copper production [12,13]. In this paper, the CCA performance is experimentally investigated for the feasibility of applying it as the connecting tube in air conditioners.

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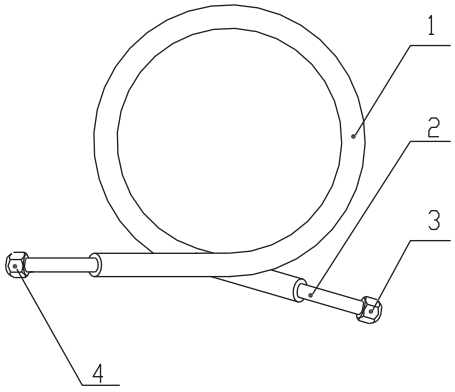


1-insulating layer; 2-copper tube; 3-copper nut; 4-copper nut

**Fig. 1.** Schematic plan of indoor and outdoor connecting pipe of air conditioner.

## 2. Performance test of CCA tubes

### 2.1. Technical requirement on connecting tubes of air conditioners

The tested CCA tube consists of outer copper of T2M and inner aluminum of 3003. The mechanical properties of the copper of T2M and the aluminum of 3003 are shown in Table 1. The CCA tube is used to connect indoor and outdoor units when both are fixed to the wall. In the actual installation of air conditioners, the CCA connecting tube needs a long bending rate. Air conditioner connecting tubes require good bending rate, good mechanical property, good process property, good pressure resistance, and good corrosion resistance.

To meet these requirements, air conditioner connecting tubes with three different diameters–$\varphi$6.35 mm, $\varphi$9.52 mm, and $\varphi$12.7 mm–are investigated.

### 2.2. Mechanical property of CCA tubes

Mechanical properties of CCA tubes include strength extension and elongation percentage. With good mechanical property, the connecting tube bears extension with malleability and avoids fracturing. The experimental method used is in accordance with Chinese national standards, GB/T 228-2002 [14]. The experimental results are shown in Table 2. Compared with the data in Table 1, the strength extension of CCA tubes falls between 154.3 MPa and 192.4 MPa. The extension strength of CCA tubes is lower than that of copper tubes and higher than that of aluminum tubes. The three types of CCA tube tested all have elongation percentages above 40%. In terms of both strength extension and elongation percentages, the three types of CCA tube meet the technical requirement of connecting tubes.

**Table 1**
Mechanical properties of copper tube and aluminum tube.

| Type | Material | Strength of extension (MPa) | Elongation percentage (%) |
|---|---|---|---|
| Copper | T2M | ≥205 | ≥40 |
| Aluminum | 3003 | 95–130 | ≤25 |

**Table 2**
Mechanical properties of CCA.

| Type of CCA ($mm^2$) | Strength of extension (MPa) | Elongation percentage (%) |
|---|---|---|
| $\varphi$6.35 × 0.6 | ≥182.4 | ≥47 |
| $\varphi$9.52 × 0.7 | ≥192.4 | ≥42 |
| $\varphi$12.7 × 0.8 | ≥154.3 | ≥40 |

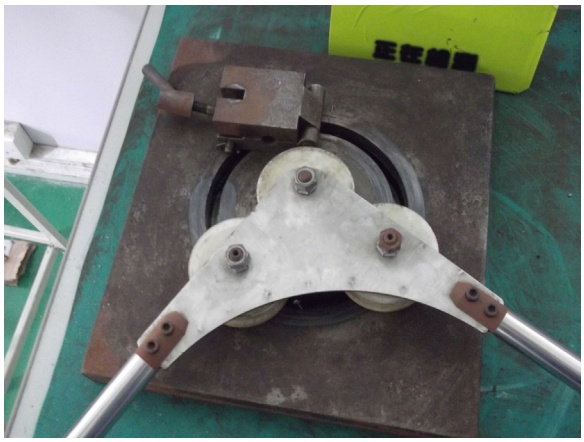

**Fig. 2.** Schematic plan of bend tester.

### 2.3. Bending performance of CCA tubes

The bending performance test is carried out in a bending tester, which is shown in Fig. 2. The experimental method goes as follows: one end of the tube being tested is fixed in the grip, and the other end is bent to 180°; the bending test is repeated eight times. When the experiment is finished and the bending joint of the CCA tube is observed, the gash should not appear on the surface. In addition, there should be no segregation between aluminum and copper on the cross-section of the bending joint.

The experimental results, presented in Table 3, show that the gashes do not appear on the surface of the bending joints of any of the three types of CCA tube. Moreover, the results reveal that when the experiment is finished, aluminum and copper are not segregated on the bending joint cross-sections. The experimental results support that the bending performance of the three types of CCA tube can meet with the technical requirements of connecting tube.

### 2.4. Process property of CCA tubes

Connecting tubes involve flares and therefore must have good flaring performance [12,13], or process. An experiment on the process property of CCA tubes is carried out using manual expanding apparatus. The experimental method employed is in accordance with Chinese national standards, GB/T 242-2007 [15]. This experiment involves, first of all, cutting a proper length in each tube on one side and, secondly, expanding the top with 90° punch – the expansion rate of which is 50% – for the flaring test. The third step entails checking the expansion of the top; there should be no be visible cracks. As the results of this experiment, shown in Table 4, reveal, the flaring rate of CCA tubes is not lower than that of copper tubes (≥50%), which illustrates that CCA tubing has a high toughness, similar to copper, and that it can be an alternative to meet the requirements.

In practical application, connecting tubes link indoor and outdoor units with flarings. There are two flaring production processes in CCA tubes. One directly expands on its side—the result is shown in Fig. 3. In this flaring, the inside material is aluminum, while the valve is connected to copper. With long-lasting contact, it will result in electrochemical corrosion of the metal surface [12,13], which will affect reliability.