Research Journal of Applied Sciences, Engineering Technology 5(9): 2858-2862, 2013
ISSN: 2040-7459; e-ISSN: 2040-7467

Submitted: August 17, 2012 Accepted: October 03, 2012 Published: March 20, 2013

Experimental Research on Properties of Materials of Grounding Resistor

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Abstract: In this study, we have a experimental research on properties of materials of grounding resistor. Experiment test of the grounding resistor in the state of analog ground fault have been done, the performance parameters on the mechanics, thermal and electrical of alloy materials with different kinds and different specification have been got. The performance and its character of alloy materials have been grasped in the state of analog ground fault by analysis and processing. The research results have an important significance on the material selection and structure design of low resistance grounding resistor.

Keywords: Analog ground, experiment test, grounding resistor, parameter analysis

INTRODUCTION

In high-voltage distribution system, the choice of the grounding way of neutral point is an all-around technical problem. "With the increase of load, the overhead line is substituted by cable line gradually, the grounding way by small resistance is more and more adopted" (Zhao *et al*., 2007; Ming-Yan, 2004). But because its short circuit current is high "(100 A-2000 A)" (National Technical Supervision Bureau, 2001), it will has an obvious impact on the performance of alloy material because of high temperature. In order to assure the low resistance grounding resistor can run in the state of safety, stability and economic, the test experiments of alloy materials in the simulated state of earth fault were done, the experimental results were analyzed. The research result will has important significance for the choice of material and structural design.

CURRENT DENSITY AND MAXIMUM TEMPERATURE RISE OF ALLOY MATERIALS

Test data: The alloy materials with different kinds and different specifications in the state of simulation ground fault were tested and the current duration is 10 sec. The highest temperature rise and maximum current density were obtained. The results of through-flow test of alloy materials with different kinds and size were shown as Table 1.

Data processing and basic conclusions: The so-called maximum temperature rise is the highest temperature variation value of the resistance chip without permanent deformation. At this time, the current value of unit cross-sectional area is the maximum current density of this kind of specification material that can withstand. Form Table 1, we can see that all kinds resistance chip composed of different materials withstand the maximum temperature rise and the biggest current density are related to the structure, specification and materials properties. Alloy material, such as Cr20Al3, Cr15Al5, "the relations of biggest current density and cross-sectional area are shown as Fig. 1 and 2. From the figures, we can see that the biggest current density of material is increasing with its cross-sectional area increases" (Dae-Jung *et al*., 2009; Da-Jiang *et al*., 2011).

The highest temperature variation value of different size with the same alloy is related to the current density and current continue time. According to the heat balance theory, the relationship of alloy material between temperature rise and its current density is shown as follows (Dae-Jung *et al*., 2009) (calculated in the adiabatic condition, without consideration of decalescence of ceramics and other non-metallic insulation materials):
by

$$I^2 \cdot R \cdot t = c \cdot m \cdot \Delta T \quad (1)$$

Obtain:

$$\Delta T = \frac{\left(\frac{I}{S}\right)^2 \frac{\rho_0}{\gamma} \frac{t}{c}}{1 - \left(\frac{I}{S}\right)^2 \cdot \frac{\rho_0}{\gamma} \cdot \frac{t}{c} \cdot \alpha} \quad (2)$$

In the formulas，ΔT represents temperature rise of the material, I, R, t represents the current, resistance and current duration separately , c, m, S represents specific heat, mass and cross sectional area; ρ_0, α, γ express

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Table1: The test datum of the maximum current density and the top temperature rise of alloy materials

Material name	Specification	Effective cross-sectional area (Coefficient 0.98)	The Maximum current density (A/mm2)	The top temperature rise (°C)
Cr15Ni60	1.5×12.9×616	18.963	17.61	488.7
Cr20Ni80	2.5×20×290	49.0	22.12	906.7
Cr19Al2	1.5×12.6×616	18.522	19.17	395.9
Cr19Al3	1.5×12.9×616	18.963	18.68	363.4
Cr19Al3	1.5×13.9×170	20.433	19.34	755.2
Cr20Al3	1.5×12.9×616	18.963	16.54	525.1
Cr20Al3	1.5×14.5×170	21.315	17.25	488.1
Cr20Al3	2×12.9×616	25.284	19.38	605
Cr20Al3	2×14.2×170	27.832	21.05	798.8
Cr15Al5	0.25×29.5×220	7.38	14.78	362
Cr15Al5	0.5×29.5×220	14.75	16.98	556.4
Cr15Al5	1.0×29.5×220	29.5	18.22	648.2
Cr15Al5	1.2×29.5×220	35.4	20.40	802.2
Cr15Al5	1.4×29.4×220	41.2	23.27	928.6

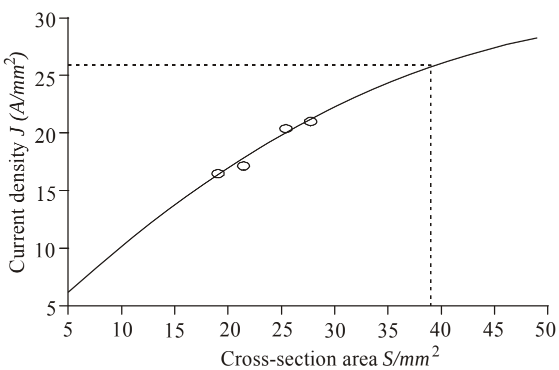

Fig. 1: The relation of biggest current density and cross-sectional area of alloy material Cr20A13

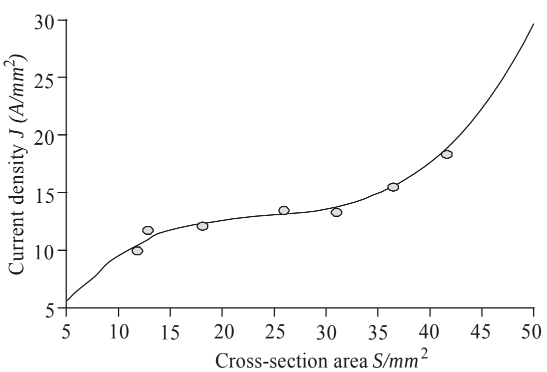

Fig. 2: The relation of biggest current density and cross-sectional area of alloy material Cr20A15

resistivity, temperature coefficient and density of alloy material at 20°C respectively. In this test, t is set at 10 sec, from expression (2), it can be seen that the maximum temperature rise of alloy material is proportional to the square of the maximum current density approximatively. The variation relation of the maximum temperature rise and the square of the maximum current density of Alloy materials Cr15Al5 with different specifications is shown in Fig. 3. In Fig. 3, we can see that experimental results are basically consistent with the theoretical analysis and the error is mainly due to the heat dissipation of alloy material.

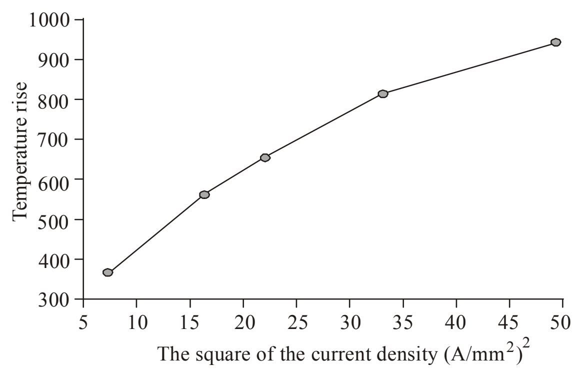

Fig. 3: The relation of biggest current density and cross-sectional area of alloy material CR15A15

In order to save alloy materials, reduce the size of resistor, we should raise the temperature rise of material to its highest temperature that it can tolerate as far as possible. From formula (1), (2),we can get formula (3) as follows:

$$S = \left(\frac{I^2 \cdot \rho \cdot t}{c \cdot \gamma \cdot \Delta T}\right)^{1/2} = \left(\frac{I^2 \cdot \rho_0 \cdot t + I^2 \cdot \rho_0 \cdot \alpha \cdot \Delta T \cdot t}{c \cdot \gamma \cdot \Delta T}\right)^{1/2} \quad (3)$$

It can be seen from the formula (3) that the temperature rise of alloy material is inversely proportional to the square of the cross-sectional area. When the failure response time and fault current are fixed, the smaller cross-sectional area of the material, the higher temperature rise of the material can withstand. Therefore, from the perspective of saving alloy material, it should be possible to improve the temperature rise of the alloy material in the design of grounding resistor. Of course, setting too high the temperature rise of the alloy material will affect the stability and safe operation of the grounding resistor to some extent. So, in order to achieve the safety and economic operation of grounding resistor, it needs a comprehensive consideration of various factors, such as cost of material, resistor stability, security and so in the designing of the resistors (Zhen-Dong and Gong, 2006; Yu-Shi *et al*., 2005).

Table 2: The test results of the resistivity of Aludirome materials with different specification

Material name	Specification	In 20°C resistivity (uΩ.m)	Temperature coefficient (1/°C)
Cr15Ni60	1.5×13.5×170	1.08	1.05×E-4
Cr20Ni80	2.5×20×290	1.12	1.85×E-4
Cr15Al5	0.5×29.5×220	1.33	0.46×E-4
Cr19Al2	1.5×12.6×616	1.02	8.64×E-4
Cr19Al3	1.5×12.9×616	1.15	7.13×E-4
Cr20Al3	1.5×12.8×616	1.18	5.4×E-4
Cr21Al6	1.5×12.9×616	1.39	0.23×E-4
Cr23Al5	1.5×12.9×616	1.39	0.62×E-4
Cr25Al5	3×13.5×300	1.40	0.41×E-4

Table 3: The test results of the tensile test of materials

Material name	Specification	Tensile strength at Room Temp. (16°C.Mpa)	Reduction of area % (16°C)	Tensile strength at high-temp. (730°C.Mpa)	Yield strength at high-temp. (730°C Mpa)	Young modulus at lowertemp. (4°C.Gpa)	Young modulus at high-temp. (730°C.Gpa)
Cr15Al5	1.4×29.4×220	575	22	392.2	293.7	180	2.9
Cr19Al2	2×13×170	680	15.5	33.68	25.3	28.7	0.48
Cr19Al3	1.5×12.9×616		11	35.1	26		23.4
Cr20Al3	1.5×12.8×616	780	10.5	40.98	38.0	35.8	13.1
Cr23Al5	1.5×12.9×616		0.5	83.49	62.7	36.4	17.1

RESISTIVITY OF ALLOY MATERIAL

Test data of alloy material resistivity: The resistance value of different material with different current density is tested and the current is set at 10 seconds. After deduction ,we get the resistance value and temperature coefficient of various alloy materials in 20°C, shown as Table 2.

Data processing and basic conclusions: In general, the resistivity of nickel-chromium-iron alloy is lower than the radiohm alloy with higher percent of Al and Cr. Considering cost savings and size reducing, the radiohm alloy material should be selected in the low resistance grounding resistor. Chromium and aluminum are the main elements to improve the resistivity in the Fe-Cr-Al alloy series materials. It can be seen from the test results that the resistivity will increase with the Al, Cr content increasing.

The resistance-temperature coefficient of the alloy material is related to the material composition, especially the content of the main compositions such as nickel, chromium, aluminum. From the experimental test results, we can see that the resistance-temperature coefficient will decrease with Al content increases for Fe-Cr-Al alloy series materials. The alloy materials such as Cr19Al2, Cr19Al3, Cr20Al3 etc. have higher resistance-temperature coefficient because the content of Al composition is lower, for this reason, the resistivity will increase obviously in the process of current work. When the voltage is maintained, the current will continue to reduce and then the current operating power is instability. But heating power stability is not necessary to the grounding resistor which is used to provide energy instant release channels. Conversely, in the design of the grounding resistor, its nominal resistance value can adopt tight design scheme, which can not only save resistance material but also basically reach the rated value of the earth fault current. Table 3 shows the test results of the tensile test of materials.

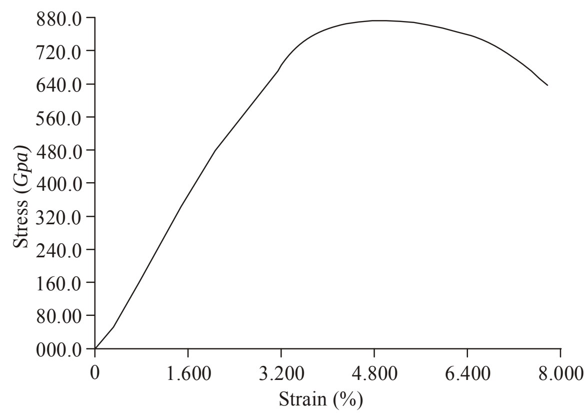

Fig. 4: The relation of atress and strain of Cr20A13 material in normal temperature

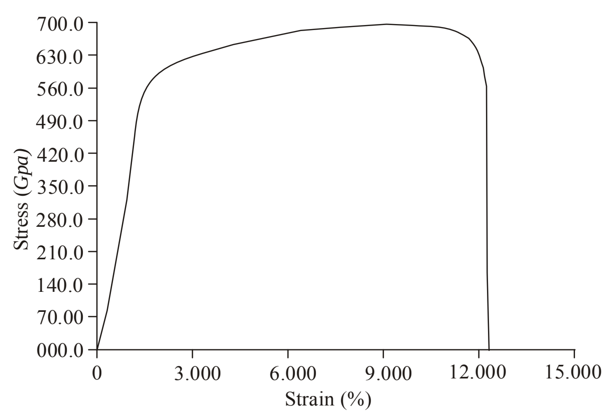

Fig. 5: The relation of atress and strain of Cr15A15 material in normal temperature

THE MECHANICAL PROPERTIES OF RADIOHM ALLOY MATERIAL

Test data:

Data processing and basic conclusion: The mechanical properties of radiohm alloy materials such

Table 4: Thermal expansion coefficient of alloy materials (unit: E-6*1/°C)

Temperature (°C)/ Material name	20-200°C	200-400°C	400-500°C	500-600°C	600-750°C
Cr19Al2	10.81	11.71	12.10	12.62	13.39
Cr19Al3	7.76	10.12	10.92	11.92	13.03
Cr20Al3	10.53	11.73	12.33	13.26	13.54
Cr23Al5	8.66	10.89	11.98	14.27	15.92
Cr21Al6	9.49	11.30	12.27	14.48	15.75
Cr25Al5	/	11.75	12.50	/	15.72

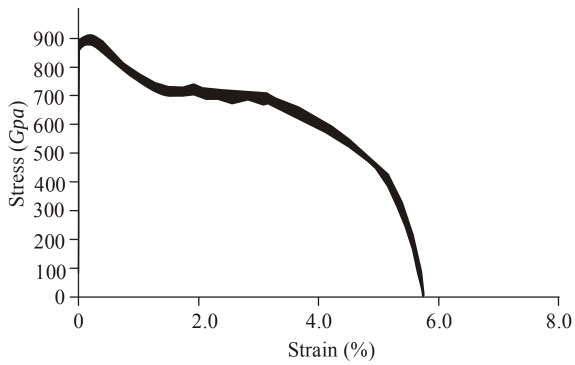

Fig. 6: The relation of atress and strain of Cr20A13) at 730 °C

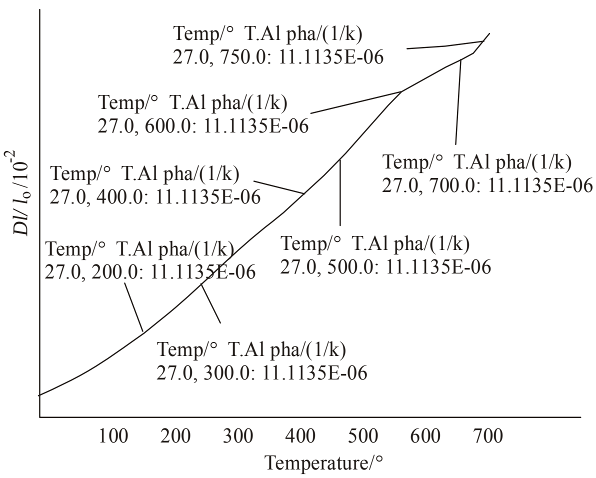

Fig. 7: The test result of Coefficient of thermal expansion Cr20A13

as Tensile strength in room-temp. and plasticity are related to the element content of Al,Cr ,etc and the most obvious is the content of Al element. The tensile results of Cr20Al3, Cr15Al5 at room-temp is shown as Fig. 4 and 5 respectively. By comparison of Fig. 4 and 5, it can be seen that when the aluminum content increases, the plasticity of the alloy decreased. Table 4 shows Thermal expansion coefficient of alloy materials (unit:: E-6*1/°C)

The tensile curve of Cr20Al3 at high temperature (730°C) is shown in Fig. 6. Comparing Fig. 4 and 6, it can be seen that under the condition of high temperature, the Fe-Cr-Al alloy material tensile strength, plasticity will rapid decline, but the brittleness will increased.

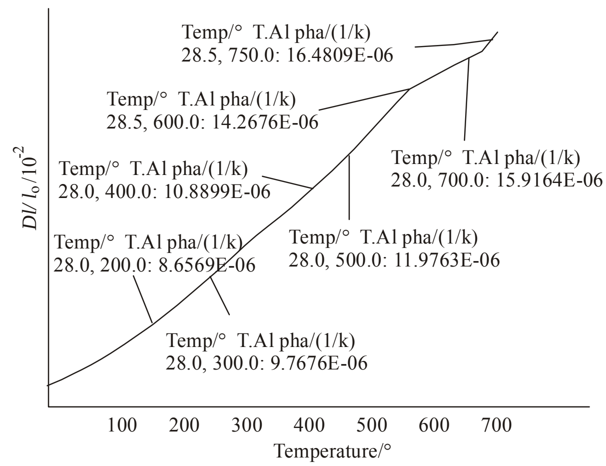

Fig. 8: The result of coefficient of thermal expansion of Cr23A15

HERMAL PROPERTIES OF MATERIALS

Test data:

Data processing and basic conclusions: The test results of coefficient of thermal expansion of alloy materials such as Cr20Al3, Cr23Al5 are shown respectively as Fig. 7 and 8. It can be seen from the figures that the coefficient of thermal expansion of alloy materials will increase with the temperature increasing, the higher the content of aluminum chromium, the more obvious that the thermal expansion coefficient will increases with the increase of temperature.

CONCLUSION

The test results show that when the grounding resistor is in the ground fault condition, its force, thermal and electrical performance characteristics is not only related with the type of material, but also related with the specifications and component content of materials. For the radiohm alloy materials, Chromium, aluminum component content of materials have the most obvious influence on material properties, in order to achieve the safety, stability and economic operation of low resistance grounding resistor, various factors should be comprehensively considered.

REFERENCES

Da-Jiang, H., Y. Heng-Ling, J. Xiao, J. Qu and L.Y. Liu, 2011. Performance research of resistance materials of low resistance grounding resistor under the short-circuit state. Adv. Mater. Res., 382: 137-140.

Dae-Jung, H., L. Long-Fu, S. Peng-Fei, X. Jia-Zhu, Z. Jun-Hua and S. You-Qiong, 2009. Development of neutral-grounding resistor made of alloy material. Power Sys. Technol., 33(18): 214-218.

Ming-Yan, L., 2004. Selection of neutral grounding modes in power distribution network. Power Syst. Technol., 28(16): 86-88.

National Technical Supervision Bureau, 2001. Neutral Grounding Resistor in the Distribution System (DL/T780-2001). Standard Press, Beijing, China.

Yu-Shi, C., Jin-Yi and C. Sun, 2005. Development of large-power loaded resistor. J. Yangtze River Sci. Res. Ins., 22(1): 60-62.

Zhao, R., T. Wei-Pu and Y. Yi-Han, 2007. Analysis of neutral grounding operation modes for distribution network. Relay, 35(4): 22-26.

Zhen-Dong, W. and Y. Gong, 2006. Electrothermal Alloy. Chemical Industry Press, Beijing.

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