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COMPARISON OF SELECTED CONTACT MATERIALS USED IN LOW-VOLTAGE RELAYS

Low-voltage relays are widely used in many areas of electrical applications. There are used for such applications as protection, signalization or control of electrical installations. There all are similar in many ways were it comes to construction and operating principles. However for different applications different contact materials must be used. There are many materials used for contacts in electrical appliances. In this paper contact materials used especially in low-voltage electromechanical relays are described. Their electrical and mechanical properties are characterised.

KEYWORDS: contact materials, relays, rivets

1. LOW-VOLTAGE ELECTROMECHANICAL RELAYS

Electric relay is a device designed to produce sudden predetermined changes in one or more electric output circuits, when certain conditions are fulfilled in the electric input circuits controlling the device. An electromechanical relay is a subtype in which the intended response results mainly from the movement of mechanical elements [1]. A classical electromechanical relay set-up with distinguished key parts is shown on Figure 1.

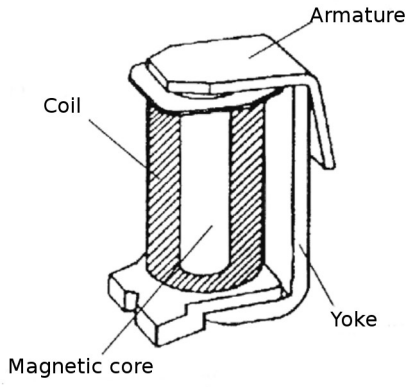

Fig. 1. Classical electromechanical relay set-up [2]

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Key part of a electromechanical relay are its electrical contact rivets. They role is to ensure proper electrical connection with little loss of energy and minimal contact resistance. They have to withstand considerable amount of contact operations. During these operations they can be exposed to potentially dangerous conditions, such as making and breaking of electrical arc [3] or closing a faulty circuit [4].

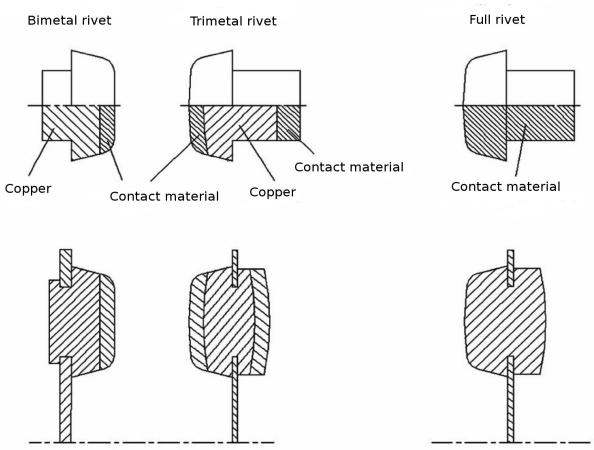

Fig. 2. Contact rivets used in electromechanical relays [2]

2. MATERIALS USED FOR ELECTRICAL CONTACTS

There are many materials than can be used for contacts. These materials are:

- pure materials: copper (*Cu*), silver (*Ag*), gold (*Au*), tungsten (*W*), platinum (*Pt*), palladium (*Pd*) and molybdenum (*Mo*),
- alloys: *AgCdO*, *AgNi*, $AgSnO_2$, *AgPd*, *AgW*, *AuPt*, *AuAg*, *AuNi*, *PtIr*, *PtNi*, *PdCr*, *PdNi*, *CuW*, *AgNiW*, *CuCr*, *Ag*-graphite.

Basic elements used for contacts are copper and silver. Coper is a cheap metal, layer of oxide and sulphide are easily created, requires use of high contact force. It is used for example in high voltage connectors and oil circuit breakers. Silver is precious metal, sensitive to sulfur and sulfides, quite prone to material transfer. Pure silver contacts can be welded easily. Silver has low melting point; fairly easy for tooling. Silver-plated contacts are used for high frequency circuits. Not suitable for contacts subject to wear. It is not suitable for large currents [6].

During make and brake operations certain phenomena may occur, including contact heating and material transfer. Heating process is linked with rising contact resistance at brake which later changes into electrical arc. Joule's heat generated during that process may lead to high temperature rise, even over

melting point of contact material. Material transfer may also negatively influence contact reliability, however it is less likely to occur in AC over DC circuits [6]. Another process that may appear is contact welding [8]. While the contacts are closed high current values are required in order to weld contacts. This phenomena may show itself with lower current values at make while contact bounces occur [7].

Because pure copper or silver contacts aren't always the best choice more often alloys are used. In order to improve properties of contact materials selected elements can be added to silver (Table 1) [6]. Addition for example of chromium *Cr* into copper contact is used in medium voltage vacuum circuit breakers, which influences their welding resistance [5].

Table 1. Effect of additions of different elements on different properties of silver [6]

Property	Additions
Arc resistance	Pb, Mg, Li, Zn, La, Sb
Abrasion resistance	Cu, Ni, Pd, Li
Lubrication	In, Zn, Sn, C
Weld resistance	In, Zn, Mn, metal oxides

Electrical contact materials can be characterised by several parameters, among which are:

- chemical elements used for rivets,
- density [g/cm^3],
- melting temperature [ºC],
- boiling temperature [ºC],
- hardness [HV/HB],
- thermal conductivity [W/(K · m)],
- electrical conductivity [m/(Ωmm^2)],
- elastic module [MPa],
- temperature coefficient of resistivity α [1/ºC].

Depending on the application of the electromechanical relay there is always a question about the best contact material to use for its contact rivets. While switching pure ohmic circuits, like electrical heating or incandescent lamps, there is little electrical hazards that may appear and so the contact material that can be used doesn't need high weld and arc resistance. Electrical circuit with low power factor, either high inductance or capacity value, cause a lot worse conditions during switching operations. these conditions include electrical arc that occurs during breaking of inductive load and current spikes while making of capacity circuits. For these types of circuits it is imperative that contact rivets are

made from the right material, that has high arc and/or weld resistance. Characteristics of selected contact materials alloys used for low-current contacts are presented in Table 2.

Table 2. Characteristics of selected alloys for low-current contacts: ρ – material resistivity, α – heat coefficient, λ – thermal conductivity, H_B – Brinell hardness, T_m – melting point temperature [5]

Alloy Composition	Density	ρ	α	λ	H_B	T_m
[%]	[kg/m^3]	[10^{-8} Ωm]	[°C^{-1}]	[W/(m°C)]	[-]	[°C]
Ag–Cu 97/3	10,5	1,8	0,0035	390	40	900
Ag–Cu 50/50	9,7	2,1	0,003	340	70	730
Ag–Au 90/10	11,4	3,6	0,0016	196	23	—
Ag–Cd 80/20	10,1	5,7	0,002	—	60	875
Ag–Pd 40/60	11,4	42	0,00025	20	—	1,33
Ag–Pt 95/5	10,88	4,65	0,0023	30	99	—
Ag–Ni 90/10	10,1	1,8	0,0035	—	90	961
Au–Pt 93/7	19,6	10,2	—	70	40	1,08
Pd–Cu 60/40	10,6	35	0,0032	38	80	—
Pt–Ni 95/5	23	20	0,00188	—	135	—
Pt–Ro 90/10	20	19,2	0,0018	—	90	—
Pt–lr 95/5	21,5	10	0,002	42	130	1,08
Cu–Cd 99/1	8,9	2,6	—	—	345	—

3. SELECTED CONTACT MATERIALS USED IN LOW VOLTAGE ELECTROMECHANICAL RELAYS

Low voltage electromechanical relays are widely used in many electrical applications. Some of theme are used in control circuits, programmable logic controllers or as the execution elements in building automation systems. They are used mostly for switching of purely resistivity circuits (e.g. electrical heating, classical light bulbs), low power and relativity high inductance circuits that include coils or circuits with electrical motors (e.g. blinds or verticals at homes and office buildings).

There are few commonly used contact materials for relay rivets. These materials are: AgNi, AgCdO and $AgSnO_2$. Their properties and usage is as follows [2]:

1. Silver-nickel alloy (90% Ag-10% Ni) - is most appropriate alloy for switching DC loads, in order to avoid material transfer, it is also wildly used for switching low current non inductive AC loads.
2. The compound of silver-cadmium oxide (90% Ag-10% CdO) - has a wide range of applications in power load due to the high welding resistance and arc extinguishing effect. Its field of application is in the range of 12 to 380 VAC and 100 mA to 30 A. It is especially used for resistive and inductive loads, such as motors load, heating resistors, lamps and other.
3. Silver material + tin oxide (carbon) $AgSnO_2$ - has similar properties to the silver-cadmium oxide, but has a higher thermal stability of the resistance and lower material transferring from one contact to another, which translates into higher stability in DC applications. $AgSnO_2$ contacts also feature a uniform wear and are recommended for applications with loads producing current surges and inductive loads. Some miniature relays offered contain small admixture of indium oxide (In_2O_3). In addition to the good results obtained switching lamps, this material also has excellent behavior with resistive loads and switching currents up to 16 A.

   Their selected material properties are presented in table 3.

Table 3. Selected properties of contact materials used in low-voltage relays [9]

Material	Density	Melting temperature	Hardness	Thermal conductivity at 20 ºC	Electrical conductivity
	[g/cm^3]	[ºC]	[HB]	[W/(K · m)]	[m/(Ωmm^2)]
AgNi10	10,3	961	50	350	54
AgCdO10	10,2	961	70	313	48
$AgSnO_2$10	9,9	961	70	307	49

Looking at material properties in table 3 there are little differences between their density and hardness and they have the same melting point temperature. Thermal conductivity has the highest value for AgNi together with the lowest value of electrical conductivity and there is only a small difference between the remaining two materials.

4. SUMMARY

There are various materials that can be used for rivets in low-voltage electromechanical relays. In order to choose the right one many factors, such as welding or arc resistance, have to be taken into account. From the three contact materials presented, frequently used in many applications are $AgSnO_2$ and AgCdO with better properties than AgNi, however the later one is cheaper.

REFERENCES

[1] International Electrotechnical Vocabulary - part 444: Elementary relays, IEC
[2] Technical catalogue - Przekaźniki, Relpol S.A., Mar. 2013. (in Polish).
[3] L. Morin, N.B. Jeman, D.Jeannot, Make arc erosion and welding in the automotive area, IEEE Transactions on Components and Packaging Technologies, vol.23, no.2, pp.240 - 246, Jun 2000.
[4] A. Książkiewicz, J. Janiszewski, R. Batura: Influence of short-circuit AC currents on electrical contact resistance of low voltage relays, Poznan University of Technology Academic Journals. Electrical Engineering, 70/2012, pp. 99 – 103, Poznań.
[5] J. Janiszewski, K. Józefowicz, An influence or electrical switching arc on the surfaces of vacuum switches contacts, Przeglad Elektrotechniczny, 2008, 84 (10), pp. 155-158.
[6] M. O. Thurston, Electrical Contacts. Fundamentals, Applications and Technology, Taylor & Francis Group*, LLC,* 2007.
[7] L. Morin, N.B. Jeman, D. Jeannot, Make arc erosion and welding in the automotive area, IEEE Transactions on Components and Packaging Technologies, vol.23, no.2, pp.240,246, Jun 2000.
[8] A.R. Neuhaus, W.F. Rieder, M. Hammerschmidt, Influence of electrical and mechanical parameters on contact welding in low power switches, IEEE Transactions on Components and Packaging Technologies, vol.27, no.1, pp.4,11, March 2004.
[9] Elesta Elektrotechnik AG, Informacja techniczna, 2002 (in polish).