United States Steel

Technical Bulletin Construction:

Warm Roll-Forming of Prepainted Sheet Steel

For further assistance on the use of steel building panels or related topics, contact U. S. Steel Construction Sales

Group: U. S. Steel Construction Sales

600 Grant Street Room 1714 Pittsburgh, PA 15219

1-877-798-7909

constructionsales@uss.com

Warm Roll-Forming of Prepainted Sheet Steel

The material in this paper is intended for general information only. Any use of this material in relation to any specific application should be based on independent examination and verification of its unrestricted availability for such use, and a determination of suitability for the application by professionally qualified personnel. No license under any United States Steel Corporation patents or other proprietary interest is implied by the publication of this paper. Those making use of or relying upon the material assume all risks and liability arising from such use or reliance.

Figure 1. Red rust on tension bends of prepainted HDG.

For further assistance on the use of steel building panels or related topics, contact U. S. Steel Construction Sales Group:

U. S. Steel Construction Sales
600 Grant Street
Room 1714
Pittsburgh, PA 15219
1-877-798-7909
constuctionsales@uss.com

United States Steel

Background

Hot-dip galvanized (HDG) and GALVALUME®[1] Coated Steel Sheets (55% Al-Zn alloy-coated steel) are widely used in the construction industry for roofing and siding applications. The zinc and aluminum-zinc alloy coatings provide excellent corrosion resistance due to both galvanic and barrier protection. These coatings are often painted to improve their appearance. Painting adds an additional barrier coating for enhanced corrosion protection.

Panels for metal building applications are usually formed into various profiles for structural, architectural and decorative purposes. Stiffening ribs are created by roll-forming processes, in which the flat steel sheet is fed through a series of rolls, which bend the steel sheet into the desired profile. This bending generates tensile strains on the outer surface of the ribs, which are referred to as tension bends. If the strain on the tension-bend exceeds the level of strain that the paint and the metallic coating can tolerate, cracks may develop in the paint and in the metallic coating. Tension-bend cracks are a common problem for prepainted HDG and GALVALUME® Sheet since they can lead to premature cosmetic corrosion of the products in service. This phenomenon may be avoided or minimized by panel design, by material and paint-system selection, by adjusting roll-forming parameters, or by warm roll-forming. In a study, U. S. Steel has demonstrated that warm roll-forming not only improves the formability of the paint film, but also improves the formability of the underlying metallic coating.

Premature Corrosion of Bare or Prepainted HDG Due to Tension-Bend

Hot-dip galvanized steel is coated with zinc, which provides corrosion resistance to the steel substrate. After severe bending or forming, fine cracks may develop in either the paint or the zinc coating on the tension side of the bend. At the initial stage of corrosion, zinc sacrifices itself to protect the underlying steel. White corrosion products might be observed around the fine cracks in the paint on the tension bends since the products of zinc corrosion are white. As the corrosion progresses, the zinc underneath the paint is consumed and the paint flakes off since there is nothing for the paint to adhere to. Red rust may subsequently develop on the underlying steel. This process may take years to initiate depending on the environment, the paint system used, thickness of the zinc coating, and the severity of the strain or radius of the bend involved. Figure 1 shows an example of red rust on the tension bends of a prepainted HDG roofing panel after several years of outdoor exposure.

[1] GALVALUME® is an internationally registered trademark of BIEC International, Inc. and some of its licensed producers.

Warm Roll-Forming of Prepainted Sheet Steel

Tension-Bend Staining of Galvalume® Prepainted Coated Steel Sheet

When tension-bend cracks are produced in the paint of prepainted GALVALUME® Coated Steel Sheet, and these cracks coincide with cracks in the metallic coating, the underlying steel substrate is exposed to corrosive attack. In this case, the zinc in the aluminum-zinc alloy coating sacrifices itself to protect the underlying steel. However, once the zinc around a crack is consumed, red rust (iron oxidation product) will develop at the base of the crack and transfer to the surface of the paint surrounding the tension bend crack. The result is tension bend staining. Eventually, the crack becomes plugged with insoluble corrosion products and the corrosion process is halted after a few years, depending on the environment. However, the paint film remains intact on the tension-bends since it remains adherent to the aluminum-rich phase of the 55% Al-Zn coating, which is protected by an adherent and insoluble aluminum oxide. While tension-bend staining is unsightly, it is only cosmetic corrosion and will not affect the integrity of the coating under normal environmental conditions. The severity of the tension-bend staining on painted GALVALUME® Sheet depends on the severity of the bend radii, the paint system employed, the environment, and the ductility of the 55% Al-Zn coating.

Effect of Warm Roll-Forming

Roll-forming processes have traditionally been carried out at room temperature and tension-bend cracking has been minimized by careful material and paint-system selection. However, a few companies have begun to practice warm roll-forming, to prevent tension-bend cracking and allow somewhat greater freedom in the choice of panel design and the manufacturing temperature. In these cases, the prepainted sheet is heated using infra–red heaters prior to entering the forming rolls. Roll-forming in this manner, at temperatures in the range of 120°F to 170°F, can significantly reduce the incidence of tension-bend cracking. Warm roll-forming not only significantly reduces tension-bend cracking in the paint film, but also in the metallic coatings of both zinc and zinc-aluminum alloy-coated products.

For further assistance on the use of steel building panels or related topics, contact U. S. Steel Construction Sales Group:

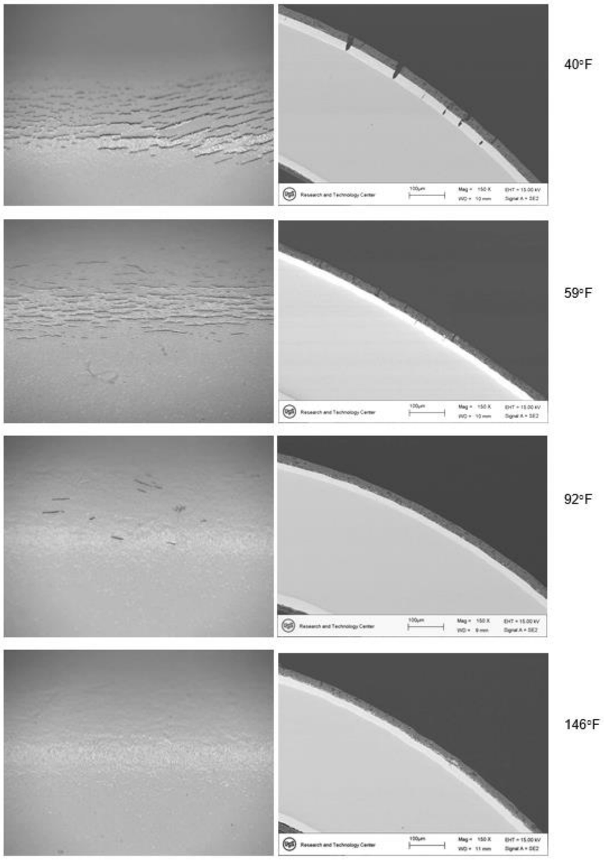
U. S. Steel Construction Sales
600 Grant Street
Room 1714
Pittsburgh, PA 15219
1-877-798-7909
constuctionsales@uss.com

United States Steel

Warm Roll-Forming of Prepainted Sheet Steel

Effect of Warm Roll-Forming of Prepainted HDG

The roll-forming temperature has a significant effect on the development of tension-bend cracks on prepainted HDG. The effect of warm roll-forming on prepainted HDG G40, G60, G90, G100 were evaluated at different temperatures ranging from 40°F to 160°F during the production roll-forming of a typical building panel design. The number of cracks developed on the tension bends was significantly reduced on panels that were formed on warm summer days with the ambient temperature at 92°F in comparison to those formed in the colder spring days when ambient temperatures were between 40°F and 59°F (Figure 2). Warm roll-forming at 120°F or higher was enough to eliminate most of the cracking in the zinc coating and in the paint on the prepainted HDG regardless of ambient conditions. Cracks were not observed either in the paint or in the metallic coating on the panels formed at the elevated temperatures, where the forming temperature was between 140°F to 160°F (Figure 2). Warm roll forming not only improved the ductility of the paint but also improved the ductility of the zinc coating. Warm roll-forming has been utilized in zinc sheet forming processes for metal roofing applications for years. Pure zinc becomes brittle at temperatures around 45°F and the ductility of zinc increases with increasing temperature. It has also been noted that hardness of the HDG coating decreases with increasing temperature.



For further assistance on the use of steel building panels or related topics, contact U. S. Steel Construction Sales Group:

U. S. Steel Construction Sales
600 Grant Street
Room 1714
Pittsburgh, PA 15219
1-877-798-7909
constuctionsales@uss.com

United States Steel

Warm Roll-Forming of Prepainted Sheet Steel

The material in this paper is intended for general information only. Any use of this material in relation to any specific application should be based on independent examination and verification of its unrestricted availability for such use, and a determination of suitability for the application by professionally qualified personnel. No license under any United States Steel Corporation patents or other proprietary interest is implied by the publication of this paper. Those making use of or relying upon the material assume all risks and liability arising from such use or reliance.

Figure 2. Optical micrographs of the surfaces and SEM micrographs of the cross-sections of prepainted HDG G100 at 30X and 150X magnifications, respectively. The panels were formed at different ambient temperatures, 40°F, 59°F and 92°F, with the heater off, and warm roll-formed at 146°F.

Effects of Warm Roll-forming of GALVLUME® Prepainted Coated Steel Sheet

The effect of warm roll-forming on prepainted GALVALUME® Sheet was evaluated using U. S. Steel Grade 80, AZ50 and AZ55 GALVALUME® Sheet at different temperatures ranging from 40°F to 160°F. The paint systems included a polyester primer with SMP and PVDF topcoat.

Several cracks were developed on the tension bends when the prepainted GALVALUME® Sheet with SMP topcoat was roll-formed with the oven off at an ambient temperature of 40°F. Under this forming condition, the paint was severely cracked on the bends and in some places, the cracks penetrated both the paint and the 55% Al-Zn alloy coating. However, the same material formed in the summer at an ambient temperature of 80°F showed no cracking in the paint or metallic coating (Figure 3). Cracks were not observed in the paint or in the metallic coating when the roll forming was conducted at elevated temperatures between 140°F to 160°F. Warm roll-forming not only improved the ductility of the paint, but it also improved the ductility of the aluminum-zinc coating. The cracks on the tension bends were eliminated because the formability of both the paint and metallic coating was improved by increasing the forming temperature. Choosing the right paint system is a very important factor for eliminating tension-bend cracking. Typically, PVDF topcoat is more flexible than polyester or SMP topcoat. It is believed that tension-bend cracking on the prepainted GALVALUME® Sheet could be virtually eliminated by using flexible paint systems and warm roll-forming practices.

For further assistance on the use of steel building panels or related topics, contact U. S. Steel Construction Sales Group:

U. S. Steel Construction Sales
600 Grant Street
Room 1714
Pittsburgh, PA 15219
1-877-798-7909
constuctionsales@uss.com

United States Steel

Warm Roll-Forming of Prepainted Sheet Steel

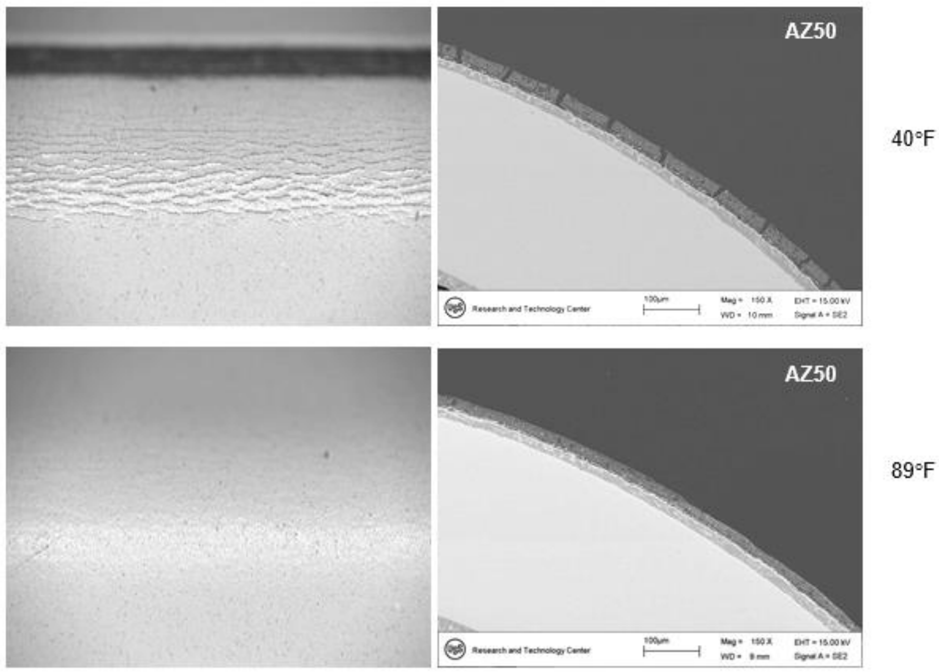


Figure 3. Optical micrographs of the surfaces and SEM micrographs of the cross-sections of prepainted GALVALUME® Sheet at 30X and 150X magnifications respectively. The prepainted GALVALUME® Sheet was AZ50 painted with an SMP topcoat and formed at 40°F and 89°F.

Summary

Warm roll-forming has a significant effect in reducing or eliminating tension-bend cracks in the paint and in the metallic coatings of both prepainted HDG and prepainted GALVALUME® Sheet. The elevated temperature used in warm roll forming increases the ductility of zinc in the metallic coatings, which allows the coating to tolerate higher strains without cracking. Warm roll-forming at 120°F or higher was enough to eliminate most of the cracking in both the zinc coating and the paint on the prepainted HDG and was enough to eliminate cracking on the tension bends for prepainted GALVALUME® Sheet in typical production building panels.

Although the roofing and siding panels have been formed at ambient temperature for decades and are providing years of excellent service life, this research confirms the benefits of warm forming. Jobsite roll-formers should take steps to ensure that coils are properly warmed prior to roll-forming especially when ambient temperatures are below 50°F. Factory based roll-formers should store coils in climate-controlled conditions to insure adequate coil temperatures.

For further assistance on the use of steel building panels or related topics, contact U. S. Steel Construction Sales Group:

U. S. Steel Construction Sales
600 Grant Street
Room 1714
Pittsburgh, PA 15219
1-877-798-7909
constuctionsales@uss.com

United States Steel