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Development of Olefin Laminated Steel Sheet Substitute for Polyvinyl Chloride

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A laminated steel sheet was developed to answer the demands for substitutions for polyvinyl chloride from materials and the electronics field using polyvinyl chloride laminated steel sheets. The laminated steel sheet that was developed is an olefin laminated steel sheet that includes absolutely no halogen or molding agents that are compounded into elastomer from PP co-polymer and it is already being used in item such as office automation equipment, CPU packages and closet doors and recently it is also being used in unit-baths. It is superior in heat, chemicals and stain resistance in comparison to the polyvinyl chloride laminated steel sheets from the characteristics of PP resins and although there was the problem of the surface being easily scratched, or whitened during low temperature forming, we have improved that while verifying through testing on the actual-size level.

1. Introduction

Polyvinyl chloride (PVC) products are excellent materials in terms of design and quality, and have been used as daily necessities in many applications. Generation of hydrogen chloride and other toxic substances from the incineration of PVC and designation of DOP (dioctyl phthalate) added as plasticizer to PVC as endocrine disrupter have accelerated the shunning of PVC in the building material, electronic, automobile, and many other industries[1]. Pattern-printed steel sheet laminated with PVC was used in interior and exterior building materials, electric appliances, and communication equipment. Nippon Steel Metal Products Co.,Ltd. started work on the development of new laminated steel sheet as a substitute for the PVC-laminated steel sheet.

2. Design of film as substitute for polyvinyl chloride

A film mainly composed of polypropylene (PP) was adopted as a film to substitute for polyvinyl chloride (PVC). The properties of the PP film are compared with those of the PVC film from the standpoint of laminated steel sheet in **Table 1**. The PVC film is an easy to use film with durability, formability and chemical resistance designed in a well-balanced manner. The PP film excels in stain resistance and chemical resistance, but is poor in adhesion and paintability. Being rubber-like, the PP film stretches well, but it is less slippery and is difficult to cut and form. The PP film is inferior to the conventional PVC film in some material properties. Since these shortcomings cannot be all improved at one time, they were solved by selecting a compound design or surface treatment to meet specific applications.

3. PP-laminated steel sheet

3.1 Composition of PP-laminated steel sheet

The surface structure of PP-laminated steel sheet is schematically illustrated in **Fig. 1**. The surface structure is basically the same as that of PVC-laminated steel sheet. Galvanized steel sheets are pretreated chemically (not shown in Fig. 1) and laminated with a PP film and a composite PP film through adhesives. The single-colored PP-laminated steel sheet has an embossed colored PP film laminated on the steel sheet, while the patterned PP-laminated steel sheet is a steel sheet to which a pattern-designed colored PP film is applied first, followed by a clear PP film.

Each construction is already employed for the conventional PVC-laminated steel sheet. Olefin does not provide a high enough adhesive force. After many experiments, adhesives were developed that

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Table 1 Comparison of properties of PP film and PVC film

Item	PP film	PVC film
Environment and health	○ Halogen free	× Incineration produces toxic gas
Chemical resistance	○ Excellent	△ Swelling by strong solvents like acetone
Stain resistance	○ Excellent	× Stains difficult to remove
Adhesion and paintability	× Adhesive and paint difficult to apply due to surface inactivity	○ Practical
Formability	○ High extensibility	○ Practical
Low-temperature formability	× Easy whitening, ○ Embrittlement temperature –50°C	○Low whitening tendency, ×Embrittlement temperature –20°C
Scratch resistance	× Scratch Resistance	○ Practical
Electrical properties	× High static charge	○ Practical
Heat resistance	○ 100°C	△ Maximum heat resistance of about 70°C
Combustion tendency	× Not self-extinguishing	○ Self-extinguishing
Property controllability	△ Rubber-like and too extensible	○ Free
Surface design and hiding power	△ Ink and adhesive selectable, and low hiding power	○ Easy to color and print, and high hiding power

Evaluation: ○ advantage, △ × disadvantage

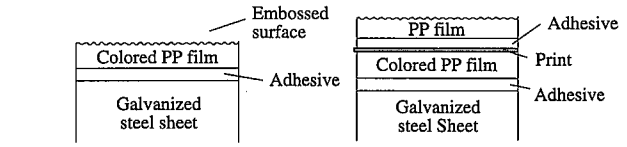

Fig. 1 Construction of new PP-laminated steel sheet

provide the adhesive forces required between the PP/PP layers and between the PP film and steel sheet that are comparable to the levels of the conventional PVC-laminated steel sheet.

The PP-laminated steel sheet is manufactured by applying an olefin-dedicated adhesive to a galvanized steel sheet with a roll coater, heating galvanized steel strip to a temperature above the melting point of the colored PP film, roll pressing the colored PP film onto the galvanized steel strip, and rapidly cooling the assembly.

3.2 Performance of PP-laminated steel sheet

Table 2 lists the performance properties of the new PP-laminated steel sheet as evaluated in comparison with those of the conventional PVC-laminated steel sheet according to JIS K 6744. Satisfactory results were obtained, except for self-extinguishment.

The performance test results of the new PP-laminated steel sheet for a simulated office automation (OA) equipment application are shown as compared with those of the conventional PVC-laminated steel sheet in **Table 3**. Formability and especially, whitening and scratch resistance improvements are at practically acceptable levels as a result of the selection and compounding of the base PP copolymer and elastomer[2,3], and the study of additives and surface treatment. The cross-sectional micro-graph of the bent portion of a specimen whitened in 180° bend test at 0°C is shown in **Photo 1**. The PP film faithfully follow the bend of the steel sheet and shows no peeling or cracking. The whitening caused in the PP film is probably

Table 2 Comparative evaluation results of single-colored PP-laminated steel sheet and PVC-laminated steel sheet (refer to JIS K 6744 for PVC-laminated steel sheet)

	Test item	Test condition	PP-laminated steel sheet	PVC-laminated steel sheet
JIS test	(1) Adherence	Crosscut Erichsen 6 mm	No peeling	No peeling
	(2) Folding property	R 2 mm, 90° bend	No peeling	No peeling
		180° bend	No peeling	No peeling
	(3) Low temperature workability	90° bend at 0°C	No peeling	No peeling
	(4) Boiling water resistance	Immersion in boiling water for 60 min	No change	No change
	(5) Chemical resistance	10% hydrochloric acid	No change	No change
		Saturated calcium hydroxide	No change	No change
		10% sulfuric acid solution	No change	No change
		10% sodium hydroxide	No change	No change
		Kerosene	No change	No change
		Ethanol	No change	No change
	(6) Corrosion resistance	Salt spray test for 1,000 h	No change	No change
	(7) Self-extinguishment	Heating for 20 s and extinguishing immediately after removal of flame	PP difficult to ignite and extinguish	PVC easy to ignite and extinguish

Substrate metal: 0.8 mm electrogalvanized steel sheet (Zinc 20 g/m² per side), PP film: 150μm (mat embossed)

Table 3 Performance test results for office machinery

	Test item and evaluation	Test condition		PP-laminated steel sheet	PVC-laminated steel sheet
Evaluation for electronic application	(1) 180° bend* (Whitening limit condition)	180° bend (Die temperature)	Room temperature	1T, 1T	0T, 0T
			0°C	2T, 2T	1T, 1T
	(2) 90° bend (Whitening limit condition)	Crank press (Die temperature)	Room temperature	1.5 mm, 1.5 mm	0 mm, 0 mm
			0°C	2.0 mm, 2.0 mm	0.5 mm, 0.5 mm
	(3) Surface scratch resistance (Minimum load)	Coin scratching		100 g	300g
		Fingernail scratching		500 g	1 kg
	(4) Pencil hardness	Measurement under load of 1 kg		Scratched with 6B pencil	Not scratched with 3B pencil
	(5) Heat shock test	−30°C for 1 day → 20°C for 1 day → 50°C and 95%RH for 1 day		No change	No change

180° bend: 0T (direct), 1T (over one thickness of same sheet), 2T (over two thicknesses of same sheet)

Table 4 Performance test results for simulated unit bathroom application

	Test item and evaluation	PVC-laminated steel sheet	PP		PP/PP
		Single colored	No treatment	Improved	Improved
Unit bath panel	2T bend at 0°C	No change	No change	No change	No change
	Forced peeling by crosscut Erichsen test on 5-point scale	5	5	5	5
	Peeling after intermittent boiling water immersion test for 20 days	No peeling	No peeling	No peeling	No peeling
	Peeling after chemical resistance test (benzene immersion test) for 2 h	Edge peeling	No peeling	No peeling	No peeling
	Marking ink staining (wipe with alcohol)	Poor	Excellent	Excellent	Excellent
	Silicone sealant adhesion	Excellent	Peeling	Excellent	Excellent

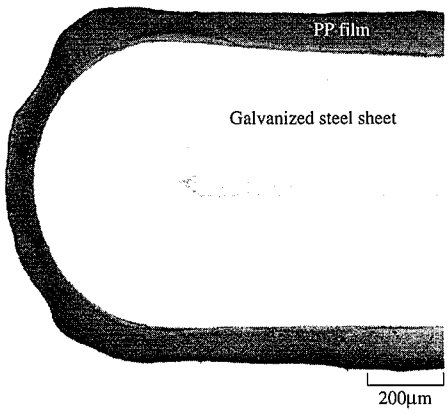

Photo 1 Cross section of PP-laminated steel sheet whitened by 180° bending

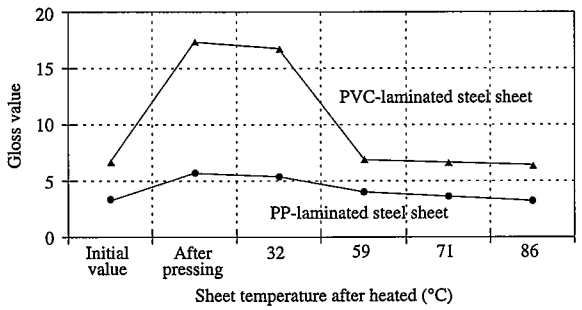

Fig. 2 Pressure mark tendency of PP-laminated steel sheet

because the low-temperature and high-speed deformation re-crystallized the PP film or formed microvoids and reduced the transparency of the PP film.

Table 4 gives the performance test results of the new PP-laminated steel sheet and the conventional PVC-laminated steel sheet for the simulative unit bathroom operating environment that requires long-term durability. Ink, adhesive, and surface treatment improvements provided the PP-laminated steel sheet with the same level of water-resistant adhesion as the PVC-laminated steel sheet. It was difficult to apply sealant, but this practical problem was solved by applying an appropriate surface treatment. The pressure marks that form on the PP-laminated steel sheet as it is coiled were evaluated. The pressure measured with pressure-sensitive paper during coiling was applied to the PP-laminated steel sheet on a hot press, and the resultant pressure marks were investigated. The test results are shown in **Fig. 2**. It was found that the PP-laminated steel sheet is less likely to form pressure marks than the PVC-laminated steel sheet and that its embossed pattern is restored by post-heating.

4. Conclusions

To meet the need for substitution for polyvinyl chloride (PVC), steel sheet laminated with polypropylene (PP), an environmentally-friendly olefin, was developed. The new PP-laminated steel sheet is comparable to the conventional PVC-laminated steel sheet in printed pattern appearance and interlayer bond strength, the two most important properties. It also features excellent chemical resistance and stain resistance. We will work to solve the remaining problems of formed portion whitening and surface scratch resistance.

References

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3) Shimizu,S.: Plastic Age. (8), 153 (1988)