

Hot Dip Galvanized Information Sheet No.14

Hot Dip Galvanized Surface Finishes caused primarily due to the effect of Silicon and Phosphorous in Steel

(Refer also to Information Sheet No. 4)

The quality and surface finish of hot dip galvanized carbon steels are directly related to the chemistry of the components being processed. Fundamentally, two elements, being silicon (Si) and phosphorous (P) within carbon steel, influence the surface finish in terms of uniformity, colour (shine or matt dull grey) and relative smoothness.

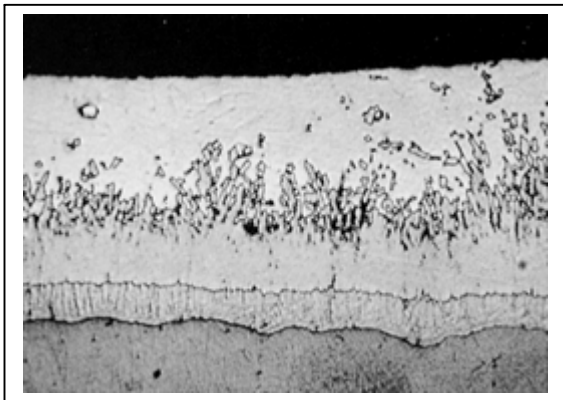
Carbon steels can be defined within two broad categories, namely

- Aluminum killed steels, < 0.03% Si, or
- Silicon killed steels, > 0.03% Si

The term “killed steels” relates to degassing and de-oxidizing during the production of carbon steels.

Coating thickness and appearances produced by hot dip galvanizing, at normal molten zinc temperatures ranging between 445 to 455°C, is a function of two chemical elements in carbon steel. These two elements, Si% and or P% or in combination, increases the metallurgical reaction when such carbon steels are immersed into molten zinc. In order to understand this reaction, a series of micrographs with associated finished product will be reviewed.

Micrographs of hot dip galvanized coatings (Magnifications of 150 to 200x)



Typical micrograph of a hot dip galvanized coating with “aluminium killed” carbon steel (Silicon < 0.03% and zinc temperature 450°C)

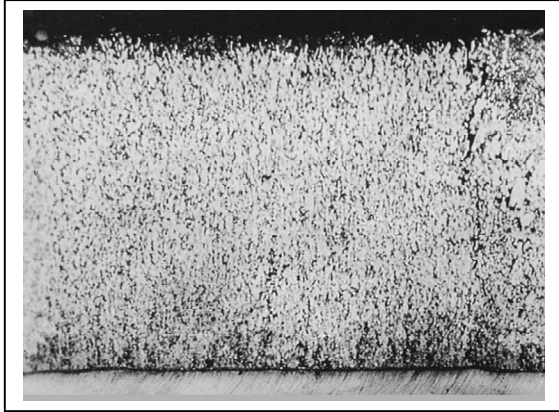


Coating thickness range between 50 to 70µm and surface finishes have a bright silvery shine. Given time (3 to 4 months exposure) all surfaces form a uniform dull grey patina of $ZnCO_3$, refer to Information Sheet No. 11 “How does zinc protect?”

Hot Dip Galvanized Information Sheet No.14

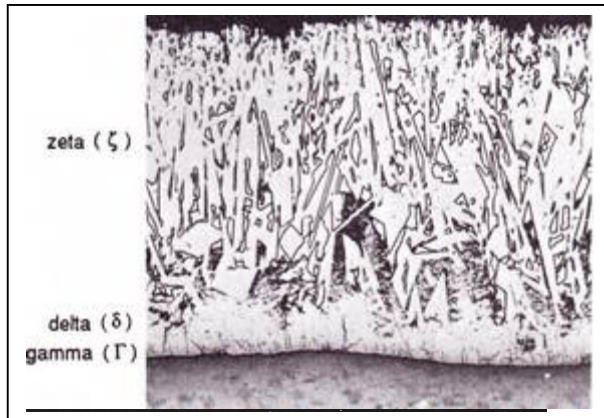
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Cross-section through zinc coating on silicon killed steel > 0.03% to <0.15%, typically Si = 0.06%

Zinc coating thicknesses range between 150 μ m to 250 μ m



Preferred structure of hot dip galvanized coating produced using "silicon killed" steel within the silicon range of 0.15% to 0.25% and P >0.02%

Zinc temperature 450°C

Coating thicknesses range from 120 μ m to 200 μ m.



Two examples of typical surface finishes obtained with varying Si% content in steel

Hot Dip Galvanized Information Sheet No.14

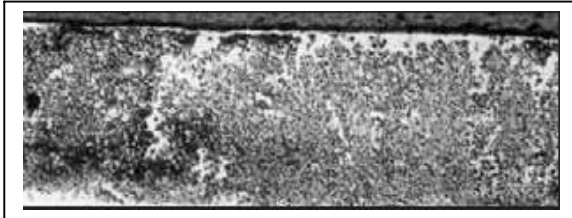
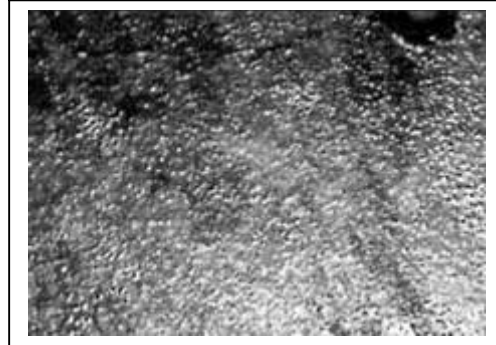
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Example of Si and P in combination

Si <0.04% and P from 0.025 to 0.035%
Localised defects due to outbursts of zeta alloy layer. e.g. "pimples" or "tree bark" effect, particularly on tubular and curved sections



With high Phosphorous (P)

Low Si <0.04%, but P >0.035%
Pronounced surface defects with tendency to flake, particularly under impact loads, such as mechanical damage from poor handling procedures



Note: The examples of extremely thick coatings, generally >200µm, are due to the development of the hard and brittle zinc iron alloy layers that propagate through to the outer surfaces. These coatings can result in different surface appearances and finishes, but do not detract from the corrosion control characteristics of hot dip galvanizing.

Aesthetics

Surface appearance of reactive "silicon killed" steel outside of the ideal silicon range of 0.15% to 0.25% and P <0.02%
This example also clearly illustrates the variation of chemical elements that occur at the surface of carbon steels components

Hot Dip Galvanized Information Sheet No.14

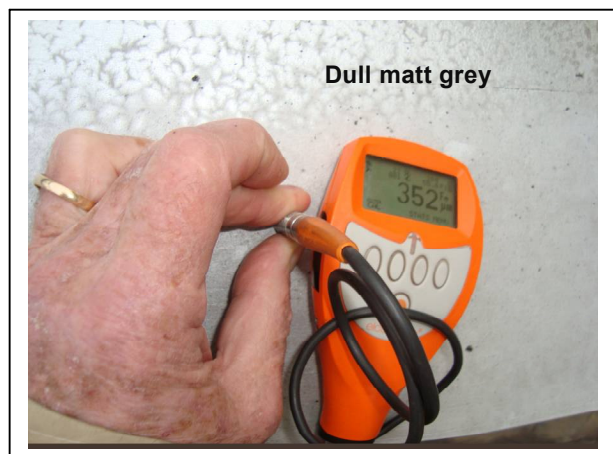
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Examples of differential cooling rates

Heat retained after hot dip galvanizing, by a concentrated mass of steel in an area will result in a continuation of the metallurgical reaction with the delta layer (matt grey colour) coming through to the outer steel surface



On the same surface

Photo A – Surface finish - Bright Silver Shine, caused as a result of relatively pure zinc solidified on the outer surface, coating thickness 414 μ m

Photo B – Surface finish – Dull Matt Grey, caused by the zinc iron alloy growth through to the outer surface and no relatively pure zinc layer, coating thickness 352 μ m

All surfaces will react with the atmosphere to form a zinc carbonate layer, (barrier protection) which is a dull matt grey finish

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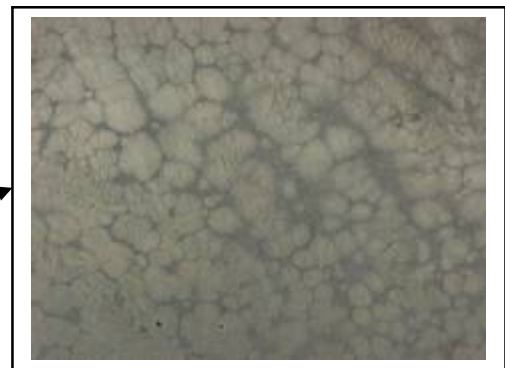
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All the examples, shown above, have been selected in order to illustrate various surface finishes, none of which represent poor quality of hot dip galvanized steel. From a corrosion control standpoint the following extract from the SANS 121 (ISO 1461:2009) specification is appropriate in terms of surface finish quality.

Appearance (Reference ISO 1461:2009 paragraph 6)

NOTE 1: The primary purpose of the galvanized coating is to protect the underlying iron or steelwork against corrosion. Considerations related to aesthetics or decorative features should be secondary. Where these secondary features are also of importance it is highly recommended that the galvanizer and customer agree the standard of finish that is achievable on the work [in total or in part], given the range of materials used to form the article. This is of particular importance where the required standard of finish is beyond that set out in this section. It should be noted that 'roughness' and 'smoothness' are relative terms and the roughness of coatings on articles galvanized after fabrication differs from mechanically wiped products, such as galvanized sheet, tube and wire. It is not possible to establish a definition of appearance and finish covering all requirements in practice.

The occurrence of darker or lighter area (e.g. cellular pattern or dark grey areas) or some surface unevenness shall not be cause for rejection: also wet storage stain (white or dark corrosion product – primarily basic zinc oxide – formed during storage in humid conditions after hot dip galvanizing) shall not be cause for rejection, providing the coating thickness remains above the specified minimum value.



Close up of the weathered surface

Weathered hot dip galvanized surface finish, dull matt grey