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# Inorganic Dry Film Lubricant Coated Galvannealed Steel Sheet with Excellent Press Formability and Adhesive Compatibility*



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***Synopsis:***

*An inorganic dry film lubricant coated galvannealed steel sheet has been developed in order to improve the press formability of automotive body panels. The frictional property and the press formability of this steel sheet are equivalent to those of galvannealed steel sheet coated with an Fe-P electroplated upper layer. The developed inorganic dry film lubricant coated galvannealed steel sheet shows good compatibility with various kinds of adhesives, such as structural adhesives and mastic adhesives. The spot weldability of this steel sheet is equal to that of a galvannealed steel sheet. The properties followed by phosphating are the same as those of galvannealed steel sheet, due to the film dissolvable property into alkaline decreasing solution. The inorganic dry film lubricant layer can be easily coated with a conventional coater roll and a drier on galvannealed steel sheets.*

compatibility with adhesives, weldability and phosphatability. This article describes the design conception of the inorganic dry film lubricant layer and characteristics of the developed steel sheet.

## 2 Structure and Design Conception of the Developed Steel Sheet

**Figure 1** shows a cross-sectional view of the developed inorganic dry film lubricant coated galvannealed steel sheet. The inorganic dry film lubricant layer is coated on a galvannealed coating layer. This inorganic dry film is composed of a zinc compound and binder. The zinc compound works as a lubricant to prevent metallic contact between a galvannealed coating layer and a press die during press forming and improves the material flow and thus the formability.

Another superior characteristic of this developed steel sheet is excellent compatibility with various adhesives.

two specimens were dipped into the rust preventive oil, taken out, and then hold upright for 24 h. Then, the adhesive was coated between two specimens spaced 0.2 mm apart with an adhesion area of 25 mm × 200 mm, after which the adhesive was cured under a baking condition of 170°C for 20 min. After 24 h, the T-peel tests were conducted at a rate of 200 mm/min. The compatibility with structural adhesive was determined by the T-peel strength and the fracture modes i.e., cohesion failure and adhesion failure denoted CF and AF respectively.

The adhesion test using mastic adhesive was a shear test. Using two specimens treated by the rust preventive oil in the same way as above, the adhesive was coated between two specimens of 3 mm apart with an adhesion area of 25 mm × 25 mm, and then cured under a baking condition of 170°C for 20 min. After 24 h, the shear tests were conducted at a rate of 50 mm/min. The compatibility with mastic adhesive was determined in terms of the shear strength and the above-described fracture modes.

### 3.5 Spot Weldability

**Figure 5** shows the spot welding conditions in the present test. Specimens with a thickness $t$ of 0.8 mm were welded by using DR type electrodes. The welding force was 1.96 kN, and the welding pattern (squeeze time-weld time-hold time) was 25 cycles-12 cycles-1 cycle. The weldable current range was estimated from measured nugget diameters. The lower limit of the weldable current was defined as the point satisfying 4 the friction test in case of using no oil. **Photo 1** shows the results. The surface of the galvannealed steel sheet

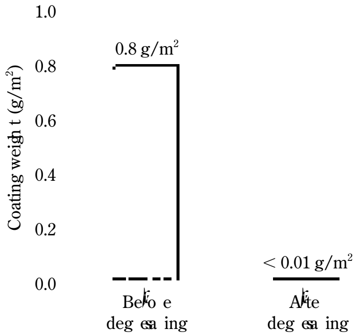


Fig. 11 Degreasability of inorganic dry film lubricant

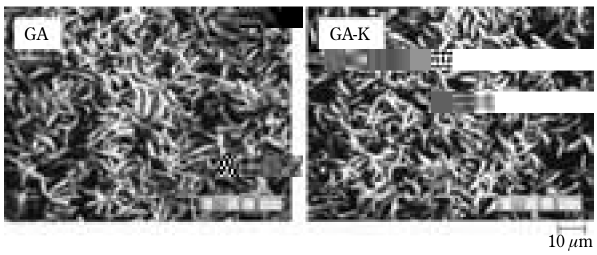


Photo 2 SEM images of phosphate crystals

### 4.5 Alkaline Degreasability and Phosphatability

**Figure 11** shows the coating weight of the developed inorganic dry film lubricant layer before and after alkaline degreasing treatment. The coating weight of the film was degreased by alkaline degreasing treatment from 0.8 g/m$^2$ to less than 0.01 g/m$^2$. This shows that the developed inorganic dry film lubricant layer was almost completely dissolved into an alkaline degreasing solution by ordinary alkaline degreasing treatment.

**Photo 2** shows the SEM images of phosphate crystals. The phosphate crystals of the developed steel sheet were equivalent to those of the galvannealed steel sheet, and the faults, such as missing or unevenly distributed crystals, were not observed. These findings indicate that the phosphatability and the pr(v) eas6.9yties induced by the phosphating of the developed steel sheet were the same as those of the galvannealed steel sheet, due to the dissolving of the film into an alkaline degreasing solution.

## 5. Conclusions

An inorganic dry film lubricant coated galvannealed steel sheet with excellent press formability and good compatibility with adhesives has been recently developed. This steel sheet can be applied to automotive body panels. The characteristics of this steel sheet are as follows:

(1) The frictional pr(v) eas9.9yties and the press for this steel sheet are equivalent to those of galvannealed steel sheet coated with an Fe-P electr(vlated upv) e]TJ CAMP-

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