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SILVER–COPPER–CADMIUM ELECTRICAL CONTACT ALLOY

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Abstract. An attempt has been made to obtain uniformly distributed microscopic particles of about 10% copper and 2% cadmium in the matrix of silver under controlled conditions of pouring and casting. A study of the alloy formed from Ag–Cu; Ag–Cu–Cd; Ag–Cu–Ni and Ag–Cu–Ni–Cd was made for their contact properties. Effect of addition of Cd and Ni has been studied.

Industrial electrical contacts are used to interrupt or establish electrical circuits over a wide range of conditions. Many classes of contacts exist; four important types may be mentioned: (a) very light current contacts used in telephones, radios or instruments for carrying currents measured in milliamperes; (b) medium-duty contacts for interruption of currents of up to say, 15 amp; (c) arc-break contacts interrupting into about 10 amp at up to 440 volts and (d) heavy-duty air or oil-break contacts dealing much larger units of power. Chaston has listed some of the qualities that are required in contacts of these types.[1]

In medium-duty-arc-break contacts which are of wide range applications, a considerable number of operations may be carried out within the life of the contacts. The desirable characteristics of an electrical contact material or alloy in various service conditions are extremely diverse and no single metal can be considered ideal for contact material. The materials for the manufacture of contacts are generally metals having high electrical conductivity. These metals of course, can be replaced by suitable alloys, especially the alloys of precious metals.

Many patents of varying compositions for electrical contacts, suitable to withstand severe loads, have been published in the literature.[2] Keeping in view their large uses in electrical industry, contacts have been made for general purpose applications, from Ag and Cu with small addition of Cd and Ni. Keeping in view their applications in relays, motor starters, safety switches, selector switches, arc-welding sets etc., work has been carried out for the preparation of these contacts.

Experimental

Ag–Cu contact alloys of different compositions were cast in dry-sand-moulds. Alloying elements used were electrolytically pure, while Ag and Cu were taken from technically pure ingots. The charge was melted in graphite crucible in natural-gas-fired furnace. Care was taken to get castings free from casting defects like porosity, blow-holes, etc. In the case of Cd addition the castings were carried out by melting down Ag and Cu in the required proportions and adding the required quantities of Cd just before pouring, homogenizing the melt, pouring it at as low a temperature as possible, to prevent the loss of Cd due to volatilization to avoid holding the melt for too long at a high temperature.

Sound castings free from inclusions of CuO, formed during the melting process and appearing as a potential source of weakness, were obtained by melting under a plentiful supply of charcoal then pouring under reducing conditions. From different compositions, required cast-to-test specimens were carefully prepared. Contact properties of representative castings were tested by subjecting the test pieces in the arc-welding set to a continuous load of 12–15 amp and intermittent supply of 80 amps.

Results and Discussion

The silver-base alloys containing other elements, e.g., Cu, Ni and Cd, are increasingly used for electrical contacts and other delicate parts operated at elevated temperatures. The preparations of these alloys is simple. The foundry technique required demands more care than that for other simple alloys.

This communication embodies the results of studies of sand-cast alloys made in these laboratories. Results of different physical properties found in the contact alloys of varying compositions are shown in Table 1. In the manufacture of electrical contacts, it is universally accepted that no single pure metal exists that can furnish all the properties required in a contact material. All contact materials are, therefore, made of two or more metals intimately mixed. Hardness is an important requirement in an electrical contact material. Table 1 shows that contact compositions (1 and 4) containing only Ag and Cu have low values of hardness (B.H.N. 54–56) as compared with 9, 10, 12 and 13 containing small percentages of Cd and Ni. The other important requirement is its freedom from segregation, which may be present in cast alloys due to the presence of two or more distinct separated (solid Ag and Cu or other added elements) phases. This must be removed completely or restricted to a minimum. The castings were carried out with maximum care and the segregation defect was tried to be minimised by giving whirling motion to the crucible. Microscopic examination of the specimens showed uniformity in distribution of elements in the alloys. From the table the appropriate compositions of the contact alloys can easily be worked out for the required service conditions. The separation of contacts in a circuit-breaker results in the formation

TABLE 1. PHYSCIAL CHARACTERISTICS OF MEDIUM-DUTY-ARC-BREAK CONTACTS.

No.	Contact alloy composition (%)				Approx. m.p. (C°)	Sp. gr.	Coeff. of expansion (20–100°C) ×10⁻⁴	Electrical conductivity (mohms) ×10⁴	Hardness, B.H.N. (1 mm ball 10 kg load)	Remarks
	Ag	Cu	Ni	Cd						
1	95·0	5·0	0	0	860	10·37	0·196	65·0	54·0	Colour white, pitting occurs, sticks after some use.
2	94·5	4·4	0	1·1	850	10·32	0·197	58·3	57·2	
3	94·7	3·2	1·1	1·0	880	10·30	0·196	59·1	59·8	White, pitting occurs, sticks after fairly long use.
4	90·1	9·9	0	0	885	10·35	0·194	63·1	56·2	As No. 1 above.
5	89·8	9·1	0	1·1	870	10·30	0·195	56·6	60·6	As No. 2 above.
6	90·0	8·2	0	1·8	850	10·24	0·198	52·1	61·5	White, sticks after long use.
7	90·3	7·5	1·2	1·0	865	10·28	0·195	61·7	62·5	White, less pitting, less sticking, good for contacts.
8	90·1	6·9	1·1	1·9	870	10·22	0·196	50·2	61·8	
9	84·9	11·0	2·0	2·1	895	10·20	0·192	48·6	68·2	Better than No. 8, fairly good corrosion resistant and hard.
10	85·0	10·2	1·1	3·7	860	10·15	0·198	43·2	66·0	
11	85·1	9·7	0	5·2	850	10·12	0·200	41·2	65·5	Good contact property but with less corrosion resistance.
12	85·0	10·0	1·0	4·0	855	10·10	0·197	45·7	64·5	Better than No. 11.
13	81·0	10·4	2·1	6·5	865	10·21	0·195	43·2	69·8	Good contact property, less corrosion, less pitting, less sticking, white.
14	84·9	13·0	0	2·1	862	10·19	0·195	47·1	64·2	As No. 6. above.
15	79·0	20·0	1	0	900	10·18	0·190	60·6	62·1	As No. 4 above.
16	70·0	30·0	0	0	930	10·10	0·187	58·8	65·2	As No. 15 above.

of an arc.[3] It is due to the low boiling point of Cd enabling small amount of vapour formed in the arc by thermal dissociation and providing a conducting path which 'quenches' the arc. Moreover, these alloys are somewhat harder and stronger than pure Ag. The hardness increased from 54 to 57.2 B.H.N. with the addition of 1% Cd an Ag–Cu alloy (composition 2). In general, alloying has a deteriorating influence upon the electrical conductivity of pure metals and is used in those cases where electrical conductivity is of secondary importance. The theory underlying the functional mechanism and lifetime of contacts has been outlined by various workers.[4,5] The electrical conductivity is reduced considerably by small additions of Cd. On the other hand, Ag and Cu meet the conductivity requirements but can only be used where their shortcomings of wear, pitting, or material transfer are not serious. Medium-duty-arc-break contacts which meet the requirement of hardness for their well-working, alongwith arc-quenching and minimum material transfer demand the addition of such elements as Cd and Ni. The increased hardness, resistance to corrosion, high density and less material-transfer are shown in Table 1. These properties are obtained with the addition of Ni. The ideal material for most contact purposes would be one that matches the hardness, density and low material-transfer of tungsten, in addition to the high electrical and thermal conductivity of Ag.

The adverse effect of rising temperature due to the production of an arc can be controlled to a certain extent by selecting a properly designed contact material of high thermal conductivity, necessitating the use of Ag and Cu. Addition of Ni improves the contact resistance if the Ni content is not above 15%.[6] At the same time the alloy is harder and shows less tendency to 'stick' than pure Ag. Although contact resistance is somewhat higher than pure Ag, it is still low. This low and constant contact resistance combined with the nonsticking properties at high pressures make Ag–Ni contacts very suitable for high voltage disconnect switches. The ternary alloy (Ag–Cu–Cd) is more resistant to wear than either pure Ag or binary Ag–Cu alloy. The complex material is used principally in small circuit breakers and relays.

In cases the contact alloy requires medium hardness (up to 64–70 B.H.N.) and corrosion resistance, an alloy of 80–90% Cu, 2–1% Cd and 1–1.5% Ni is suitable. However, great care must be taken during casting to avoid porosity and non-uniform distribution of alloying elements. An alloy having 75–80% Ag, 15–20% Cu, 5–10% Ni and 1.5% Cd give the most satisfactory results in medium-duty-arc-break circuits. Loss of Cd during alloying is greater than that of other elements, yet the results obtained by its use in small quantity fully compensate for the losses by giving an alloy which has better corrosion-resistance, hardness and arc-quenching properties. However, the suitability of such contacts is determined by practical wear tests. The performance is, to some extent, related to the manufacturing conditions, but the quality of the metal used is also of influence. The material merits great interest, especially if it can be produced free of pores.

References

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