Coating Processes and Surface Treatments

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Improving Uniformity of Appearance

Introduction

The surface of zinc and zinc alloy-coated steel sheet can be treated using one or more of many methods. **This GalvInfoNote deals with a mechanical surface treatment used to improve uniformity of appearance.** Other treatments are used for different reasons, namely:

- Treatments for enhancing formability (see GalvInfoNote 2.9)
- Imparting resistance to storage stain (see GalvInfoNote 2.10)
- Preparing galvanize for field painting (see GalvInfoNote 2.11)
- Pretreatments for metallic-coated sheet (see GalvInfoNote 2.12)
- Treatments for resistance to handling and fingerprint marks (see GalvInfoNote 2.13)

While most of the above treatments are performed directly on the hot-dip line after the metallic coating has been applied, some can also be carried out on separate process lines/facilities, or in the field.

Improved Surface Uniformity

Whether it is galvanize, galvanneal, aluminum-zinc, or aluminum coatings, many end uses require a surface that is more topographically uniform than obtainable directly off hot-dip coating lines. This is so that the underlying surface does not show through paint coatings used for such appearance critical applications as exterior automotive body panels, some appliance parts, and prepainted building panels. The method most often used to make the surface more uniform is known as "temper passing", "temper rolling" or "skin passing" and is done with a temper mill or skin mill. Figure 1 shows strip passing through the work rolls of a stand-alone 4-high temper mill.

Fig 1 Temper Mill

(Photo source: Blair Steel Strip Company)

Figure 2 includes a schematic of a 4-high temper mill located in a continuous coating line. Both in-line and stand-alone temper mills typically consist of two back-up rolls and two work rolls. The work rolls contact the two sheet surfaces with up to several hundred tons of force. This load combined with the sheet being under high tension between the entry and exit bridle rolls imprints, in part, the work roll finish to the sheet surface. Depending on the load employed, the sheet is extended in length (and reduced in thickness) by as much as 2%, although in most cases it is in the range of 0.5 to 1.0%.

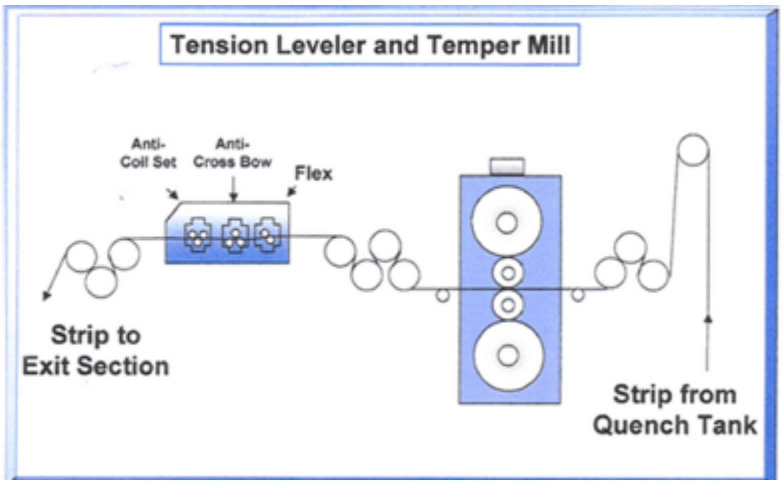


Fig 2 Schematic of in-line 4-Hi temper mill

With coated steel sheet, temper rolling is generally performed with work rolls having a blasted surface finish. The roll finish is partially imparted to the sheet surface, and has the effect of reducing the metallic sheen of bright hot-dip coatings to a uniform dull appearance. With zinc-iron alloy (galvanneal) coatings, the change to surface appearance is not so obvious. Whether the product is galvanneal or zinc coated, for automotive end uses the primary purpose of temper rolling is ensure the surface conforms to surface requirement similar to those of Figure 3.

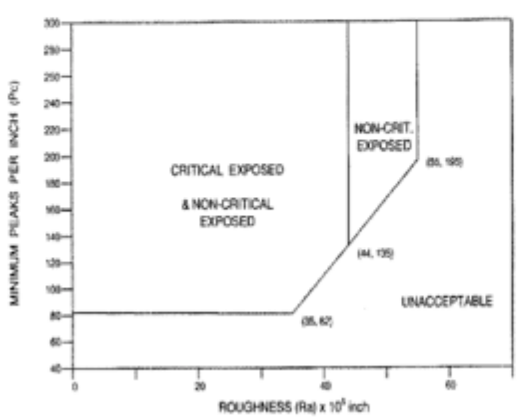


Fig 3 Automotive specified surface finish parameters

This figure is a chart of average surface roughness (Ra) versus peaks per inch (ppi). Temper passing using work rolls with the appropriate degree of surface roughness and mill load ensures that the finish imparted to the sheet has a Ra and ppi that falls into the upper left region. This guarantees the correct "distinctness of image" (DOI) on the final painted automotive panel. Sheet with too low a ppi and/or too high a Ra will result in an unsuitable painted appearance.

In the case of galvanize coatings made with lead-free zinc, the surface is quite flat after coating and temper passing using a moderate mill load is able to produce a matte surface with controlled roughness and little, if any, evidence of the zinc spangle or metallic lustre. It is difficult to flatten galvanize that is produced with large spangles because of the spangle boundary depressions. For a more in-depth discussion of spangle, see GalvInfoNote 2.6. Most galvanize products made today use lead-free zinc.

As a matter of interest, temper rolling of coated sheet is performed "wet" with a very small amount of water sprayed onto the sheet as it enters the bite of the work rolls. This is to wash away the small flakes of zinc or zinc-iron that the work rolls abrade from the sheet surface to prevent them from being rolled back into the surface as "zinc pick-up". The moving sheet is immediately dried as it leaves the temper mill.

As most temper rolling of coated sheet is done on a mill stand that is located in the coating line (although it can be done on a stand-alone mill), it is important that the sheet flatness not be adversely affected by the operation. Obtaining good sheet flatness is part of the operational control exercised during temper rolling. Given that the sheet is usually extended 0.5 to 1.0%, its thickness is reduced accordingly. To achieve the optimum final sheet thickness, allowance for temper rolling should therefore be made when calculating the required cold-rolled sheet thickness set-point value.

Eliminating Stretcher Strains

The small amount of cold work imparted to the steel by temper rolling to smooth the surface finish has the added benefit of eliminating the yield point phenomenon exhibited by low carbon steel (if not temper rolled, leveling of the sheet also accomplishes this). The upper yield point is the peak in the stress-strain curve shown in Fig 4, at the left near YS. For many end uses it is important to suppress this peak because if not done, the sheet will show discontinuous yielding behavior due to yield-point-elongation (YPE), and will exhibit stretcher strains when stretch-formed, or flute when bent. The upper yield point and YPE is associated with interstitial elements such as carbon and nitrogen in the steel. Yield-point-elongation is deformation that occurs at constant load.

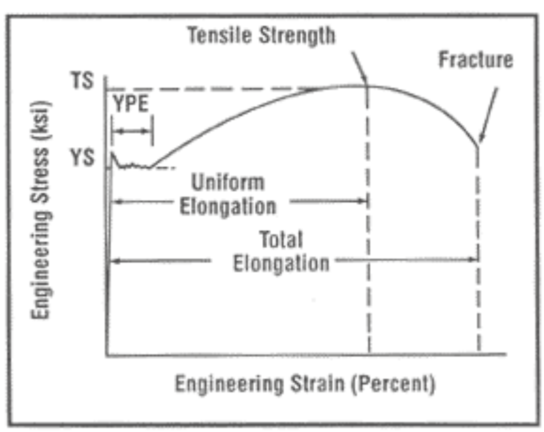
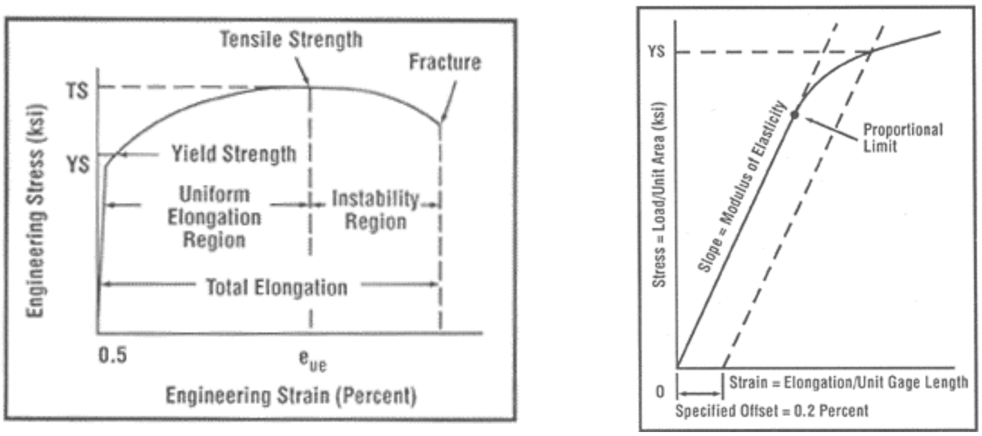


Fig 4 Stress-strain curve with yield point phenomenon - (Source: Auto/Steel Partnership)

The small amount of cold work imparted to the sheet during temper rolling (or leveling) suppresses the yield point phenomenon as evidenced in the shape of the stress strain curve in Fig 5 (a). With the discontinuous yielding behavior having been masked, the steel can be formed with no concern about stretcher strains or fluting. The resulting small changes in mechanical properties are generally not harmful to subsequent forming operations or the properties of the final part. Heavy temper passing could impart too much cold work to the sheet and detract from formability. Lead-free zinc coatings help in minimizing unwanted cold work, as only moderate temper mill loads are necessary to achieve the necessary smoothness. A rougher, spangled coating might require such high rolling loads that the mechanical properties, formability, and flatness characteristics would be adversely affected.



(a) (b)

Fig 5 Stress-strain curve with no yield point phenomenon (a), and 0.2% offset YS (b) - (Source: Auto/Steel Partnership)

For the stress-strain curves of Fig 5, the yield strength can no longer be measured as a distinct yield point, so the most popular convention is to measure it at 0.2% offset strain. With this method, shown in Fig 5 (b), the YP is defined as the point where a line, offset at 0.2% strain, and drawn parallel to the slanted, elastic modulus line, crosses the plastic rounded part of the stress-stain curve. The value obtained by this method may, in fact, be slightly less than the upper yield point of Fig 4. It must always be remembered, however, that with ageing, the yield point will return over time. The steel must be consumed within a reasonable period to avoid this happening.

Discontinuous yielding does not occur on steels made from stabilized ultra-low carbon steel. The complete absence of solute carbon and nitrogen in these steels removes the yield point. Stress strain curves for such steels are the same as those of Fig 5 without temper rolling or leveling and they are not subject to strain lines.

Non-Matte Smooth Surfaces on Coated Sheet

While the above discussion focuses on the use of blasted temper mill work rolls, some non-automotive coated sheet is temper passed using smooth-ground work rolls. These rolls impart to the sheet a smooth and non-matte shiny appearance that has a very low average roughness (Ra) value. Such an appearance is preferred for some end uses.

Summary

When required, the surface finish of metallic-coated steel sheet can be controlled very closely to provide a smooth and uniform appearance for critical end uses. The use of in-line equipment to achieve this allows it to be done not only at will, but with consistent results. Improvements to mechanical properties can also be achieved.