Application of Tungsten- and Molybdenum-based Materials to Resistance Welding Electrodes

タングステン・モリブデン系材料の抵抗溶接用電極への応用

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Key words; Resistance welding electrodes, weld conditions, tungsten, molybdenum, NDB electrode

キーワード；抵抗溶接電極、溶接条件、タングステン、モリブデン、NDB 電極

Abstract

In recent years, objects to be welded by resistance welding have been diversified and the load of welding conditions is sometimes too much for a generally-used copper alloy electrode. There are some cases that such load decreases the life of a welding electrode and makes the joining quality unstable. Under specific severe welding conditions, W- and Mo-based materials have been used as electrode materials with increasing frequency making the life of an electrode longer and improving the joining quality.

近年、抵抗溶接における被溶接物が多様化されており、一般的に使用される銅合金電極では、溶接条件の負荷が大きすぎる場合がある。この場合、抵抗溶接電極が短寿命になる場合や接合品質が安定しないといった事例がある。特定の過酷な溶接条件下では、W・Mo 系材料が電極材料として用いられるケースが増えており、電極の寿命化や接合品質の向上などの実績を上げている。

1.Introduction

Resistance welding method is to overlap metals to be welded, pinch the welding point with electrodes with adequate welding pressure and apply high current to generate heat sufficient to melt and join metals. This is one of welding techniques and widely used for joining various products such as auto parts and home electronics.

The roles of a resistance welding electrode are to:

① Apply high current to the weld,

② Apply a high voltage to the weld, and

③ Cool down the surface of the weld.

To fulfill above roles, the following characteristics are required for a resistance welding electrode:
① Hardly deformed by high pressure or high temperature
② Excellent thermal/electric conductivity
③ Hardly alloyed with the weld or plating metals
④ Hardly oxidized in the atmosphere
⑤ Low cost

A precipitation hardened alloy, chromium copper (CrCu), is most commonly used as a resistance welding electrode which fulfills above conditions. During the resistance welding, however, precipitates are dissolved in Cu matrix by heating repeatedly and the hardness and electric conductivity of the electrode decrease and reach the end of service life.

In addition, there is another electrode called alumina-dispersed copper which increases its hardness and electric conductivity by dispersing hard particles into copper. The performances of this electrode are less deteriorated by heating repeatedly unlike precipitation hardened copper, but its lifetime is shortened under the following welding conditions:
① Copper is alloyed with the weld or its plating film,
② Cu wire having a high thermal conductivity is welded,
③ High-current or long-time welding, and
④ Welding shot cycle is fast.

2.Results and Discussion

2.1 Characteristics of Tungsten and Molybdenum

(1) Tungsten (W)
・The melting point is the highest among metals (3,387℃).
・The hardness is high at both normal and high temperatures.
・Tungsten (W) starts oxidizing from about 400 ℃ forming W_3O, WO_2 and $W_{20}O_{58}$ and rapidly oxidizes from about 700 ℃ forming WO_3.
・The electric resistivity is high (5.5×10^{-8} Ω m).
(2) Molybdenum (Mo)
・High melting point
・At high temperature, the mechanical strength is high.
・Molybdenum oxidizes rapidly at above 500 ℃ . At above 650 ℃ , it changes to gray-white-colored MoO_3.
・The electric resistivity is high (5.7×10^{-8} Ω m).

As above, tungsten and molybdenum have high mechanical strength at high temperature and are frequently used under the welding condition where heat load on the electrode is high such as high current and fast shot cycle. However, the amount of heat generated by the electrode becomes relatively larger due to its low thermal conductivity. In the case of workpiece materials alloyed easily with tungsten or molybdenum or plating materials, weld deposit and sputtering may awfully grow.

In addition, tungsten and molybdenum tend to oxidize so it is necessary to cool down the electrode as much as possible so that oxidative consumption can be suppressed.

2.2 The field of application and proper use of tungsten- and molybdenum-based electrode materials

(1) Tungsten and molybdenum

Tungsten and molybdenum have an excellent high-temperature strength and are available for workpieces or plating products that are easily alloyed with copper and often used for heating workpieces using exotherm of an electrode and performing thermal caulking under high pressure. Tungsten and molybdenum are used separately depending on the following advantages:

・Tungsten tends to be cracked by thermal shock. Molybdenum is often used when cracks or breaks occur frequently.

・Oxidative consumption of molybdenum is higher than that of tungsten. Tungsten is often used when placing emphasis on lifetime.

・The high-temperature strength of tungsten is higher than that of molybdenum.

(2) S-TUN

S-TUN is a tungsten material having non-directional structure. This isotropic structure sometimes works as a countermeasure against cracks and has been used for a heater tip for fusing welding. However, the mechanical strength is weaker than conventional tungsten depending on the size or the shape.

(3) Cu-W/Ag-W alloy

Both Cu-W and Ag-W alloys have a high temperature strength and a high electric conductivity. Our company has various compositions of them and is able to provide the best one according to the welding conditions.

Recently, Ag-W alloy electrodes have been often used from the viewpoint of preventing short-circuit accidents caused by copper contamination in a manufacture line. Since Ag is hard to be alloyed with Fe or Ni, it is often used for welding of SUS and Ni foil.

(4) Ag-WC alloy

When tungsten reacts with carbon and becomes WC, the oxygen resistance increases and is effective for oxidation consumption measures, but the electrical resistivity decreases. By alloying WC with Ag and Cu, the resistivity and the heat conduction are improved and such alloys have been commercialized.

(5) Heavy alloy

Heavy alloy mainly consists of W with sintering aids such as Ni, Cu and Fe. A W-Ni-Cu alloy with 94 % or higher W content (HAC_2) is used as a chuck electrode for welding solder plating wire with a diameter of about 1 millimeter such as resistors and capacitors. Heavy alloy has advantages such as higher oxidation resistance than W, free-cutting and low cost.

Cost is also the most important factor for choosing an electrode. Rare metals such as W and Mo, precious metals such as Ag and intractable metals are costly.

Figs. 1-6 show structures of metal materials manufactured by our company. Table 1 shows the characteristics of them.

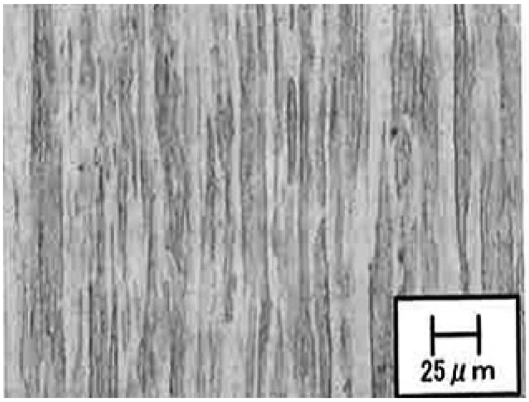

Fig.1. Internal structure of tungsten

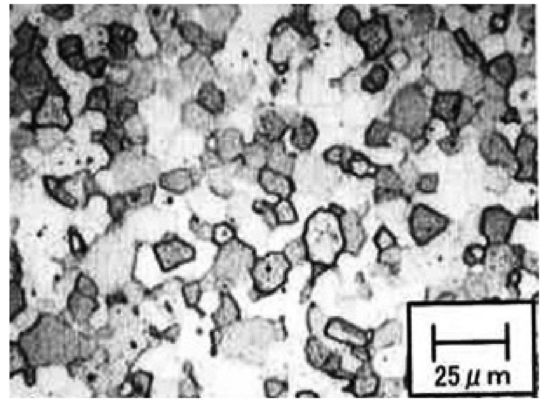

Fig.2. Internal structure of “S-TUN”

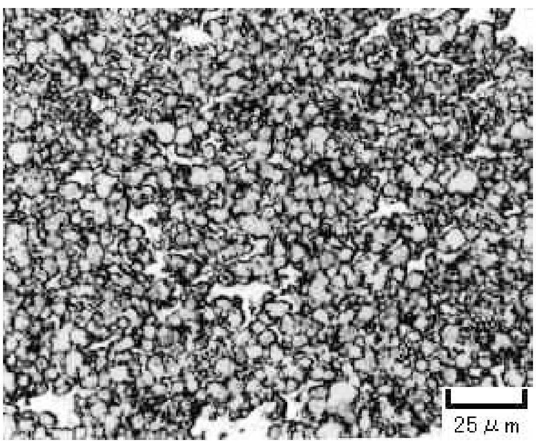

Fig.3. Internal structure of 30%Cu-W alloy

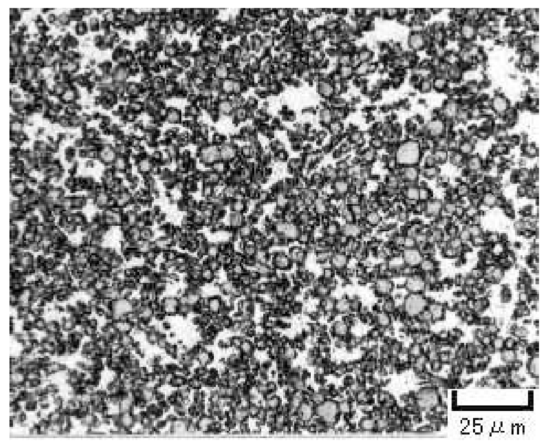

Fig.4. Internal structure of 35%Ag-W alloy

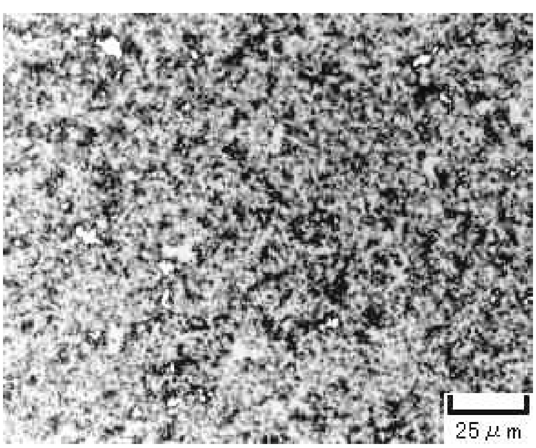

Fig.5. Internal structure of 40%Ag-WC alloy

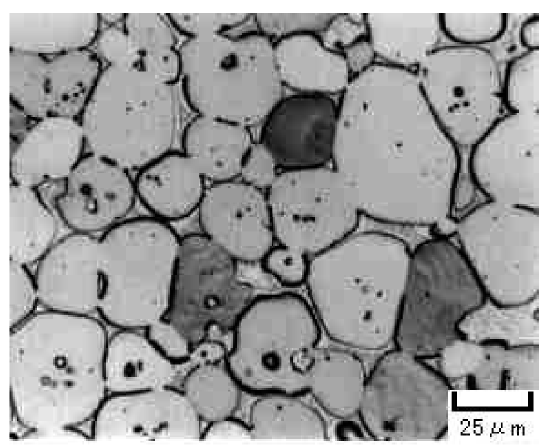

Fig.6. Internal structure of heavy alloy (94%-Ni-2%Cu)

Table1. Characteristics of metal materials manufactured by our company

	product name	composition	specific gravity	hardness(HV)	IACS%	cutting
Metal materials made in our company	tungusten(W)	W:99.9% and over	19.3	450	31	hard
	Molybdenum(Mo)	Mo:99.9% and over	10.2	250	30	normal
	C10B2	11%Cu-W	16.8	330	30	free-cutting
	C20B2	20%Cu-W	15.6	280	40	free-cutting
	C30B2	30%Cu-W	14.2	225	48	free-cutting
	S35A2	35%Ag-W	14.8	210	53	free-cutting
	HS1	40%Ag-WC	12.8	250	37	hard
	HAC2	94%W-Ni-2%Cu	17.9	280	19	free-cutting
Metal to compare	chromium copper	1%Cr-Cu	8.9	150	80	easy
	alumina-dispersed copper	0.5%Al2O3-Cu	8.7	150	80	easy

※free-cutting>easy>normal>hard

Fig. 7 shows workpiece materials used for metallic electrodes and electrode conditions.

Tungsten- and molybdenum-based electrode materials are less used for steel sheet welding which is high demand but used for welding non-ferrous materials such as copper and nickel making use of the high strength at high temperature.

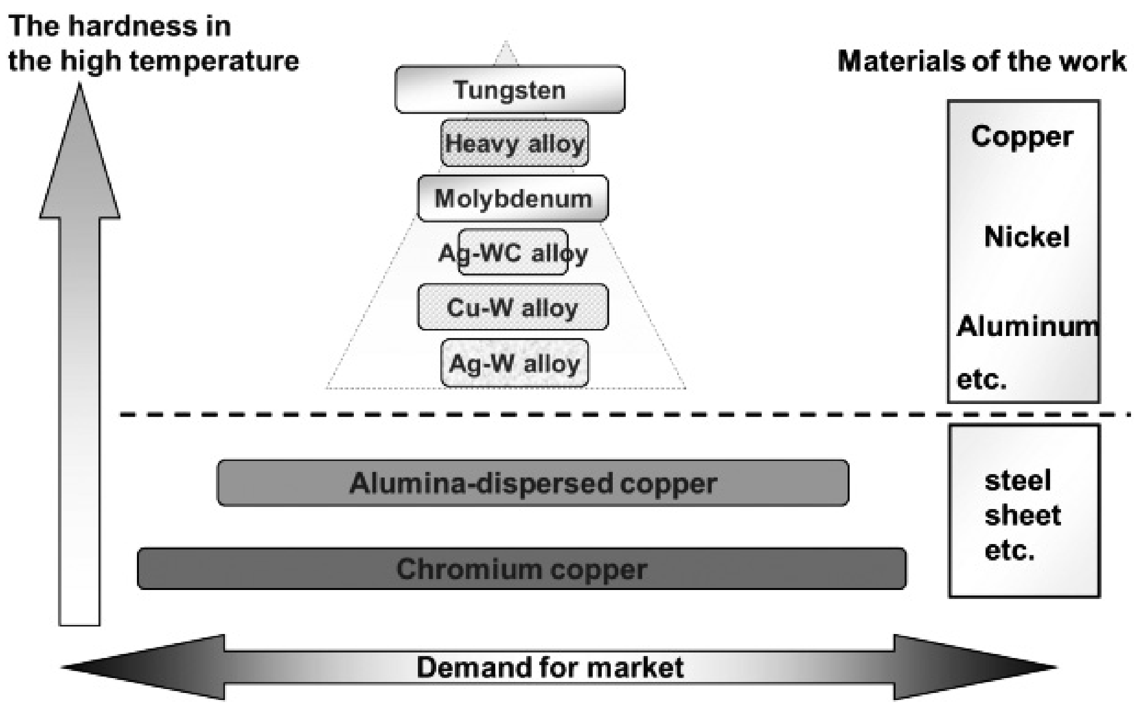

Fig. 7. Workpiece materials used for metallic electrodes and electrode conditions

2.3 NDB (Non-Defective Bonding) method

W, Mo and their alloys are used for a tip of an electrode for resistance welding and Cu and Cr-Cu alloy are used for its shanks (holders or part of cooling holes). Though “silver brazing” and “pressure welding” are generally used to join an electrode with a shank, the joining quality is apt to vary and/or the life of an electrode might be shortened due to drop out of the electrode material, decrease in heat conductance or heat generation at the junction.

Our company provides customers electrodes manufactured using NDB method which was developed by improving conventional joining methods. NDB (Non-Defective Bonding) method is a joining method to directly join copper with W, Mo or Cu-W alloy developed and patented by our company. The process of

NDB is shown in Fig. 8. Since NDB product has good thermal conductivity to the shank (Fig. 9), the electrode can be cooled down quickly while the energization is suspended. It not only avoids electrode burnout but also hastens the shot cycle to contribute to productivity improvement and enables the welding cycle which cannot be achieved by brazing or pressure welding.

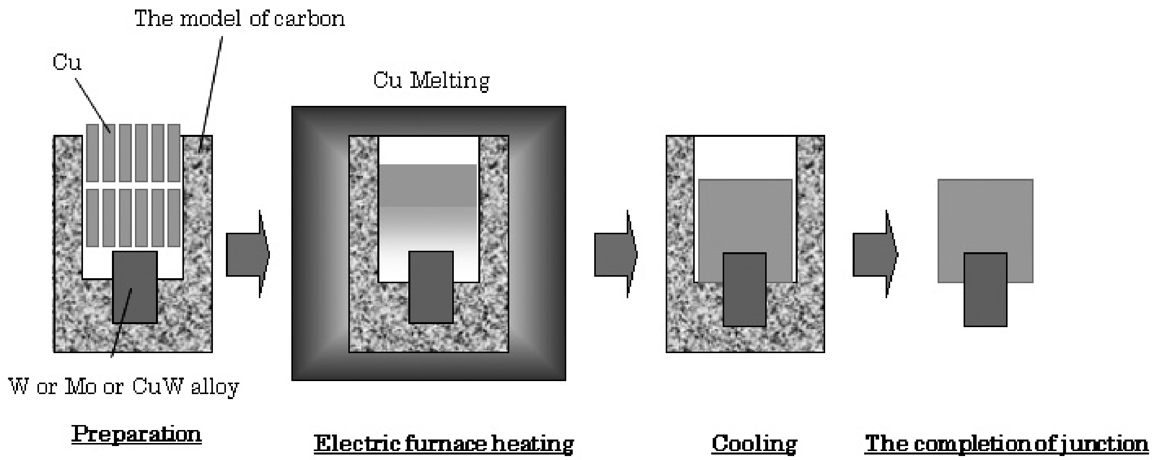

Fig. 8. The process of NDB.

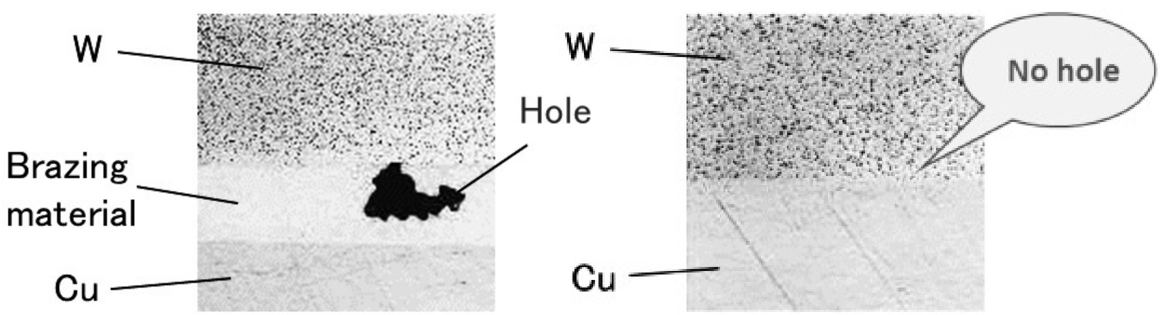

Fig. 9. Comparison of joining qualities (left: brazed electrode, right: NDB electrode)

2.4 Cooling performance of NDB electrode

In order to compare performances of NDB-W, W-brazed and W-solid electrodes, we measured the change in electrode temperature when cooling down from 1000 ℃ to 300 ℃ as shown in Fig. 10. The results are shown in Fig. 11. From these results, i.e. the NDB electrode is cooled down 304 msec. faster than the W-brazed one and 1688 msec. faster than the W-solid one. Therefore, the cooling performance of the NDB electrode is the best.

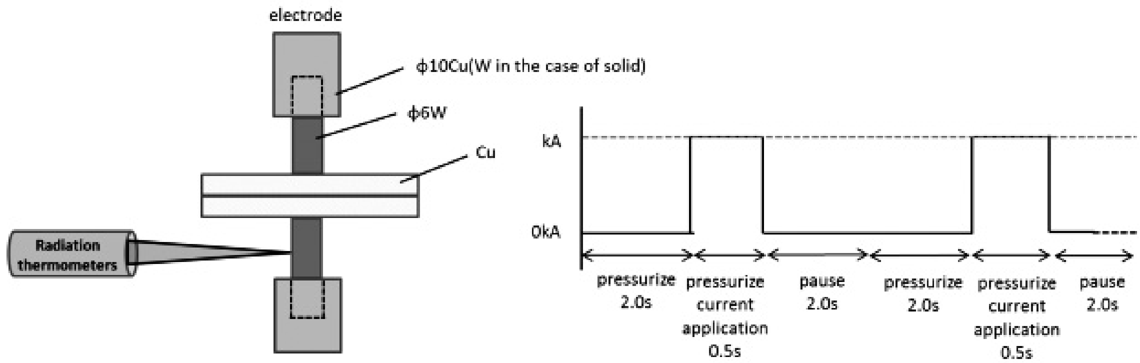

Fig. 10. Schematic diagram of the competitive experiment

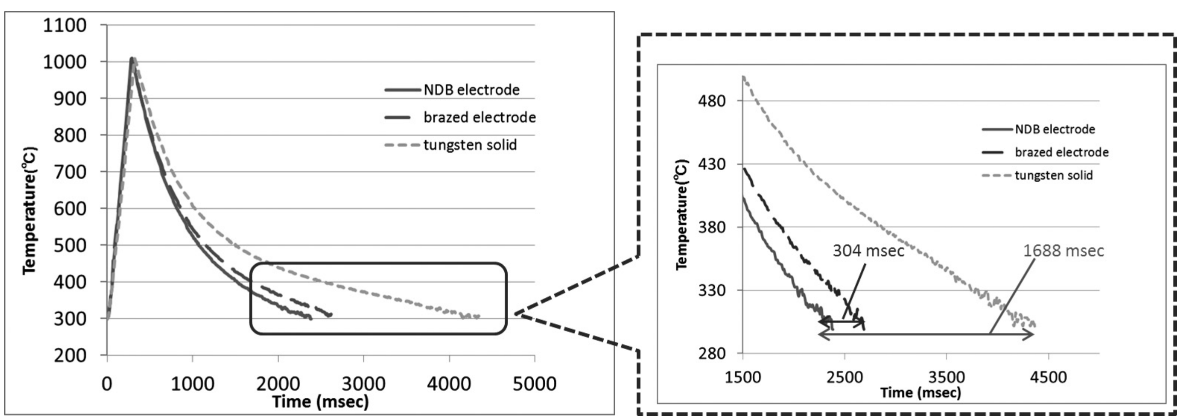

Fig. 11. Results of the competitive experiment

3.Conclusions

Welding conditions are varied depending on the quality of materials to be welded and the welding machine. Tungsten, molybdenum and their alloys have excellent high-temperature strength but the electric and thermal conductivities are poorer than those of Cr-Cu alloy and Al_2O_3 dispersion strengthened Cu alloy. Therefore, even under the same welding conditions as Cr-Cu alloy, the welding temperature excessively increases and may cause a deposition. It is important to find out electrode materials, electrode joining methods and welding conditions so that the heat balance between an electrode and a workpiece is appropriate.