Development of Environment-Harmonized Electric Wires

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ABSTRACT In recent years, adequate consideration on the problem of environment preservation has become a social task, requiring wire materials to be halogen-free to minimize the environmental effects at landfill and incineration. While conventional halogen-free materials have such problems as insufficient mechanical properties, sensitivity to mechanical damages, and poor heat resistance, the new halogen-free material developed this time is provided with not only excellent flame retardant properties but also superior mechanical properties. Moreover, since the material does not contain toxic heavy metals and phosphorus without mentioning halogens, it can cope with recycling processes, thus making it very useful for covering electric wires. Besides electric appliance wires, the material has a wide area of applications such as automotive wires and the like. The authors have also developed a molding material suitable for plugs of insulated flexible cords.

1. INTRODUCTION

Waste disposal and recycling have become an essential social task, requiring the volume reduction and resource recycling of waste. Thus, the development of engineering products that are harmonized with the environment is an urgent need to be pursued.

Figure 1 compares the disposal system of conventional wires and cables with that of environment-harmonized ones. At present, although the recycling process for the conductor inside the wires and cables has been established thus enabling the reuse of the material, the process for the covering material remains undone allowing only a small fraction of the covering material to be recycled.

While most of the covering materials are disposed of by landfill and incineration, these materials may cause a problem, when buried in the earth, such that toxic heavy metals are eluted into the earth. That is, we cannot deny the possibility of environment contamination by lead compounds used as a stabilizer for polyvinyl chloride (PVC) -- a general-purpose covering material for electric wires-- after the covering material is disposed of by landfill. Recent years have seen a countermeasure for this in which lead stabilizers have been replaced by new stabilizers containing zinc and the like.

Furthermore, the covering material system has to be completely halogen-free in order to suppress the emission of toxic gases at incineration. However, the present situation is such that the polymer that constitutes PVC contains in itself chlorine --one of halogens-- and polyethylene contains halogen compounds to make it flame retardant.

To cope with such a situation, we have developed an environment-harmonized material together with electric wires using it. The material, while provided with intrinsic properties equivalent to those of conventional materials, contains neither halogens nor toxic heavy metals and thus imposes little impact on the environment at the time of landfill and incineration. This report describes the development.

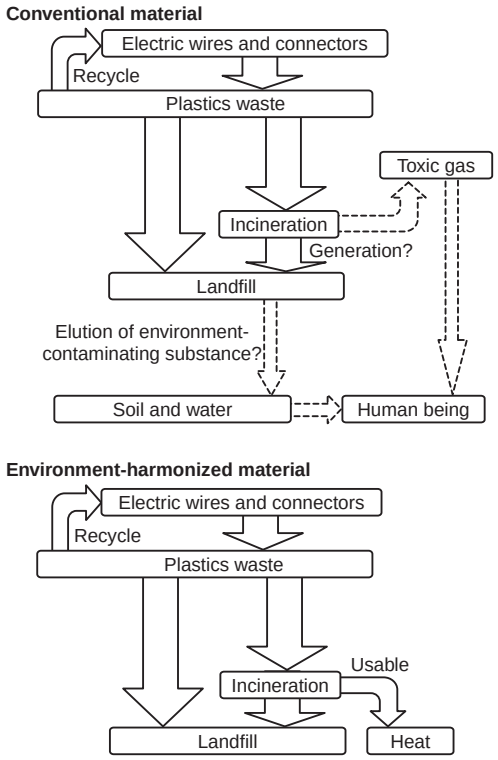

Figure 1 Disposal systems for the conventional and environment-harmonized wires and cables

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2. PROBLEMS WITH FLAME-RETARDANT MATERIALS USED IN CONVENTIONAL WIRES

Various developments of flame-retardant materials using no halogens are known so far. However, since they are less effective in flame retardance than halogen flame-retardant materials, non-halogen flame retarders have to be added in large quantities to ensure the desired level of flame retardance. This incurs the following problems when compared with the conventional halogen flame retarders: (1) Degradation in mechanical properties, (2) Degradation in formability, (3) Degradation in termination workability; each of which will be briefly discussed below.

2.1 Degradation in Mechanical Properties

Non-halogen flame retarders dispersed in polymers degrades the mechanical properties of the material substantially, when the quantity added exceeds a certain level. Specifically, such properties as tensile strength, elongation, and abrasion resistance degrade in addition to flexibility.

2.2 Degradation in Formability

Inorganic flame retarders such as hydrous metals reduce, when added to a large quantity, the fluidity of materials at the time of material melting, thus reducing the formability in the extrusion or injection molding. The degradation in formability adversely affects the productivity and appearance of products. Especially in injection molding, it often results in poor molding.

2.3 Degradation in Termination Workability

Electric wires are usually removed of their covering on their ends and terminated with connectors. Insufficient termination workability leads to covering residuals formation on the exposed conductors due to unsuccessful cutting, thus causing poor electrical contacts.

3. DEVELOPMENT

In this development, a goal has been set such that the new material not only excludes environment-affecting materials such as halogens but also solves the entire problems that vex the conventional flame-retardant wires. The specific goal is thus to develop both a wire covering material and a connector molding material that are provided with such mechanical properties, formability, and termination workability as are equivalent to those of PVC. Making efforts to this end, we have been successful in developing the materials that fulfill the above-mentioned goal thereby complying with the JIS standards as well.

Table 1 Properties of the environment-harmonized material

Item	Evaluation conditions	Unit	Developed material	Conventional PVC material
Tensile strength	JIS K 6723	Mpa	18.0	20.0
Elongation		%	180	250
Hardness	JIS K 7215	–	86	85
Oxygen index	JIS K 7201	–	32	28
Brittleness temperature	JIS K 6723	°C	-52	-35
Heat deformation	JIS K 6723	%	8.0	7.0

4. DEVELOPED MATERIAL AND ITS PROPERTIES

Preliminary production and evaluation of the developed environment-harmonized materials were carried out to give the results described below.

4.1 General Properties of the Environment-Harmonized Material

1) Tensile strength and elongation [JIS K 6723]
2) Hardness [JIS K 7215]
3) Oxygen index [JIS K 7201]
4) Low temperature resistance [JIS K 6723]
5) Heat deformation [JIS K 6723]

Table 1 compares these evaluation results with those of PVC material for flexible cords. As can be seen, the developed material harmonized with the environment has the properties equivalent to those of conventional PVC material as well as an excellent brittleness temperature. The developed material is white in natural color since it does not include phosphorus and the like, enabling easy coloring by using a color master batch for general purpose.

4.2 Application to Flexible Cords

Prototypes of single flexible cord (VSF-0.75SQ) and flat flexible cord (VFF-0.75SQ), both specified in JIS C 3306 "PVC Insulated Flexible Cord", were manufactured using the developed environment-harmonized material. The cords were evaluated in accordance with the JIS, giving the results shown in Table 2 in comparison with those of

Table 2 Properties of insulated flexible cords

Item	Evaluation conditions	Unit	Developed cord	Conventional PVC cord
Dielectric withstand voltage	JIS C 3306	-	Good	Good
Tensile strength	JIS C 3306	Mpa	15.2	19.6
Elongation	JIS C 3306	%	180	240
Tensile strength after aging	JIS C 3306 120°C 96 hr	Residual ratio %	103	102
Elongation after aging	JIS C 3306 120°C 96 hr	Residual ratio %	102	95
Flame retardance	JIS C 3306	-	Good	Good
Cold bend	JIS C 3306	-	Good	Good
Heat-shock	JIS C 3306	-	Good	Good

Table 3 Properties of insulated wires for electrical apparatus

Item	Evaluation conditions	Unit	Developed wire	Conventional PVC wire
Dielectric withstand voltage	JIS C 3316	-	Good	Good
Tensile strength	JIS C 3316	Mpa	18.0	20.0
Elongation	JIS C 3316	%	173	250
Tensile strength after aging	JIS C 3316 120°C 96 hr	Residual ratio %	99	99
Elongation after aging	JIS C 3316 120°C 96 hr	Residual ratio %	96	106
Tensile strength after JIS #2 oil test	JIS C 3316 85°C 4 hr	Residual ratio %	90	97
Elongation after JIS #2 oil test	JIS C 3316 85°C 4 hr	Residual ratio %	104	98
Flame retardance	JIS C 3316	-	Good	Good
Cold bend	JIS C 3316	-	Good	Good
Heat-shock	JIS C 3316	-	Good	Good
Heat deformation	JIS C 3316	%	21	5
Heat shrinkage	JIS C 3316	%	0	0

conventional PVC cords. It has been confirmed, as is clear from the table, that the developed cords have the properties equivalent to those of conventional PVC cords, conforming to the type 1 (VSF) and type 2 (H-VSF) cords specified in JIS C 3306. The developed cords are highly resistant to surface scratches, making themselves quite suitable for practical use. Moreover, the cords are superior in termination workability, so that the same termination procedures as those for conventional PVC cords are applicable to the new cords.

4.3 Application to Insulated Wires for Electrical Apparatus

Prototypes of insulated wire for electrical apparatus (KIV-0.75SQ) specified in JIS C 3316 "PVC Insulated Wires for Electrical Apparatus" were manufactured using the developed halogen-free material; and the wires were evaluated in accordance with the JIS, giving the results shown in Table 3 in comparison with those of conventional PVC wires (H-KIV). It has been confirmed again, as is clear from the table, that the developed wires have the properties equivalent to those of conventional PVC wires, conforming to the type 1 (KIV) and type 2 (H-KIF) wires specified in JIS C 3316.

4.4 Application to Automotive Wires

Automotive wires are required to be provided with an excellent abrasion resistance which is higher than that for electrical appliance wires, to protect them from insulation breakdowns due to harsh contact with other members. Prototype wires equivalent to AVSS-0.5SQ specified in JASO D 611 --standards for Japanese automotive wires-- were manufactured using the developed halogen-free material; and the wires were evaluated in accordance with the standards. Table 4 shows the results in comparison with those of conventional AVSS wires. As can be seen from the table, it has been confirmed that not only are the developed wires in compliance with the JASO standards, but also they are as abrasion resistant as the conventional AVSS wires covered by PVC.

Table 4 Properties of automotive wires

Item	Evaluation conditions	Item	Developed wire	Conventional AVSS wire
Dielectric withstand voltage	JASO D 611	-	Good	Good
Tensile strength	JASO D 611	Mpa	18.5	21.8
Elongation	JASO D 611	%	200	190
Oil resistance	JASO D 611	-	Good	Good
Flame retardance	JASO D 611	-	Good	Good
Cold bend	JASO D 611	-	Good	Good
Heat resistance	JASO D 611	-	Good	Good
Abrasion resistance	JASO D 611	times	Approx. 1500	Approx. 1500

Table 5 Properties of injection molding material for insulated flexible cords

Item	Evaluation conditions	Unit	Developed material	Conventional PVC material
Insulation resistance	JIS C 8303	MΩ	>1000	>1000
Dielectric withstand voltage	JIS C 8303	-	Good	Good
Heat resistance	JIS C 8303	-	Good	Good
Sharp-bend resistance	JIS C 8303	-	Good	Good
Shell compression	JIS C 8303	-	Good	Good
Ammonia resistance	JIS C 8303	-	Good	Good
Water-tightness	JIS C 8303	-	Good	Good
Flame retardance	JIS C 8303	-	Good	Good
Entire breakage bending	JIS C 8303	times	Approx. 50×103	Approx. 40×103

4.5 Application to Molding Material for Flexible Cords

The molded portion of flexible cords is required to be excellent in both flexibility and appearance. While the developed environment-harmonized material was intended to be used for extrusion molding, we have been successful in developing another environment-harmonized material for injection molding. Prototypes of flexible cords for home appliances having injection molded portions were manufactured using the developed environment-harmonized material for injection molding use. The molded prototypes were subjected to tests in accordance with JIS C 3316 to give the results shown in Table 5. It is thus shown that the developed environment-harmonized material for injection molding conforms to JIS C 3316, and that it compares favorably with conventional molded plugs in terms of bendability as well. Furthermore, the plugs for

insulated flexible cords thus obtained are excellent in external appearance and are sufficiently resistant to such mechanical damages as scratches.

5. CONCLUSION

The environment-harmonized materials developed this time are provided with excellent low temperature resistance and flame retardance in addition to superior flexibility and mechanical characteristics equivalent to those of PVC. Since the materials do not contain such environment-affecting substances as toxic heavy metals and phosphorus without mentioning halogens, they are excellent in terms of safety and recyclability at waste disposal. The materials, including those for injection molding, are believed to be useful for a variety of electric components as well as electric wires.

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