Effect of Radiation on the Flexing Property of Cables

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Effect of Radiation on the Flexing Property of Cables

Shinichi OKAMOTO*, Tokuhiro OHNISHI*, Yoshihiro UEDA**,
Takuo TANAKA** and Nobuhiro FUJIO**

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Gamma rays from ^{60}Co were used to irradiate cables with the stranded wire made of high-strength copper alloy as conductors and with insulating and jacketing materials consisting of three kinds of plastics. The conductivity of the wire in the cables and the flexing property of the cables were examined before and after irradiation. It was found that the wire in the cables with insulating and jacketing materials containing halogen became blackened by gamma-ray irradiation. However, no significant change occurred in the conductivity, the tensile strength and the elongation of wires. The maximum wire-breaking numbers of the conductors in irradiated cables with thermoplastic polyurethane elastomers as their insulating and jacketing materials were larger than the other cables.

1. Introduction

Electric cables for various robots and automatic equipment employed in the radioactive environment need high radiation resistance and high flexing resistance. We prepared the cables with high-strength copper alloys as their conductors. The copper alloy contained a small amount of iron, phosphorus and special elements, and has high electrical conductivity and high tensile strength. The cables used three kinds of materials as their insulating and jacketing materials. After irradiation by gamma rays from ^{60}Co, the changes in roughness on surfaces of the conductors in the cables and those in their flexing property were carefully examined for three kinds of plastics (PVC, ETFE and TPU) as insulating and jacketing materials.

* Research Center of Radiation, Research Institute for Advanced Science and Technology.
** Tatsuta Electric Wire & Cable Co., Ltd.

2. Experiment

2.1 Test specimen

Figure 1 shows a typical cross section of the cables used in this experiment. Table 1 shows the list of conductors, insulations and jackets that formed the cables.

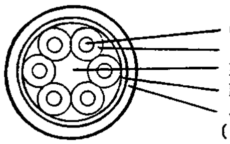

Fig. 1 Cross section of the cable

Table 1 Materials used for cables

Specimen No.	Conductor	Insulation	Jacket
No. 1	High-strength copper alloy	PVC	PVC
No. 2		PVC	TPU
No. 3		ETFE	TPU
No. 4		TPU	TPU
No. 5	Pure copper	TPU	TPU

Note PVC : Polyvinylchloride
ETFE: Ethylene-terafluoroethylene copolymer
TPU : Thermoplastic polyurethane

2.2 Test method

The cables were wound around a stainless steel drum whose outer diameter was 400 mm. They were exposed to the gamma rays from ^{60}Co at a dose rate of 9 kGy/h and at RT in the atmosphere. The irradiation doses to the cables were 2 and 4 MGy. The following tests were carried out.

2.2.1 Examination of conductors

The conductors of the cables were stripped off and then the properties (conductivity, tensile strength and elongation) of each wire were examined on the following items.

1) Color changes on the conductors : This was observed visually with the eye.
2) Electrical conductivity of the wires : This was measured by a double bridge (at 24 ℃). The results were represented in the percentage to IACS's data under the assumption that IACS (International Annealed Copper Standard) was 100.
3) Tensile strength and elongation of the wires : These were measured by

pulling a test specimen at a rate of 100 mm/min, at 24 ℃.

2.2.2 Flexing property

As shown in Fig. 2, a cable was sandwiched between two cylinders with 25-mm diameter. A load of 1 kg was hung down at the lower end of the cable. The

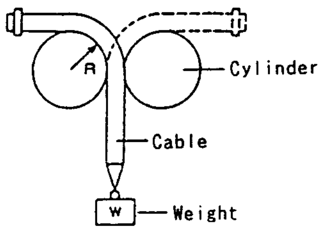

Fig. 2 Cross section of cable bending test machine.

upper part of the cable was bent toward left and right up to the angle of 90 degrees, and this handling was repeated at a rate of 40 times/min until all single wire consisting of the strands in the cable were broken completely. Then the bending times were counted, and this counts were employed as flexing property.

2.3 Results and discussion

Table 2 shows the color changes at the surfaces of the strands in irradiated cables. Figures 3, 4 and 5 show the changes in conductivity, tensile strength and elongation of the strands in them.

Table 2 Color change of tested conductors.

Specimen No.	Color change of conductor specimen	
	After 2–MGy	After 4–MGy
No. 1	Blackened	Blackened
No. 2	Blackened	Blackened
No. 3	Blackened	Blackened
No. 4	No change	No change
No. 5	No change	No change

Figure 6 shows the relationship between the numbers of bending of the cable until the strand in it was completely broken and irradiation doses. From table 2, it is apparent that the strands in the cables with PVC jackets and ETFE insulators containing halogen became blackened by gamma-ray irradiation. However, no color change occurred to the strands in the cable with thermoplastic polyurethane insulator. It is considered that this phenomenon is caused from the release of hydrogen halides from insulating and jacketing materials by gamma-ray

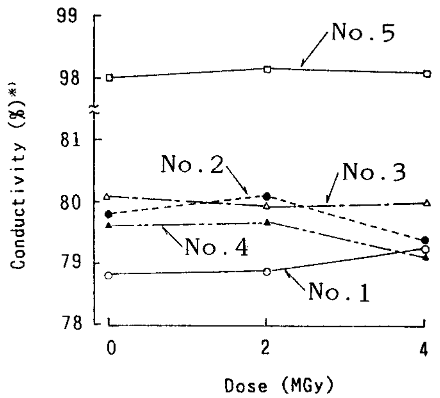

Fig. 3 Relationship between conductivity of conductors and irradiation dose. ※) Conductivity of conductors in the percentage to IACS's data.

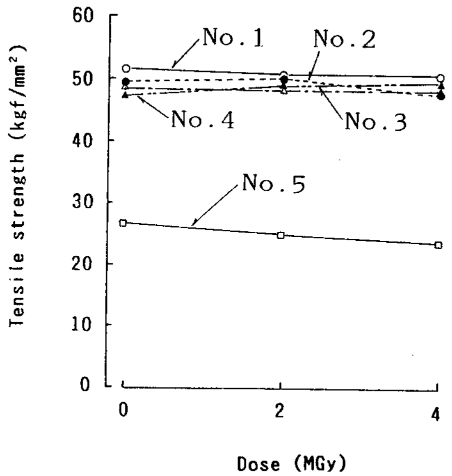

Fig. 4 Relationship between tensile strength of conductors and irradiation dose.

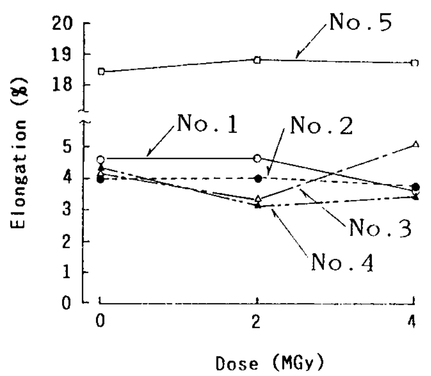

Fig. 5 Relationship between elongation of conductors and irradiation dose.

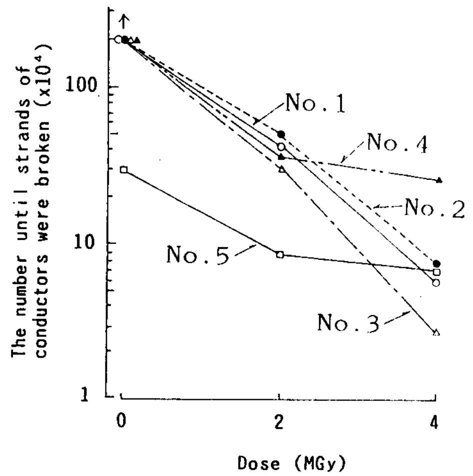

Fig. 6 Relationship between maximum wire-breaking number of conductors and irradiation dose.

irradiation.

The conductivity, tensile strength and elongation of the strands in the cables irradiated by gamma rays had no significant changes. The color changes at the surfaces of the strands irradiated is only limited to the thin layer near the surface of the conductors. It seems that there were no damage in the strands by oxidation.

The flexing resistance of the cables with the strands using high-strength copper alloy is essentially superior than that of those using pure copper as conductor. The reason for this is that the strands of high-strength copper alloy have essentially superior flexing property than those of pure copper. The maximum wire-breaking number of the strands in the cables decreases with increasing does (Fig. 6). This tendency seems to be significant on the strands in the cable with ETFE as insulator and TPU as jacket (No. 3). The surfaces of all single conductors in the strand inside ETFE insulator became rougher by corrosion with increasing dose, and also the flexibility of insulator became hardened by crosslinking with increasing dose. Then it is considered that the slipperiness among all single conductors in the strand and that between the strand and the hardened insulator in the irradiated cable decrease with increasing dose.

In the comparison between the cables (No. 1 and No. 2) with PVC and TPU jacketing materials, the TPU (No. 2) gives a slightly higher maximum wire-breaking number than the cable with PVC (No. 1). However, it is considered that the effect of jacketing material in cables on the maximum wire-breaking number of a strand is insignificant compared with that of insulator, because the jacketing material does not contact directly with the strands like the insulators in the cable.

The maximum wire-breaking number of the cable (No. 4) with high-strength copper alloy as conductors and with TPU insulators and a TPU jacket after irradiation of 4 MGy is nearly equal to the initial number of the cable (No. 5) with pure copper as conductors and with TPU insulators and a TPU jacket before gamma-ray irradiation. Thus the cable (No. 4) can be said to have excellent flexing property.

3. Conclusion

The conductors in cables using insulating materials containing halogen became blackened and rough at their surfaces by corrosion during gamma-ray irradiation. However, no significant change occurred in the conductivity, the tensile strength and the elongation of their conductors (strands). In addition, it was demonstrated that the maximum wire-breaking numbers of the cables with high-strength copper strands and with thermoplastic polyurethane elastomers (TPU) as insulator and jacket were smaller than that of the other four types of cables after gamma-ray irradiation. From the above results, it is concluded that these cables with high-strength copper alloy as conductor and with TPU as insulators and jacketing material are the most suitable as wires and cables for robots and automatic equipments in the high-dose environments.