WELDABILITY OF Cu-W ALLOY AND COPPER USING FRICTON WELDING METHOD①

Hou, Saizhang Liu, Ximing
Department of Materials Science and Engineering, Central South University of Technology, Changsha 410083

ABSTRACT The weldability of Cu-W alloy and Cu was studied using the friction welding method; relatively good technical parameters for friction welding of Cu-W alloy and Cu were obtained using the orthogonal method.

Key words Cu-W alloy friction welding weldability orthogonal method

1 INTRODUCTION

Cu-W alloy, as a high temperature resistant and arc erosion resistant eletric material, has been widely used to make such parts as high-voltage contacts, electric spark drilling electrodes, spot-welding electrodes, rolling welding machine rollers and conducting nozzles. This material is usually connected with Cu to be used as an integral, which is due to the fact that the Cu-W end possesses such properties as high temperature resistance and arc erosion resistance and the Cu end possesses good conductivity. This integral form can also save raw material W. Therefore, great attentions have been paid to the welding technology of Cu-W alloy and Cu for a long time.

Friction welding as an advanced welding technology first came into being at the middle and later periods of the 1950s[1]. The characteristics of this method are as follows: using the theory of friction prodcing heat, make the welding surfaces contact under pressuring and rotate oppositely at high speeds, thus make the contact surfaces produce high temperature; when this temperature reaches the fusion welding temperature of the two alloys, stop the rotating workpieces right away and exert an upsetting force, thus the workpieces are bonded together firmly. The schematic diagram of friction welding is shown in Fig. 1. The friction welding method has the advantages of high speed, high efficiency (welding a workpiece only needs several seconds) and good welding quality. Because of the short welding time, the internal structures of the materials are not affected on the whole. Moreover, the welding ratio of the welded surfaces can reach 100%, so that this method is especially suitable for welding long and thin round workpieces. It has been successfully used to weld such materials as Cu-Al, Cu-steel, steel-

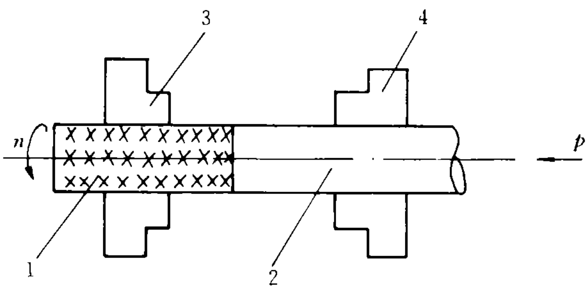

Fig. 1 The schematic diagram of friction welding
1—Cu-W alloy;
2—red copper rod;
3—rotating holder;
4—non-rotating holder;
n —rotating speed; P —axial pressure

① Received Apr. 18, 1995; accepted May 26, 1995

steel[2]. No reports can be found on successful technologies of friction welding for Cu-W alloy and Cu, and even some people have doubts about their weldability. This paper studied the welding technology of Cu-W alloy and Cu and obtained good effectiveness.

2 EXPERIMEINTAL MATERIALS AND METHOD

The specimens were powder metallurgic Cu-W alloy rods and red copper rods. A C_{20} type friction welding machine[3] with a rotating speed of 2 000 r/min and an uppsetting force of 0～100 kN (adjustable) was used to perform friction welding tests.

In consideration of the technical parameters affecting the welding quality such as friction pressure, friction time, dwell time and cooling rate of workpieces, the orthogonal method was adopted to optimize the combination of the technical parameters, thus find out the relatively good technical parameters of friction welding for the Cu-W alloy and red copper. The test factors and their levels are shown in Table 1.

Table 1 Test factors and levels

Level	Factor			
	A	B	C	D
1	40	3	1	1 000
2	60	2	2	500
3	80	1	3	100

Notes: A—Friction pressure, MPa;
B—Friction time, s;
C—Dwell time, s;
D—Cooling rate, ℃/min.

According to the selected factors and levels listed in Table 1, the $L_9(3)^4$ orthogonal table[4] was adopted in this paper, see Table 2.

The welding quality was evaluated through measuring the tensile strength of the contact surfaces. The welding workpieces were processed into tensile rods and the welding surfaces were kept in the range of effective gage length.

Table 2 The orthogonal table ($L_9(3)^4$)

Test No.	A	B	C	D
1	A_1	B_1	C_1	D_1
2	A_1	B_2	C_2	D_2
3	A_1	B_3	C_3	D_3
4	A_2	B_1	C_2	D_3
5	A_2	B_2	C_3	D_1
6	A_2	B_3	C_1	D_2
7	A_3	B_1	C_3	D_2
8	A_3	B_2	C_1	D_3
9	A_3	B_3	C_2	D_1

The tensile tests were carried out on a WD-10A electronic tensile test at a rate of 2 mm/min. The metallographic observation of the cross-section of the junction surfaces was finished on an X650 SEM.

3 RESULTS AND DISCUSSION

The tensile strength σ_b of the welding surfaces obtained using the orthogonal method are listed in Table 3.

Table 3 Tensile strength σ_b of the welding surfaces under different technical conditions

Test No.	σ_b /MPa
1	218. 6
2	264. 2
3	258. 9
4	250. 4
5	249. 6
6	252. 1
7	272. 7
8	270. 3
9	306. 1

The limit error analysis results on the data in Table 3 are shown in Table 4. W_{ij} is the mean value of the tensile strength σ_b of factor i at different levels j, i. e. $W_{ij} = \frac{1}{3}\sum_{j=1}^{3}\sigma_{bj}$. R is the difference of maximum $\sigma_{b,max}$ and minimum $\sigma_{b,min}$.

Table 4 Limit error analysis of data in Table 3

Level	Factor			
	A	B	C	D
1	247.23	247.23	247	258.1
2	250.70	261.37	273.57	263
3	283.03	272.37	260.4	259.87
R	35.80	25.14	26.57	4.9

The larger the *R*-value is, the larger the influence of a factor on the welding strength is. It can be seen from Table 4 that the first principal factor affecting the welding strength is the friction pressure, the seconds are the friction time and the dwell time, and the last is the cooling rate.

In order to show the influence of the various factors on the welding strength σ_b more clearly, using the data listed in Table 4, diagrams were drawn to express the change of the welding strength σ_b with the levels of different factors, as shown in Fig. 2.

It can be known from Fig. 2 that the relatively good technical paramenters of friction welding for the Cu-W alloy and Cu are: friction time 1 s, dwell time 3 s, cooling rate 500 ℃/s.

Using the above parameters to repeat the test, a welding strength of 270 MPa was obtained. This strength is much higher than that

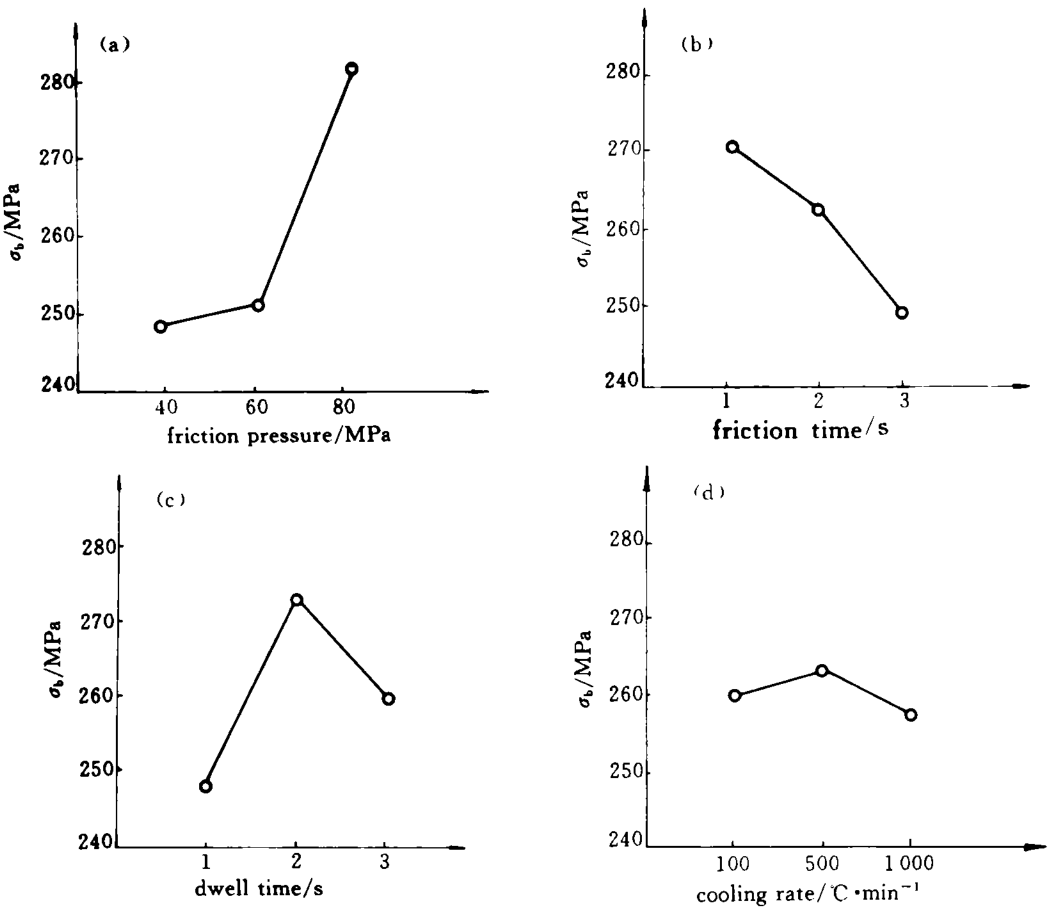

Fig. 2 The change of σ_b with the levels of different factors
(a)—friction pressure-σ_b; (b)—friction time-σ_b; (c)—dwell time-σ_b; (d)—cooling rate-σ_b.

in JB1373—74(≥150 MPa).

The rotating speed of the friction welding machine used in tests was kept at 2 000 r/min. It can be seen from Table 4 that when the other conditions are the same, the friction pressure is the first principal factor affecting the welding strength. This is due to the fact that the larger the friction pressure is, the larger the friction force between the rubbing surfaces is, therefore the larger the heat produced by friction is and the higher the temperature is, consequently this is beneficial for the workpieces to be welded firmly in short times. The second principal factor is friction time. It can also be known from Table 4 that the friction time should not be too long. Too long friction time will soften the materials, in particular the red copper part by annealing, thus reducing the σ_b -value. Just like this, the dwell time should also not be too long, and it is suitable to take a dwell time of 3 s. With regard to the cooling rate, it is suitable to select a moderate cooling rate of 500 ℃/s. Because the studied Cu-W alloy is a false alloy and the red copper rod is an elemental metal, there are no phase transitions. But too slow cooling rate or too long dwell time will all soften the red copper by annealing because of high temperature at the junction surfaces, thus reducing the σ_b -values. Too fast cooling rate will reduce the high temperature diffusion of the copper atoms, thus reducing the σ_b -values similarly.

The welding strength σ_b obtained using the optimized technical parameters is much higher than that in JB1373-74. This is because that metallurgic bonding is realized between the junction surfaces. The cross-section SEM metallography of the junction surface is shown in Fig. 3

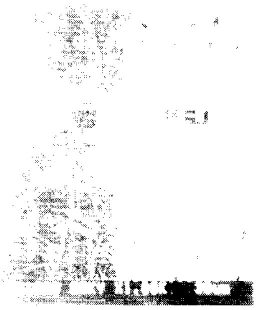

Fig. 3 The cross-section SEM metallography of the junction surface

It can be seen that the contact surfaces are well metallurgically bonded together and there is a homogeneous defects-free transition layer.

4 CONCLUSIONS

(1) It is completely practicable to prepare Cu, W-Cu integral material using Cu-W alloy and Cu by friction welding technology.

(2) The relatively good technical parameters of friction welding for Cu-W alloy and W are: friction pressure 80 MPa, friction time 1 s, dwell time 3 s and cooling rate of welded workpieces 500 ℃/s. The welding strength obtained under these parameters is 270 MPa.

(3) At the present time, the friction welding method is only suitable for rotary type workpieces.

REFERENCES

1 Ning Peizhang, Cai Yinxian. Friction Welding. Beijing: Machinery Industry Press, 1—4.

2 Harbin Welding Research Institute. Applications of Electronic Beams Welding and Friction Welding. Beijing: Machinery Industry Press, 1975: 66—80.

3 Yu Weiming *et al*. Handbooks for Selection of Welding Equipments. Beijing: Machinery Industry Press, 1974: 373—380.

4 Anon. the Orthogonal Method. Beijing: National Defence Industry Press, 1976: 56—60.