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Performance of LV vacuum contactors with condensed composite multicomponent contacts

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Paper presents and discusses the investigated results of LV vacuum contactors with contacts made of selected condensed composite materials under both rated and short circuit conditions of operation.

Keyword: *LV-vacuum contactors, condensed composite, operation under rate and short circuit.*

Introduction

For vacuum chambers used in low voltage contactors the fine powder sinters based on copper-tungsten-chromium compositions mostly are recommended as a contact material. The fine powder metallurgy is unfortunately a sophisticated and money consuming technology therefore, seeking another alternative manufacturing of the contact materials is both technically and economically justified. One of such a solution can be application of an electron beam high-rate evaporation method with following condensation in vacuum. It has been successfully used, among others, for fabrication of various composite materials of considerable thickness up to about 12 mm in Scientific and Production Enterprise ELTECHMASH in Vinnitsa, (Ukraine) [1].

In the paper performance of vacuum contactors (1000 V, 400 A, 50 Hz) when use a selected condensed multicomponent material (Cu—W—Fe) in contacts is presented and discussed. The investigations were carried out for both rated as well as short circuit conditions of operation. After the switching test was completed, the contact surface inspection together with investigations of the material morphology and microanalysis were made using optical and electronic microscopy and spectroscopy (SEM, XRF, EPMA etc). On the basis of the investigated results the failure analysis of contacts for the failed vacuum chambers was executed and conclusions on applicability of such the contact composition material for vacuum contactors are formulated.

Contact sample selection

The new multicomponent composite material was intended for use in vacuum chambers of MVK440 type (produced in Institute of Tele-and Radiotechnics in Warszawa, Poland) for low voltage contactors applicable in coal mining. Main goal was to decrease the chambers manufacturing cost since,

T a b l e 1. Material composition (percentage by weight)

Number of contact	Cu	W	Fe	Cr	Co	Si	Al
11	75,3	23,4	0,59	0,034	0,016	0,33	0,13
14	61,9	36,7	0,62	0,042	0,024	0,3	0,15
18	44,4	54,2	0,6	0,049	—	0,47	—

Fig. 1. Partial separation of the contact sample from the contact base under manufacturing.

the contacts made at present of a fine powder technology contribute in about 30% of the final product (vacuum chamber) prize. At the beginning 20 samples were prepared for testing, each of them of 0,6 mm in thickness however, of a different copper-tungsten composition with addition of another elements, mostly iron. For preliminary investigations three of them (as indicated in tabl. 1) were involved in manufacturing process. Unfortunately, it was appeared that after soldering to the contact base ,they were failed under following processing at high temperature (at 800 ^{o}C).It was revealed by partial separation from the base due to involved thermal stress (fig. 1).Therefore, for the next step the contact material thickness was increased to 5 mm. They passed the manufacturing process successfully and were assembled as the contact sets into three vacuum chambers for further certification test of the low voltage contactors SP400 type.

Switching capacity test

The switching test was performed under both rated as well as short circuit conditions of operation. Circuit diagram and view of the test stand is shown in fig. 2. Electrical parameters of the test are listed in tabl. 2.

Under the test not only the voltage across the contact gap and the load current value were measured. The frequency, power factor, source voltage-for all phases of the 3-phase system-as well as driving current and displacement of the contact moving system were controlled for better evaluation of the switch performance. It was found that all the vacuum chambers passed the rated switching test. They were able to make (“C”) and to break (“O”) the rated current of 400 A rms successfully for one hour continuous operation independently on the contact sample applied. Performance for the selected chamber when swiches (“CO”) rated load in A-phase can be compared for example in fig. 3. The vacuum chambers passed also the short circuit test at 4,5 kA however, only at current breaking (“O”) what is indicated in fig. 4. (The load current was delivered to the contact by means of an auxiliary switch-see fig. 2).

On the contrary under making and following breaking of the short circuit current of 4,5 kA rms (“CO”) all the vacuum chambers failed in operation due to contact welding. The tendency for the contact sticking with the increased load current can be seen when compare the releasing time of the contact moving

T a b l e 2. Electrical parameters of the switching capacity test

Type of test	Voltage, V	Current, kA	Frequency, Hz	Power factor	Number of cycles per hour
Rated" CO" (close-open)	1000	0,4	50	0,35	120
Short-circuit "O" (open)	1000	4,5	50	0,35	—
Short-circuit "CO" (close-open)	1000	4,5	50	0,35	—

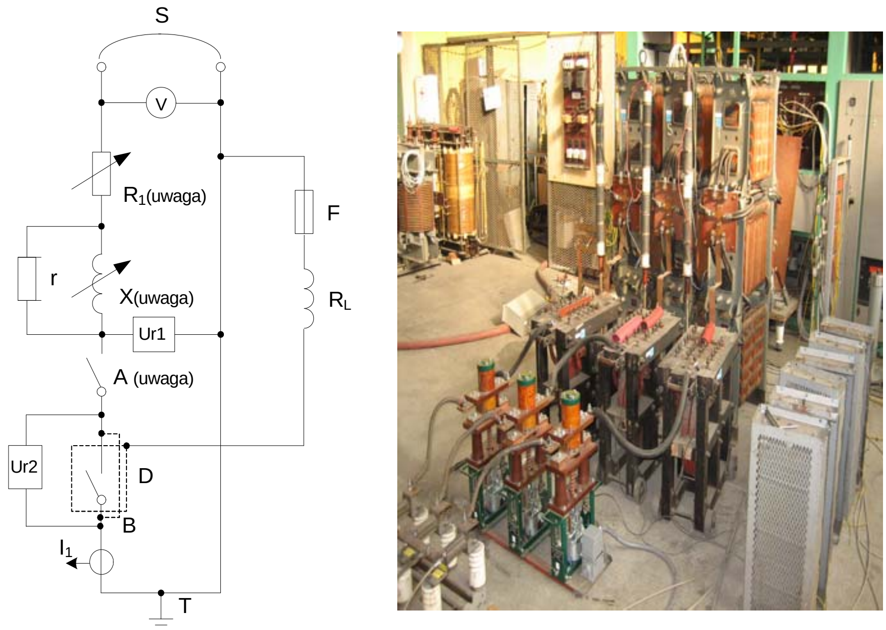


Fig. 2. Circuit diagram and view of the switching test stand: S — supply; U_{r1},U_{r2} — voltage meters; A — auxiliary switch; R_1, X — resistive and inductive controllers; F — high power fuse; R_L — ground current limiter; D — contactor under test; I_1 — current meter; r — shunt; B — link for graduation.

system (x) with this of effective current breaking — in transient-visible in fig. 3 and fig. 4 respectively.

Contact failure analysis

After the switching tests were completed the chambers were dismantled to make the contact surface inspection together with the structure and element analysis both at the surface and inside the contact volume along cross section just beneath contacting areas. View of the failed contacts after welding can be compare from fig. 5. Surface analysis has indicated an unprofitable, nonuniform distribution of particular elements, what is seen for example in fig. 6.

One can find areas of a high concentration of iron what is not considered as a good for the contact material due to much lower melting point with compare to tungsten or chromium. Also inside the volume both concentration as well as size of metallic particles is different. In a case of the contacts being torn out

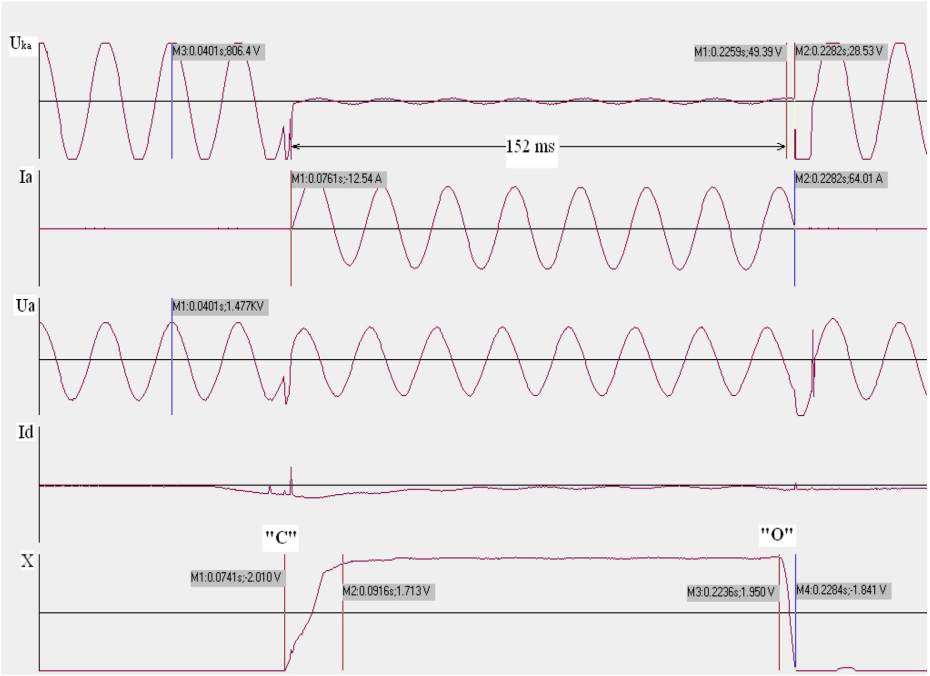


Fig. 3. Performance of the selected vacuum chamber under rated load (1000 V. 400 A, 50 Hz “CO”) switching test: U_{ka} — voltage across the contact; I_a — load current; U_a — voltage of the source in A-phase; I_d — contactor driving current; X — displacement of the contact moving system.

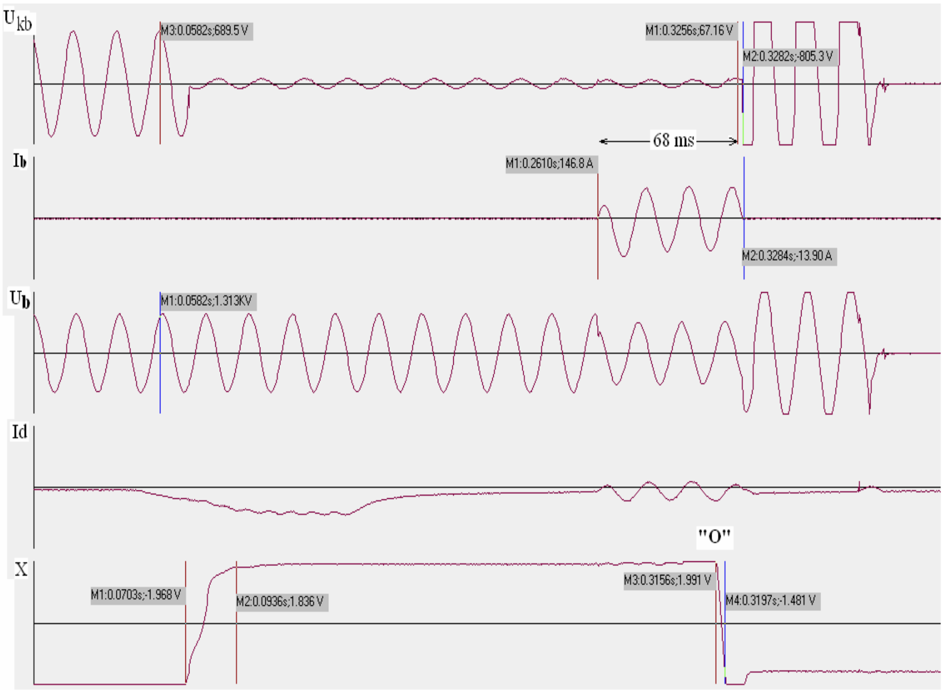


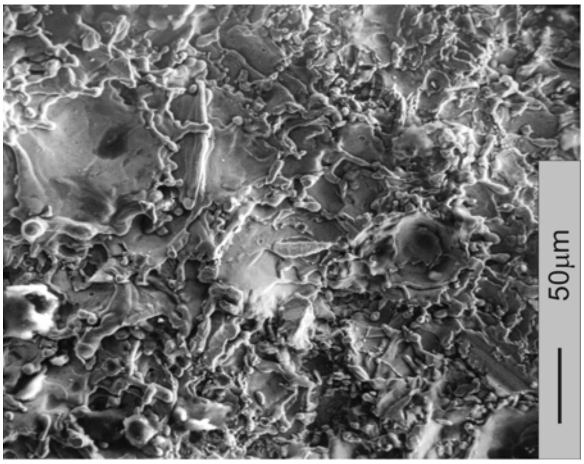
Fig. 4. Performance of the selected vacuum chamber under short-circuit switching test (1000 V; 4,5 kA,”O”): U_{kb} — voltage across the contact; I_b — load current; U_b — voltage of the source in B-phase; I_d — contactor driving current; X — displacement of the contact moving system.

Fig. 5. View of the failed contact surface after welding.

from the contact base under processing (see fig. 1.) the size of tungsten particles was found the highes at the surface and inside the middle of the contact volume. There is seen also a rapid transition from big to small size of W particles. Both various microstructure and variety of chemical composition of the contact samples made of investigated material indicates some instabilities of technology under processing. It results in high thermal stress leading to partial separation of the contact material from the contact base (in a case of the thin samples) or/and to excessive contacts areas being melted (in a case of concentrated iron) what gives fast contact welding, particularly under short circuit switching conditions.

Conclusions

Application of a multicomponent, condensed, composite material on the basis of copper with addition of tungsten and iron can replace successfully fine powder sinters in vacuum chambers of low voltage contactors only for switching under rated load (1000 V, 400 A, PF.0,35). For the increased load, particularly for short circuit conditions (1000 V, 4,5 kA) it failes in operation due to easy contact welding. It is related to nonuniform concentration of the metallic elements applied, diversity of particle size and low melting point of iron used as a dopant. To overcome this problem it is necessary to control the



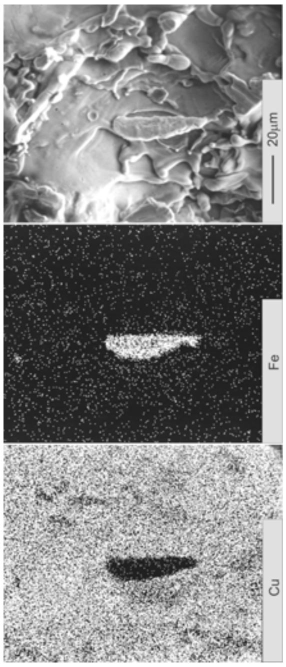


Fig. 6. Analysis of a selected contact area by means of EPMA.

technology to produce uniform concentration of all metallic components inside the contact volume. It seems also that iron should be replaced by elements of a higher melting point like W and/or Cr.

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Випробування низьковольтних вакуумних контактів з компонентами із мульткомпонентних контактів

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Представлено та обговорюються результати дослідження низьковольтних вакуумних контакторів із контактами, виготовленими з вибраних конденсованих композитів за умов комутаційних випробувань при експлуатації нормальних та коротких ланцюгів.

Ключові слова: *нізьковольтні вакуумні контактори, контакти, конденсовані композити, робота в умовах коротких і нормальних ланцюгів.*

Испытания низковольтных вакуумных контакторов с композитами из мультикомпонентных контактов

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Представлены и обсуждаются результаты исследования низковольтных вакуумных контакторов с контактами, изготовленными из выбранных конденсированных композитов при коммутационных испытаниях в условиях работы нормальных и коротких цепей.

Ключевые слова: *низковольтные вакуумные контакторы, контакты, конденсированные композиты, работа в условиях коротких и нормальных цепей.*