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Development of High Functional Black Resin Coated Electrogalvanized Steel Sheet for Digital TV Panel

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Recently Digital TV industry has drastically been moving the illuminating system, which causes an obvious product change from PDP and LCD to LED model to provide high-definition image. Due to strong competition in the digital industry, TV manufacturers make a great efforts to reduce production cost by using low-priced materials such as steels instead of aluminum and plastic *etc*.
In this paper we have developed a new low-priced electrogalvanized steel sheet, which has a black resin composite layer, to substitute conventional high-priced PCM steel and plastic mold for rear cover panel in the digital TV. The black resin composite was prepared by mechanical dispersion of the mixture solution that consists of high solid polyester resin, melamine hardener, black pigment, micronized silica paste, polyacrylate texturing particle and miscellaneous additives. The composite solution was coated on the steel sheet using roll coater followed by induction furnace curing and cooling. Although the coated layer has a half thickness compared to the conventional PCM steels having 23㎛ thickness, it exhibits excellent quality for the usage of rear cover panel. The new steel sheet was applied to test products to get quality certification from worldwide electronic appliance customers. Detailed discussion provides in this paper including preparation of composite solution, roll coating technology, induction curing technology and quality evaluation from customers.

Keywords : *Digital TV, Composite, PCM steel, Plastic, Black Resin Coated Steel*

1. Introduction

During last several decade years, digital TV industry has drastically been moving the illuminating system from CRT to LED via both PDP and LCD to provide high definition image.[1)] For the long periods, CRT had used in household television, even though there were some demerits such as limitation of screen size and thick thickness of TV set. A decade ago, PDP and LCD technology was appeared in TV market. However the global market share of PDP TV has been gradually declined due to the disadvantages of high operation power and high heat evolution. At the beginning, LCD TV had some drawback such as small viewing angle and slow image response. But, it is recently the most popular model. Furthermore is being growing in the global market share because of low operation voltage and excellent image quality. Most recently, LCD TV is gradually changing to LED TV, which is using LED lamp as a backlight source, due to easiness to be slim in TV thickness and bright color image.[1)]

With a drastic change of illuminating technology, LCD (*including* LED) TV have had general trends such as both the wideness of image screen and the slimness of set thickness. In addition, there is strong competition among the TV makers to increase global market share. Therefore TV manufacturers would like to reduce production cost by using low-priced material such as steel instead of aluminum and plastic *etc*. as a structural material. As the changes of TV style, there were some changes for rear cover panel of TV set; from aluminum to PCM(*denote* pre-coated metal) steels in the PDP TV. Originally LCD TV adopted plastic mold for a rear cover panel. Because of the increasing needs of customer for low-priced material, conventional high-priced materials such as PCM steels and plastic mold were changed to low-priced new surface coated steels which were originally developed by POSCO in 2009.

In this paper, we would like to describe the newly developed low-priced and high functional composite res-

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in coated electrogalvanized steels, and commercially named *Black Resin Coated Steel Sheet*, to substitute high-priced materials for rear cover panels in digital TV. The new steels have developed by adopting both cost effective and innovative production technology that contains in-line process, high speed roll coating and induction curing. Including preparation of black resin composite and the resulting technology, we describes in detail with quality performance evaluation from electronic appliance customers.

2. Experimental

In this section, we described the preparation methods of black resin composite, surface coated steels and quality performance from customer as followed.

2.1. Preparation of Composite Solution

The resin composite solutions were prepared from mechanical dispersion of the mixture solution of polyester resin as a binder, melamine as a hardner, curing catalyst, carbon black as a black pigment, micronized silica and polyacrylate resin as a texturing particle, respectively. These paste solutions were combined and well grounded with the bead-mill dispersion. And several miscellaneous additives were added into the resin paste; anticorrosive agent, wetting and stabilization agent of pigment, acrylate leveling agent, wax dispersion, defoamers and air release agent, rheological additive and so on. The binder resin was used for high solid polyester with high molecular weight to get the high flexibility of press forming process. For texturing and matting of dried composite layer, micronized particles are used both silica and polyacrylate resin. The solid content was measured by the weight portion after drying at 150°C for 30min. and viscosity of the composite solution was measured by DIN cup(#4), respectively.(Standard DIN 53211) The composite solution was prepared by solvent-borne system using organic solvents such as cellosolve acetate, arcosolv DPM, RDBE- K and KOCOSOL150.

2.2. Production of Black Resin Coated Steel Sheet

The black resin composite was prepared from solvent-borne solution that has appropriate viscosity and solid content. The production was carried out in-line electrogalvanized line (*denote* EGL), shown in Fig. 1, that the processes consisted of pretreatment, electrogalvanizing, roll coating, induction curing and cooling section, according to order. The composite solution was coated by two-roll reverse operation on the strip surface. The coated solution was cured by resistant heat of induced current from the magnetic field of oven, and then solvent from the coated layer was evaporated. The coated layer was dried in induction oven and then cooled to room temperature *via* air-cooling and water quenching section. The thickness of coated layer was measured with portable gauge by eddy current method and instrument by destructive method.

2.3. Performance Evaluation

The quality performances for new product were evaluated by the following condition. The corrosion resistance(ASTM B 117) was evaluated by salt spray test with edge sealing by scotch tape.[2)] Paint adhesion test(ASTM D3359) was conducted by immersion in boiling water for 2hours and subjected to tape peeling test after cross-hatching (100squares, 1mm interval). The electric conductivity was measured on the rear side of black resin coated surface and evaluated by surface resistance which was measured by four-pin probe method using Loresta EP instrumrnt. The 0T bending test was conducted after 0, 10% and 20% elongation to simulate press forming process of customer.

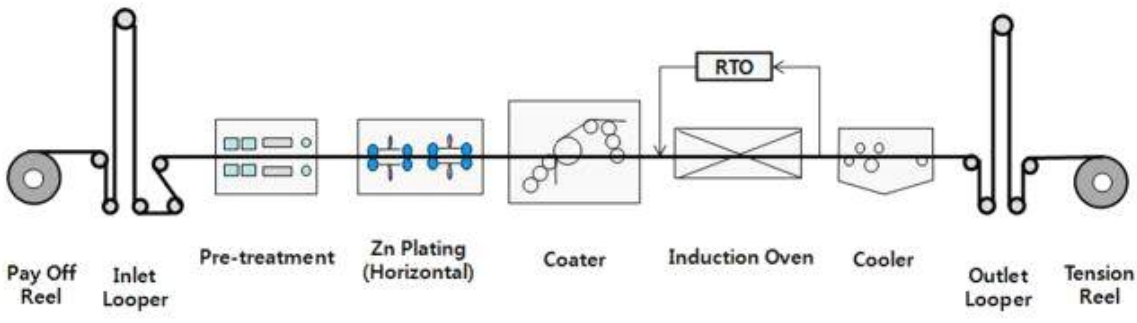

Fig. 1. In-line EGL layout for production of black resin coated steel sheet.

Conventional PCM Steel	EGL Process			Off-line CCL Process									Customer
	EG Steel	Oiling	Packaging	Transportation	Storage	Cleaning	Pretreatment	Thermal Drying	Primer	Thermal Curing	Top Coat	Thermal Curing	Packaging	TV Makers
New Product	In-line EGL Process												
	EG Steel	Skip of Process							Primer	Induction Curing	Top Coat	Induction Curing	Packaging	

Fig. 2. Process comparison between conventional off-line CCL and In-line EGL from production to customer.

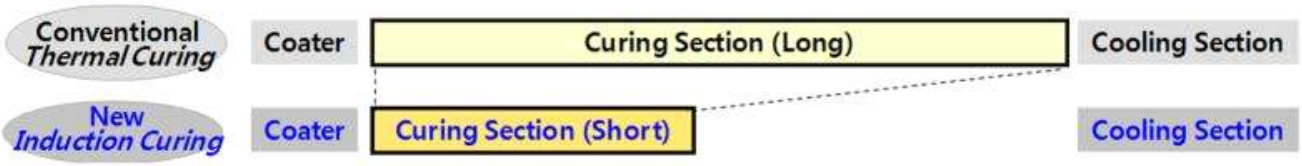

Fig. 3. Process differentiation between conventional thermal curing oven for PCM steels and induction curing oven for new product.

3. Results and discussion

3.1. Innovative Production Process

Due to the strong competition of electronic appliance industry, TV makers have a great efforts to buy low-priced materials to save production cost. Therefore, new development concept was focused on the reduction of production cost, described as followed.

First, it is necessary to simplify production process and distribution of steel product. Therefore we designed innovative coating process that is *in-line* process, compare to conventional *off-line* process. The former normally adopts thin layer coating such as anti-fingerprint steels, while the latter is common to color coating line (*denotes* CCL) that is to produce diverse PCM steels. As the mill-finish process, the in-line process can reduce production cost because of the simplification of distribution processes and the skip of production process compared to conventional PCM steels, shown in Fig. 2.

Second, new product adopts induction curing process instead of conventional thermal curing. The former uses the resistant heating of steel by magnetically induced current, and then has a merit of high speed production because of rapid heating of strip. However, the latter uses hot-air to cure the coated layer on the steel surface and cannot achieve high speed production due to slow heating of thermal oven, so production speed is limited to below 60mpm to produce PCM steels. Also there is another advantage in the facility space shown in Fig. 3. The former process can get peak metal temperature (*denote* PMT) to cure composite coated layer with short length of oven facility.

Third, new product provides low-cost materials by both thinner coated layer and simplification of coating process compared to conventional PCM steels. Traditionally PCM steels have production processes of three coating and three curing (*denotse* 3coat-3bake) in the CCL that consist of pretreatment, primer and top coating, respectively. And the coated layer of PCM steels commonly have 5±1㎛ of primer and 18±3㎛ of top coating in thickness. Meanwhile, new product consists of two coating and two curing process (*denotes* 2coat-2bake) that has only one fifth of primer and half thickness of top coating, as shown in Fig. 4., so pretreatment process was skipped and coated thickness was thinned to save production cost.

Therefore, new product is totally cost-saving material through the innovative in-line coating process and skip of pretreatment process. The adventure is succeeded by drastic increase of production speed that reached average 120mpm during production of black resin coated steels,

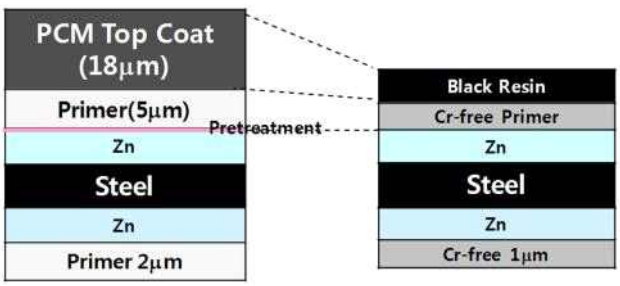

Fig. 4. Thinner coated layer of new product compared to conventional PCM steels.

truely comparative to below 60mpm of PCM steels. Especially new product was produced from solvent-borne composite solution as a mill-finish process. The in-line EGL is the first case in the world for the production of solvent-borne resin coated steels. We are pursuing the global #1 supplier through the 40% sales of new black resin coated steel sheet according to increasing demands of digital TV industry.

3.2. Preparation of Composite Solution

In this development, preparation of the black resin composite solution was started from the bead-mill dispersion of polyester binder resin and carbon black for black pigment, then added step by step with mechanical stirring such as organic and inorganic pastes, melamine hardners, curing catalyst, micronized silica and spherical polyacrylate resin for texturing, and wax for slip agent, and miscellaneous additives to improve coating properties. The binder resins were prepared from high solid polyester resin with high molecular weight to overcome severe forming of a rear cover panel. The press forming property of the coated layer is deeply dependent on the molecular weight and glass transition temperature of polyester resin. The main binder was selected from mixture of branch type and linear type of polyester to get higher flexibility of the coated layer due to thinner coating thickness. The hardner is important to get excellent coating property because it is related to crosslinking degree with resin binder. As the thickness of coated layer is being decreased to a half of PCM steels, the crosslinking degree needs to be increased while the density of the coated layer is also necessary to be compact, therefore melamine content was slightly increased. Due to the high speed production, the hardner need to provide higher reactivity, so both hardners were selected from the appropriate mixer of fully methylated melamine and partially methylated imino melamine instead of fully methylated melamine for PCM steels. The imino melamine contains three methylol group each melamine unit compared to 5~6 methylol group of the fully methylated melamine, so polar imino moiety has higher reactivity with hydroxy group of polyester.[3] Therefore during curing in induction oven, the crosslinking reaction is being stimulated with even shorten curing time at higher speed production. Another point of view is PMT(*denote* peak metal temperature) during the curing of coated layer. Generally during the curing at high temperature, the steel can increase yield strength due to thermal hardening of steel. Then, PMT in induction oven needs to be lower using both reactive hardner and curing catalyst. In this development, we uses high reactive imino melamine hardner, so partially methylated imino groups of hardner have more reactivity than that of fully methylated amine groups due to more polar property.

3.3. Preparation of Black Resin Coated Steel Sheet

New product is prepared by in-line EGL process instead of off-line of PCM steels. The in-line EGL is more cost saving process because of skip of process and minimization of transportation of steel coils. However the production in in-line process is necessary to increase production speed as much as the speed of electrogalvanizing process. In this development we have obtained higher productivity with above 120mpm than 60mpm of off-line PCM steel. The in-line EGL consists of cleaning section, galvanizing section, roll coating section, induction oven and cooling section, in order. The cleaning section, that wash out dust, scale and press oil on the strip, consists of three separate sections that are alkaline degreasing, acid cleaning and electro-degreasing. The electrogalvanizing process is consisted of a series of horizontal cell which commonly adopts for high speed production. With high speed production, roll coating technology is more important to obtain excellent surface appearance and accurate coating thickness. Generally reverse coating using two rolls is more favorable for good coating quality, but PCM steels adopt full reverse coating of V-type using three rolls for good surface appearance.[3,4] Another technology to get high speed production is induction curing using resistant heat induced by inductive current. The surface heating of steel is easy to reach high temperature for curing resin layer compared to thermal curing in CCL. Even more than 120mpm, the curing of coated layer is sufficient. The cooling next to the curing is also important for good coating quality. The cooling section consists of both air blowing for slow cooling and water quenching for rapid cooling of strip surface. Finally hot air is necessary to dry out residual water on the wet surface from the cooling section.

3.4. Quality Performance

As the thickness of the coated layer goes to be thin, the quality of the layer such as corrosion resistance and press formability is to be important. To improve both qualities in this development, high molecular weight and branch type of polyester are used and micronized particles for matting and texturing are selected to match the thickness of the coated layer as described before. Second, gradient concentration of silica was introduced in the coated layer. During the curing, hollowed silica having high surface area was floated on the surface of the coated layer, therefore the concentration of silica on the surface was increased, as shown in Fig. 5. This gradient layer

is presumably suitable for the reason of enhanced press formability. Third, using reactive hardner to increase the reaction speed, curing temperature was reduced even if the production speed is increased as described previously. Even if the coated layer slimmed excellent corrosion resistance was obtained as the result. Especially bending property was evaluated to simulate severe forming of rear cover panel after 0%, 10% and 20% elongation by ASTM standards, as shown in Fig. 6. In this development, we confirmed that new product has no crack and no peeling of the coated layer. Finally we obtained quality certification for the worldwide TV manufacturers by 2009.

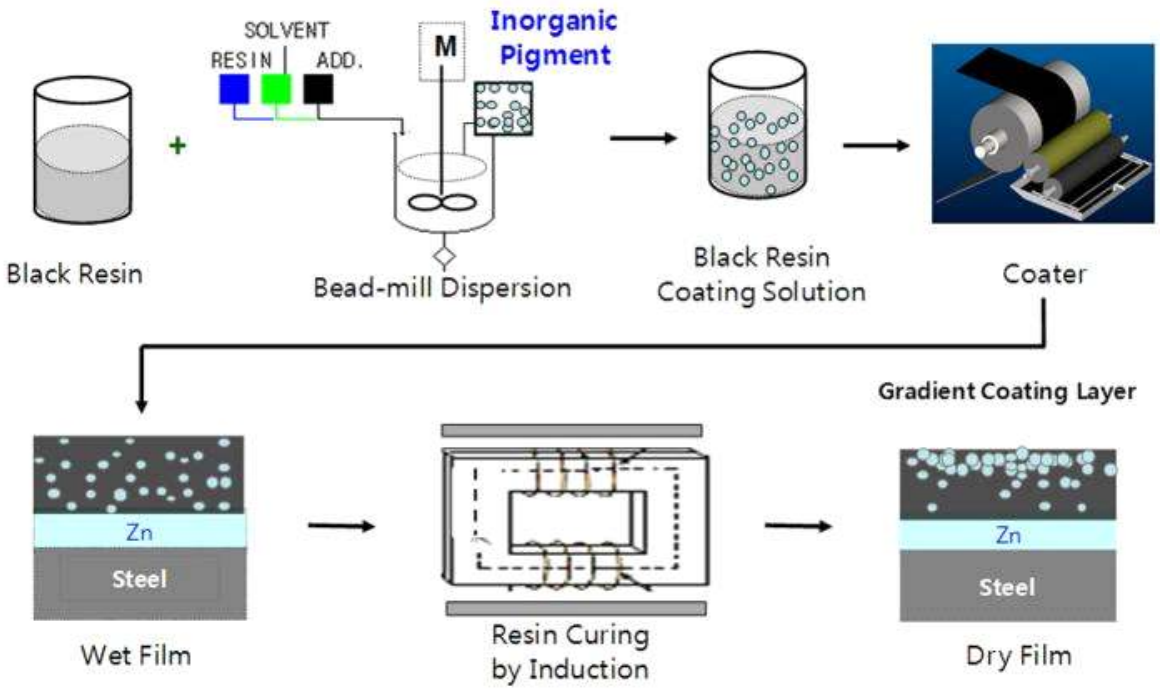

Fig. 5. Preparation of composite solution and formation of gradient coating layer during induction curing.

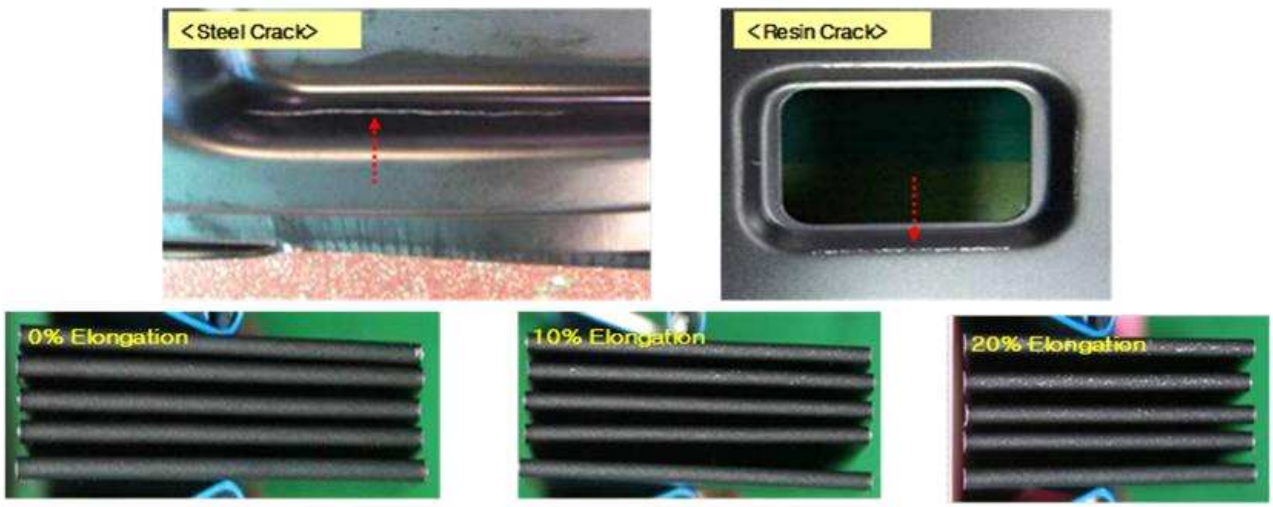

Fig. 6. During the press forming, both steel crack and resin crack occured due to poor press formability of the layer (Top). Enhanced formability evaluation by 0T bending evaluation after 0%, 10% and 20% elongation of new product (Bottom).

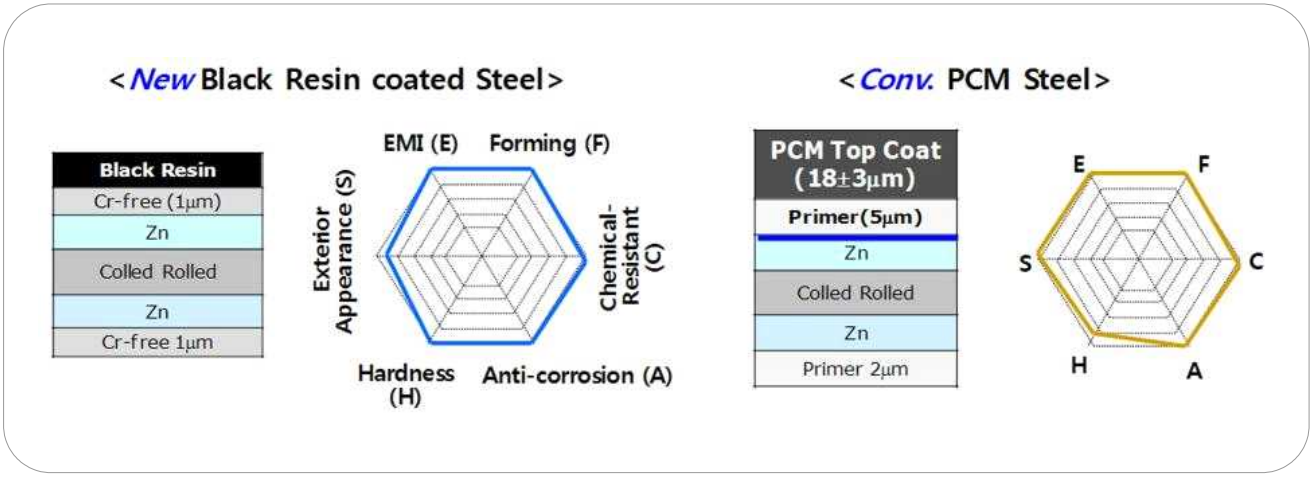

Fig. 7. Comparison in quality performances between new product and conventional PCM steel.

4. Concluding remarks

We have developed new black resin coated steel sheet to substitute conventional high-priced rear cover panels for digital TV such as PCM steels of PDP TV and plastic molding of LCD TV. Due to the low-priced new development, LCD TV makers were finally changed from large sized plastic mold to black resin coated steels by 2009.

The new product has been developed in the first world by energy-saving innovative processes which are comprised of grand transformation of production processes, off-line CCL to in-line EGL, thickness minimization of the coated layer and drastic increase in production speed due to the change from thermal curing to induction curing. The quality performances are well exhibited by evaluation from customers of worldwide electronic appliances. The comparison between new product and conventional PCM steels is depicted in Fig. 7. The new product is being provided with low-priced materials for panels in the digital TV due to cost-saving innovative process.

The new product is under mass production both at Kwangyang works since 2009 and at Pohang works since 2010. We are pursuing the global #1 production line for black resin coated steel sheet by suppling above 40% in global market share.

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