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SILVER-NANO CARBON COMPOSITES FOR CONTACTS OF LOW VOLTAGE SWITCHGEAR

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Abstract

In this paper, study on development of silver composite with carbon nano tube (CNT) reinforcement is discussed as a potential contact material for low voltage switchgear applications. The synthesis of silver (Ag) - nano carbon composite carried out with optimized powder metallurgy process to achieve homogeneous mixing of fillers in matrix. Contact tips of varying sizes prepared and characterized for hardness, electrical conductivity and microstructure of material. Further, demonstration of developed contact material was carried out using 32 A contactor with conventional contacts and Ag-CNT composite contact. Performance evaluation of contactor carried out by temperature rise test and electrical endurance test for 6000 operations as per IEC-60947-4-1 specification requirement.

Developed Ag-CNT composite contact tips showed high electrical conductivity and hardness compared to conventional contact materials. It exhibits low temperature rise compared to conventional contactor. Developed contact successfully performed 6000 operations in electrical endurance test and showed lower contact resistance and weight loss compared to conventional contact tip.

1. Introduction

Contact materials are integral part of switchgear products like MCB, MCCB, limit switches, contactors switches etc. Improvement in performance of contact materials is essential for the integrity of switchgear operations. Damage mechanisms such as wear, overheating, arc erosion, oxidation and sulfidation limits the operational life of contacts. Progress in materials against these damages led to development of contact materials based on metals, alloys and composites with varying operational capacity. Among the all type of contacts, silver based contact is very much useful for low voltage switchgear application. Silver has best electrical conductivity but due to its poor mechanical property, it is not very efficient as electrical contact material. Therefore, silver based contacts such as Ag-Ni alloy, Ag-CdO and Ag-SnO2 composites has been developed. Ag-Ni alloys widely used in vacuum switches, relays and breakers due to excellent thermal and electrical conductivity, arc erosion resistance and processing capability. However, its use limited to lower current ratings below 20 A due to poor anti-welding capability at higher currents [1-2]. In order to improve the anti-welding capability, hardness and arc-erosion resistance of silver contact, an effective solution is addition of metallic oxides such as CdO, SnO2, ZnO etc. [3-6]. Ag-SnO2 contacts performs better than Ag-Ni alloys at higher current but limits the performance due to decrease in electrical conductivity from metal oxides. Nano carbon material considered as potential filler material for electrical applications due to excellent physical, mechanical, thermal properties along with high electrical conductivity [7]. It can improve anti-welding capability (carbon has low affinity with Ag), arc-erosion resistance (better thermal properties) and reduce contact resistance (selective burning/ oxidation of carbon instead of Ag/Ni).

In view of above, the present work focused on development of silver based contacts using carbon nano tube and its performance evaluation for low voltage switchgear product applications.

2. Methodology

Synthesis of silver-nano carbon composite contact carried out using powder metallurgy technique. Raw materials used for composites includes pure silver (99.99% purity and particle size in range of 10-

15 micron) and functionalized carbon nano tubes (97% purity, 11 to 20 nm diameter and average length of 11 to 30 micron). Figure 1 shows the as raw materials used for composite development.

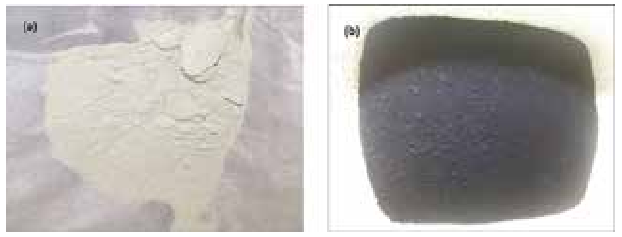


Fig-1: a) Silver powder (b) Functionalized CNT

Powder metallurgy process followed for fabrication of composite contact is shown in Figure 2. It involves the homogeneous mixing of pure silver and CNT powders, followed by compaction of mixture at room temperature by hydraulic press using pin and die to get cylindrical shape contacts. Then green compacts sintered at 900 oC for 2 hours in nitrogen atmosphere. Finally, repressing of sintered contacts was carried out to increase the density of composite contact.

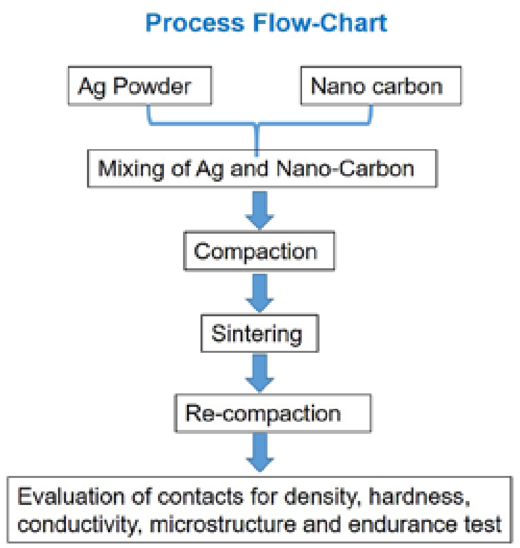


Fig-2: Process flow chart of Ag-CNT contact fabrication

The characterization of developed Ag-CNT composite contacts is done for microstructure, density, hardness, electrical conductivity and performance evaluation.

The performance evaluation of developed contact carried out using 32 A contactor (Figure 3) by temperature rise test and electrical endurance test as per IEC-60947-4-1 specification.

The parameters used for temperature rise test were rated operational current of 32 A, Cu conductor size 6 mm2 and ambient temperature maintained between 10-40 oC as per specification requirements.

Electrical endurance performance evaluation carried out by subjecting contactors the AC-3 rating as per IEC 60947-4-1. Total 6000 operations were carried-out on each contactor. Details of the endurance test parameters are given in Table-1. The wear behavior of the contact tips was evaluated through mass loss measurements and observation of physical appearance of contact surfaces.

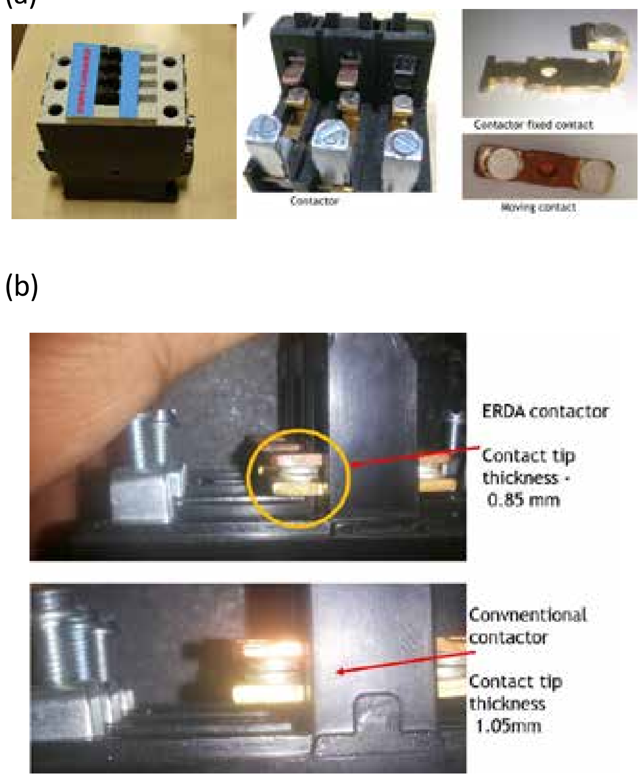


Fig-3: (a) Contactor (32 A) outer and internal view (b) contactor with conventional and ERDA developed Ag-CNT contacts for performance evaluation

Test Parameters	Requirements
Applied voltage, V	252
Test current, A	64
Power Factor, cos F	0.45
On time, ms	50
Off time, ms	10

Table-1: Electrical Endurance test parameters

3. Results And Discussions

Ag-CNT contact tip were developed in 6 mm and 8 mm diameter as shown in Figure 5. Dispersion of carbon nano tubes in composite was observed using scanning electron microscope (SEM). It shows the uniform distribution of CNT in silver matrix (Figure 4).

Fig-4: Developed contacts (a) Contact tip with 6 mm diameter (b) contactor with 8 mm diameter

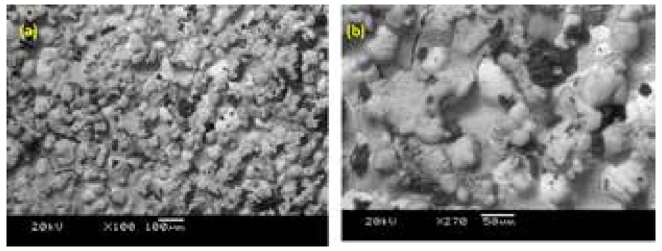


Fig-5: SEM microstructure of sintered Ag-CNT contact

Properties and performance evaluation results of Ag-CNT contact compared with conventional contact materials are represented in Figure 6.

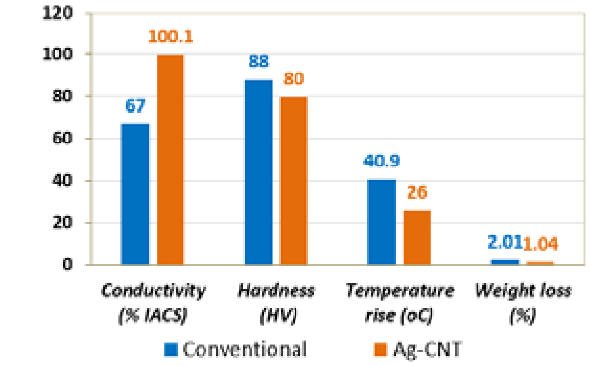


Fig-6: Properties and performance of Ag-CNT contact in comparison to conventional contact

The addition of CNT in silver matrix resulted in improvement in electrical conductivity above 100% IACS along with required hardness (80 HV) compared to conventional Ag-SnO_2 contact material.

Temperature rise results of contactor with newly developed Ag-CNT contact and conventional contact are shown in Figure 6. Both showed temperature rise within the limit of 65 oC specification requirement. But, the maximum temperature rise observed for contactor with Ag-CNT contact (26 oC) is 10 oC lower than the conventional contactor (40.9 oC). It indicates the improvement in thermal behavior of silver contact with addition of nano carbon.

Endurance test on contactors were subjected to the AC-3 rating as per IEC 60947-4-1. The contactor with developed Ag-CNT contact tip conforms to the specification for endurance test. It has withstood 6000 operations as per standard. The oscillograms of voltage & current characteristics taken after endurance test is observed similar to the one taken before endurance, and do not show any distortion (Figure 7) .

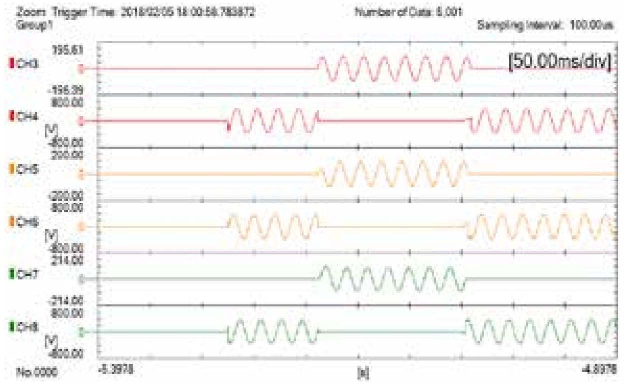
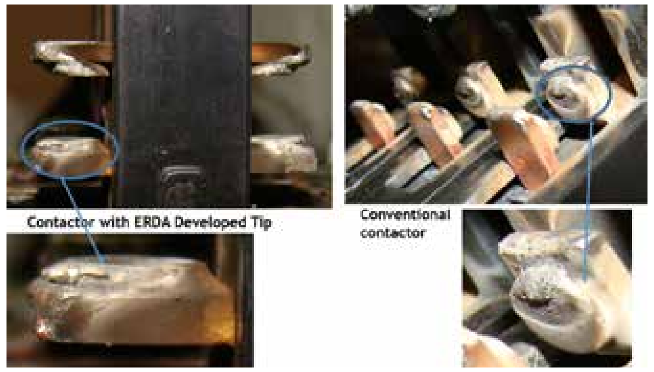


Fig-7: Voltage & current plot after endurance test for Ag-CNT contact.

Contactor examination during and after test did not show permanent arcing, welding and flashover puncture. Figure 8 shows the condition of contacts after the electrical endurance test.

Weight loss measured after test shows the lower weight loss of Ag-CNT contacts compared to conventional contact as shown in Figure 6. It indicates the better arc erosion resistance of Ag-CNT than the conventional contact material.



Contactor with ERDA Developed Tip   Conventional contactor

Fig-8: Condition of contact tips after electrical endurance test

4. Conclusions

In this paper, development of silver contacts using nano carbon filler is discussed. The fabrication of Ag-CNT contact tips suitable for contactor application carried out using optimized powder metallurgy process. The addition of carbon nano tube in silver matrix observed to increase the conductivity above 100% IACS with required hardness compared to conventional contact material. Performance of developed Ag-CNT observed better than the conventional contact. The temperature rise of contactor with Ag-CNT contact (26 oC) is observed 10 oC lower than the conventional contactor (40 oC). Ag-CNT contact tips conforms the electrical endurance test requirement as per specification and showed lower weight loss compared to conventional contact.

This study indicates the processing feasibility of Ag-CNT contact tips with reduced thickness, better thermal and electrical performance for low voltage switchgear application compared to conventional contact material.

5. Acknowledgement

Authors wish to thank the Management of Electrical Research and Development Association (ERDA), Vadodara for giving permission to present this paper.

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SMART TRANSIENTS-FREE SWITCHING ON POW THROUGH "CSD" IN BACK-TO-BACK SWITCHING APPLICATION OF EHV SHUNT CAPACITOR BANKS AND A CASE STUDY

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Abstract

In a large EHV grid-system, the EHV circuit breakers are the most important equipment. Catastrophic failure of any EHV circuit breaker may cause severe disturbance in the grid system leading to even grid-collapse. Failure of circuit breaker may take place due to the transient conditions developed while switching-in or switching-off conditions of the circuit breakers used in following EHV equipment and EHV Transmission lines:

- Shunt Capacitor Banks,
- Shunt Reactors,
- No-Load Transformers,
- No-Load EHV Transmission lines
- Shunt and Series compensated

Transmission lines, etc.

Most severe transient condition shall be experienced by a circuit breaker in Back-to-Back switching operation of EHV Shunt Capacitor banks application as compared to other aforementioned equipment & Transmission lines, resulting into catastrophic failure of that particular circuit breaker.

To obviate such conditions and to safeguard the circuit breakers against such failures due to Switching Transients, use of "Controlled Switching Device", an intelligent and smart IED is the only answer. The CSD can be set to select the PoW (Point on Wave) to close or open the Circuit Breaker. In case of Back-to-Back Switching-in of EHV Shunt Capacitor Banks, it is set at voltage"0" position of voltage wave.

In this article, a basic duty of a "Controlled Switching Device" in Back-to-Back switching operation of an EHV Shunt Capacitor banks at PoW (Point on Wave) has been explained and a case study too has been highlighted by the author.

1. Introduction

There is no single inventor or year for the "Controlled Switching device", as it's a concept that evolved over time, with key developments including the commercial release of the first thyristors in 1956 and the development of MOSFETs in the 1970s. Controlled switching, or point-on-wave switching, allows a device to activate at a specific point within the power frequency cycle. In case of EHV capacitor banks switching point-on-wave is set at the position "0" of Power frequency cycle.

To obviate most severe transient condition experienced by a circuit breaker in Back-to-Back switching operation of EHV Shunt Capacitor banks CSD is essential. Thus, threat of catastrophic failure of the circuit breaker is everted.

2. Definition Of Back-To-Back Switching-In Of Ehv Shunt Capacitor Banks;

While one Shunt capacitor bank is already on live bus and another shunt capacitor bank is to be switched-on to the same live bus, this is known as Back-to-Back switching of Shunt capacitor banks.

3. Phenomenon Of In-Rush Transients In Back-To-Back Switching

The fig.1 shows the basic schematic single line diagram of a Power system fee ding EHV bus, on which Capacitor banks C1 & C2, each having individual circuit breakers, CB1 & CB 2 are connected through bus-section circuit breaker BSCB.