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Investigation of the micro contact profile welding technics

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Abstract: The cladding preparation technology for the micro contact profile is investigated through the way of seam welding. The effects of the seam welding on different conditions including welding electrical current, welding time, electrode force and electrode material were contrasted through the way of metallographic structure, electron scanning, experiments of rectification and twist fatigue. The parameters of welding several kinds of materials were obtained. As a result, the qualified contact profile can be produced by making a control of the technical conditions: welding current, welding time, electrode force and electrode material.

Key words: micro contact profile; electric contact material; seaming welding.

CLC number: TB331, TG146.3, TG441.4 **Document code:** A

1 Introduction

Along with the rapid development of electronic technology, micro composite electric contact profile is applied widely to all kinds of electronic products such as relay switch, key press, digital switch, micro-switch, circuit recorder, controller, linker and so on[1]. Micro composite electric contact profile is a new weak electricity contact material with several layers and tiny cross section area. Generally, the electric contact layer is made from noble metal materials. In a typical case, the contact layer of a micro contact profile consists of gold alloy; the middle layer is made from silver and its alloy; copper and its alloy form the substrate layer. Specifically, $AuAg_8/AgNi_{10}/CuNi_{20}$ and $AuAg_8/Ag/CuNi_{20}$ are two famous examples. During the production process of micro contact profile, it is important to achieve excellent composite between the middle layer and the substrate layer. Typically, it can be obtained by several ways, for example, rolling coating, electroplating, welding, vapor deposition and explode composite[2]. Seam welding is one of the welding techniques. The round welding wheel was used as welding electrode, called welding wheel in this paper. In particular, continuous current passed through the electrode wheel when it was rolling. Under the effect of electrode force and current, the materials were combined together. In this paper, $AgNi_{10}/CuNi_{20}$ and $Ag/CuNi_{20}$ produced by continuous seam welding was studied. The specific technique and the effect of all factors were also analyzed.

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2 Experimental

In this research, the Ag or $CuNi_{10}$ (1.2 mm×0.3 mm) and $CuNi_{20}$ (1.2 mm×0.3 mm) strips were combined together by continuous seam welding using RW−5122 precise welding instrument. The bond strength and welding effect of the composite strip obtained from different welding conditions were analyzed. Consequently, the optimal technical parameters and welding conditions were determined. An 8500002 Stereo Microscope was used to observe the local and global morphologies of the strips, the interfacial structure, the shape of welding drops and the decohesion of metal layers. The composite strips were drawn at large deformation ratio to analyze the adhesion of the strips. Additionally, the fatigue resistance was tested by twisting the composite strips.

XJP−6A Metal Phase Microscope was applied to observe the cross section of the composite strip. The metallic phase, the character of the welding line and the change of the fine texture were analyzed to get the optimal welding conditions. The change of the composition at the interface was analyzed by Scanning Electronic Microscope to study the characteristics of diffusion.

3 Results and discussion

3.1 Welding wheel

Three welding wheels made from three different materials were applied in the welding experiments. The heat and electrical conductivities of the welding wheel A, B and C decrease in order. Different welding wheels were applied to adjust the position of high temperature zone during the welding process to ensure that the nugget was located as close as to the welding interface. Improper using of different materials can result in the drift of nugget, as shown in Fig.1(a). In this case, the nugget shifts to the silver strip, where the welding drops appear. More significant drift of nugget will cause loose welding, spray of melting metal, blowout of strips, even breaking the welding wheels. In addition, the increased current to melt strips will lead to spray of melting metal, blowout and overheating of metal strips. Fig.1(b) shows the case with proper welding wheel material, where the nugget is on the welding interface and the welding drops just cover the welding seam. Among different combinations of welding wheel materials, combination of A and C provides the best result. During the welding process, $CuNi_{20}$ alloy strip was on the top, contacted with wheel A, and Ag or $CuNi_{10}$ strip was at the bottom, contacted with wheel C. Since $CuNi_{20}$ strip possesses higher electrical resistance compared with Ag or $CuNi_{10}$ strip, wheel A with higher heat conductivity was selected to contact with $CuNi_{20}$ strip and wheel C with lower heat conductivity was contacted with Ag or $CuNi_{10}$ strip. Therefore, the heat conduction of two strips was modulated under different conditions. Consequently, the position of the high temperature zone was adjusted to improve the strip combination.

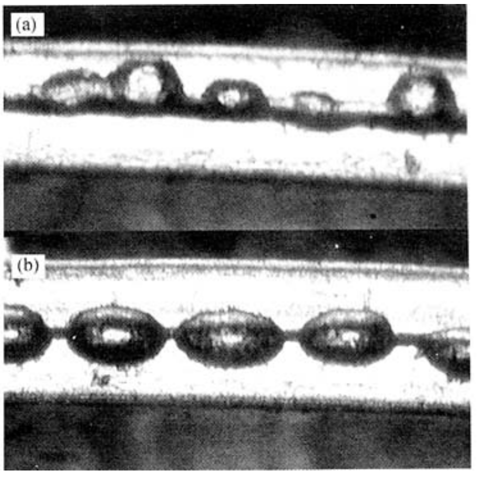

Fig.1 Different position of the welding drops because of using different welding wheels

3.2 Electrode force

The welding cycle of strips can be divided into three stages: squeeze time, welding time and forge-delay time[3]. It is important to prepare enough electrode force. Otherwise, during the squeeze stage, the low electrode force will cause large electrical contact resistance and spray of melting metal. At the welding stage, the melting metal is easier to eject. In the forge-delay stage, it will result in less compress deformation to counteract the condensation shrinkage of the metals, which produces shrinking pore, air hole and cracks in the structure. On the contrary, the larger contact area between electrode and strips due to the higher force decreases the adhesion strength because of the less heating, more conduction and smaller melting area. In addition, the soft material, $AuAg_8/CuNi_{10}$, becomes wider during the heating process, which makes it difficult for later treatment. For all the reasons mentioned above, it is critical to select suitable electrode force, and it was determined to be 1.0×10^6 Pa in this research.

3.3 Welding current

In this paper, the contrast experiment of $AgNi_{10}/CuNi_{20}$ was performed under the conditions that the heat time is 10 ms, the cool time is 10 ms and the electrode force is 1.0×10^6 Pa. The welding effect as the function of the welding current was investigated, and the results are showing in Table 1.

Table 1 Influence of the weld current on the quality of the welding (under the welding-time of 10 ms, the cooling-time of 10 ms, the electrode force of 1.0×10^6 Pa)

No.	Welding current /kA	Welding effect	Appraise
1	2.8	Bond strength was not enough, the composite strip separated in the draw test and the twisting test experiments	bad
2	3.0	Bond strength was strong, the face of weld was smooth, the composite strip passed the draw test and the twisting test experiments	good
3	3.2	Same to the sample 2	good
4	3.4	Bond strength was strong. Observed by the stero microscope, the distortion of the face of weld was obvious. There were some tiny welding drops on the face of welding. The composite strip passed the draw test and the twisting test experiments	good
5	3.6	Bond strength was strong. There were a lot of welding drops on the face of weld. The melting of the $CuNi_{10}$ strip was obvious. The composite strip passed the draw test and the twisting test experiments. But too many welding drops were not good for the later process	fairly good
6	3.8	Bond strength is strong. The $CuNi_{10}$ strip melted seriously. The face of weld was covered by the welding drops. The cracks appeared on the $CuNi_{20}$ strip	bad

Because the current was too high, there are a lot of bumps appear on the side face of sample 6, and on the bumps the triangle cracks appeared. Observing the cross section parallel to the side face, some tiny holes were found, which correspond to the bumps mentioned above (Fig.2). On the cross section parallel to the interface, the tiny holes have bow shape, as shown in Fig.3. The tiny holes will develop into cracks to break composite strip in the draw test. Fig.3 shows that there is fine grained cast structure around the hole. The holes were produced when the welding current was too high. The tapes were heated up too rapidly and the molten pool extended quickly. Because of the effect of the electrode force, the melting metal broke the partial melting region of the side face and sprayed out. On the contrary, sample 2 and 3 were welded in proper current. The phase diagram at the welding interface and the composition analyzed by SEM are shown in Fig.4 and 5, respectively. There was a diffusion region about 2.5μm between the two layers

(Fig. 5). The composite strip produced in these welding conditions has adequate bond strength. If the current is too low, the composite strip will separate in the experiments, as shown in sample 1.

Fig. 2 Microstructure of the tiny holes in the $AgNi_{10}$/$CuNi_{20}$ composite strip, 50×

Fig. 3 Microstructure of bow shape observed from the plane parallel with the junction plane, 200×

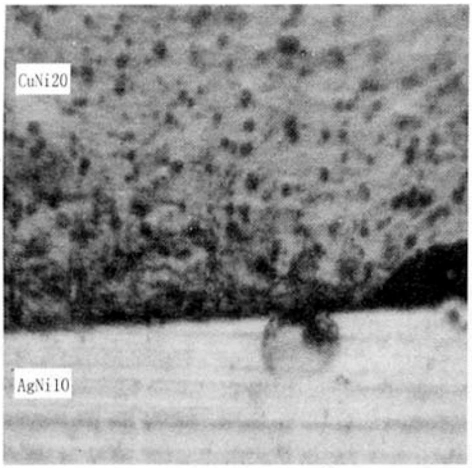

Fig. 4 Microstructure of $AgNi_{10}$/$CuNi_{20}$ junction plane with good welding effect (500×)

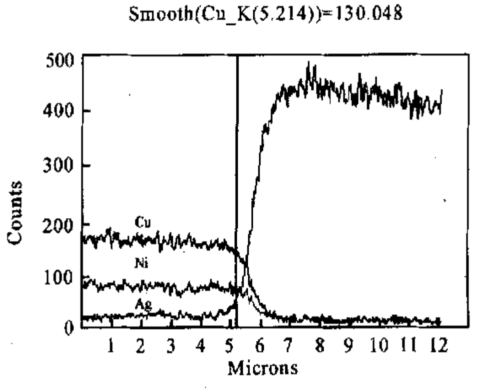

Fig. 5 Diffsion layer curve of $AgNi_{10}$/$CuNi_{20}$ by SME

3.4 Welding time

Welding time has influence on both heat absorption and conduction. The effect of welding time with 10.0bar electrode force and 3.0 kA welding current was studied under the condition of 20 ms cooling, and the results were shown in Table 2. It is not surprising that longer welding time results in heat accumulation, therefore, serious metal melting, which can cause spray of melting metal and overheat of strips. For instance, the melting of $CuNi_{10}$ created large amount of welding drops covered on the seam, as shown in sample 9. Furthermore, cracks were developed from collapse and separation in the layer of $CuNi_{10}$ due to the loss of $CuNi_{10}$. At the same time, overheating was noticed in $CuNi_{20}$ strip, which resulted in bow shape holes and hairlike cracks along the crystal. On the contrary, sample 7 shows what happened under shorter welding time, which resulted in less heat accumulation and metal melting. By analyzing all the data mentioned above, the relationships between welding current and time of $Ag/CuNi_{20}$ and $AgNi_{10}/CuNi_{20}$ under 1.0×10^6 Pa electrode force, 20 ms cooling and wheel A and C combination are shown in Fig.6 and Fig.7. Comparing these two figures, the optimal performance area of $AgNi_{10}/CuNi_{20}$ shifts leftwards and narrower than that of $Ag/CuNi_{20}$.

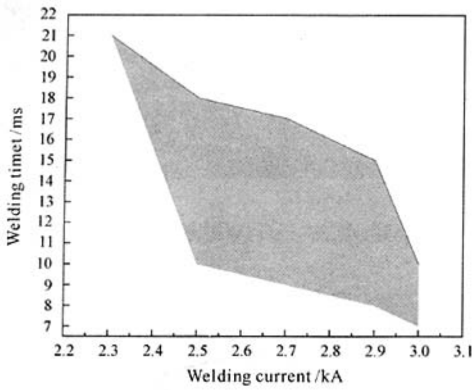

Fig.6 The good welding conditions region of $Ag/CuNi_{20}$

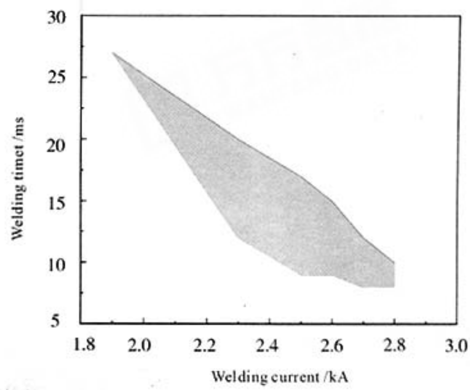

Fig.7 The good welding conditions region of $AgNi_{10}/CuNi_{20}$

Table 2 The influence of the welding-time on the quality of the welding (under the cooling-time of 10 ms, the electrode press of 10×10^6 Pa and the welding-electrical current of 2.5 kA)

No.	Welding current /kA	Welding effect	Appraise
7	9	Bond strength was not enough, the face of weld was smooth, the composite strip separated in the draw test and the twisting test experiments	bad
8	14	Bond strength was strong, the face of weld was smooth, the composite strip passed the draw test and the twisting test experiments	good
9	19	Bond strength is strong. The face of weld was covered by the welding drops. The cracks appeared on the $CuNi_{10}$ strip	bad

4 Conclusions

(1) By using the combination of wheel A and C, the position of high temperature zone can be adjusted, which is benefit for the formation of the composite strip.

(2) The electrode force of 10×10^6 Pa is optimal for the welding of $AgNi_{10}/CuNi_{20}$ and Ag/Cu. Under the same welding current and time, lower electrode force will cause spray of melting metal and higher force will result in loose and wider welding.

(3) Welding current and time have similar impacts on the welding performance of strips. Proper welding current and time is critical for better welding results. Spray of melting metal, overheating of strips and inner defects are caused by longer welding time and higher welding current; on the contrary, lower adhesion strength is resulted. The correlation between welding current and time under optimal welding performance is obtained from the experiments.

(4) The optimal performance area of $AgNi_{10}/CuNi_{20}$ shifts leftwards and narrower than that of $Ag/CuNi_{20}$.

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