From skin pass to paint – evaluation of measurements of sheet metal waviness and roughness throughout the processing chain

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Abstract

Sheet metal for manufacturing the outer panels for passenger cars is produced with defined surface topography. Various techniques to produce this so called texture are well established. The surface texture is commonly described by various 2d roughness parameters, such as the arithmetic average of roughness R_a and peak count RP_c. During deep drawing a defined roughness and peak count allows predictive sliding behaviour since it controls the mobility of lubricants and reduces static friction by lowering the bearing ratio. It is well known, that roughness parameters have to be kept within certain limits as not to compromise the following painting steps. Regarding the tendency of car makers to reduce the number of painting steps and thereby also the total coating thickness, also the yet more or less undescribed waviness of the sheet becomes more important.

Our study presents the evolution of various topography parameters from skin pass rolling over electrogalvanizing and deep drawing to ED-painting. After each processing step several 2d and 3d parameters of roughness and waviness are gauged and the changes are discussed. Investigations were carried out using mechanical profile methods and optical devices such as areal confocal microscopy and wave-scan combined with advanced post processing approaches for measurement data analysis. Special attention was paid to the wave-scan method which is usually employed to characterize high gloss finish coatings regarding orange peel appearance. To expand the limit to rather dull metal and ED-painted surfaces a high gloss adhesive tape was used. Thus, data from all steps of the examined processing chain could be obtained.

Keywords

waviness, wave-scan, longwave, processing chain, outer panels, galvanized steel sheet, deep drawing, ED-painting

1 Introduction

Galvanized cold rolled steel sheet is the state of the art material for outer panels of mass produced car bodies. In order to provide superior surface finish after deep drawing its surface topography is made according to customer specifications. Various techniques to produce textured rolls are well established. Salzgitter uses the PRETEX® topography, which is based on structural chrome plating of the steel roller surface. In contrast to shot blasting or other engraving procedures, the galvanic process allows the production of elevated hemispherical elements of controlled size and lateral density with fully stochastic distribution. Fig. 1 shows graphical images[3] of surfaces with different densities of the structural elements.

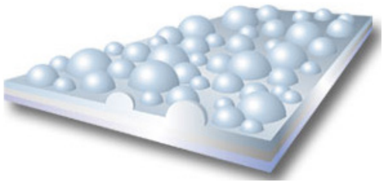

Fig. 1a: PRETEX® low density.

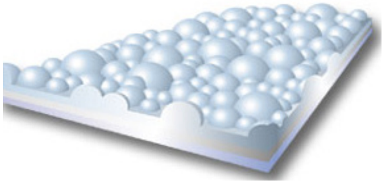

Fig. 1b: PRETEX® high density.

[3] provided by Topocrom GmbH

By slight cold rolling with textured rolls the so-called skin pass rolling (Fig.2), the structure of the roller surface is transferred to the metal sheet.

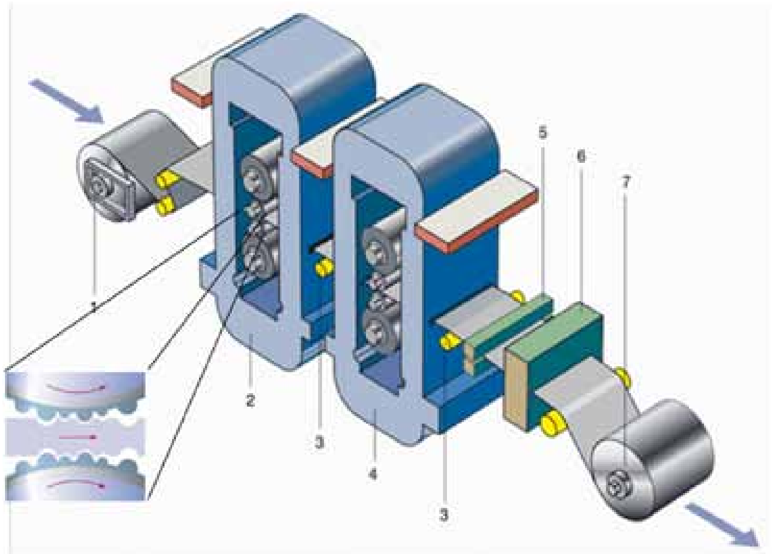

Fig. 2: Schematic of the texturing process during skin pass rolling.

For a better understanding of our work, it is important to know that skin pass rolling can take place at two different points of the production chain (Fig. 3). Usually it is performed as a pre galvanizing step for electrogalvanized strip (“EG”) while it is a post galvanizing step for hot dip galvanized surfaces (“HDG”). Hence alterations of the substrate waviness by the galvanizing process may occur in different ways.

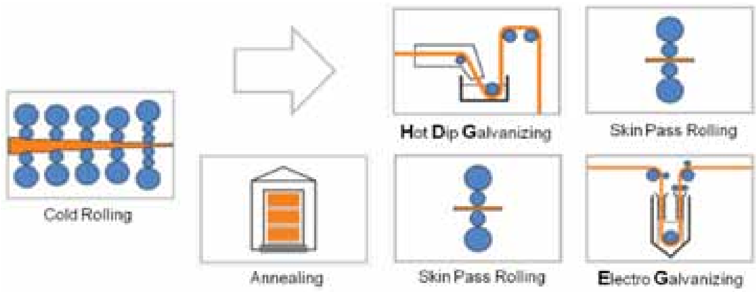

Fig. 3: Production chain for galvanized steel sheet.

2 Roughness and waviness

Currently the surface texture is commonly described by various 2d roughness parameters, such as the arithmetic average of roughness R_a and peak count RP_c [1]. However, many car manufacturers are about to define waviness limits [2] in order to control the optical appearance of the paint finish, in particular of horizontal parts e.g. roofs and bonnet. While the typical roughness of the substrate almost vanishes throughout the electrodeposition painting (“ED-painting”) (Tab. 1), its waviness may interfere with the paint structure and cause an undesired “orange peel” look. This is in particular true for painting processes without filler paint.

Tab. 1: Roughness parameters before and after ED-painting.

Processing step	Ra [µm]	RPc [1/cm]
EG steel surface	1.34	105
ED-painting, vertically cured	0.24	14
ED-painting, horizontally cured	0.25	11

The waviness of the substrate is commonly measured by tactile profile measurement or derived optical methods [3] while the paint finish is often measured by the optical wave-scan method of Byk [1]. Both methods use filtering techniques to capture wave length from ~0.5 mm up to ~10 mm but use different units. The wave-scan method depends on glossy surfaces [4]. Thus it can’t be easily utilised for measurements of semi-finished products e.g. steel substrates or ED-paints, since their surfaces are rather dull. Gloss measurements on different surfaces were done with a micro-tri-gloss meter in 20° geometry. The results are summarized in Tab. 2.

Tab. 2: Gloss of different surfaces measured in 20° angle.

Processing step	Gloss [GU]
EG steel surface	14
ED-painting, vertically cured	19
Clear coat	108
High gloss tape	109

In order to assess changes in waviness after each processing step by the wave-scan method, trials with high gloss clear paint and high gloss tape where conducted. It was found that high gloss tape alters the typical clear coat waviness towards slightly higher values (Fig. 4) while the total impact of clear coat depends on the application conditions, e.g. the number of spray passes (Fig. 5) or else.

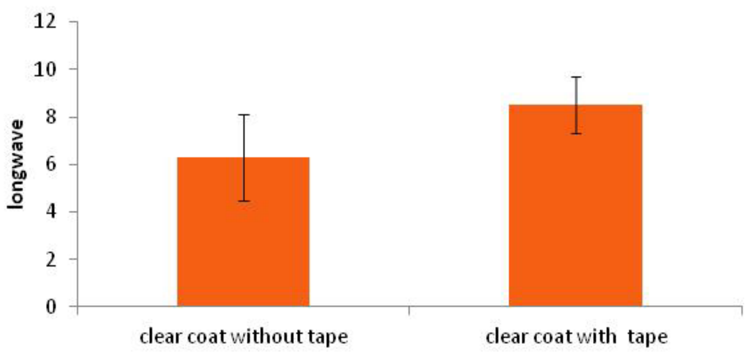

Fig. 4: Wave-scan measurement on clear coat with and without high gloss tape.

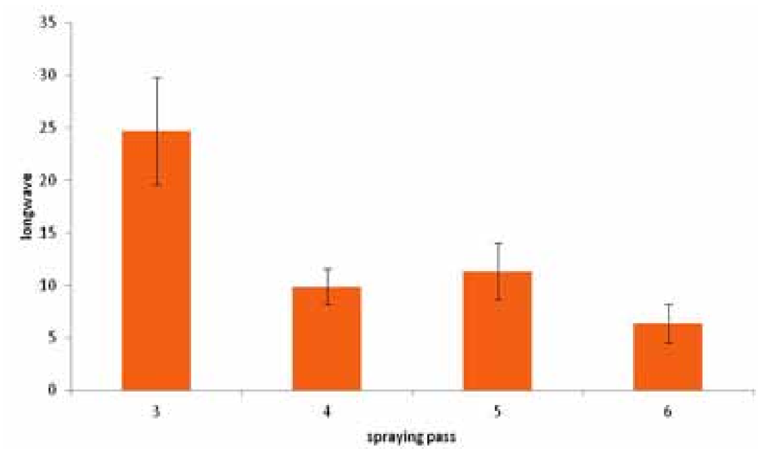

Fig. 5: Dependence of waviness on the number of spray passes.

As shown above the use of tape to obtain surfaces suitable for wave-scan has several advantages over the use of clear coat. The application of tape is more reproducible and less time consuming than spray painting. Moreover it allows measurements on identical samples throughout the whole processing chain because it can be removed from the respective surface.

3 Wave-scan measurements along the processing chain

Based on this method the longwave parameter of a steel sheet for outer panels (DC06; R_a=1.12 µm, RP_c= 85 /cm, 0.75 mm) was assessed from skin pass rolling to ED-painting. It seemed reasonable to exclude further painting steps as spray coating has shown to have non predictable influence on the surface waviness (Fig. 5).

3.1 Evolution of longwave values throughout the processing chain

Fig. 6 shows longwave values of the steel sheet described above throughout the processing steps electrogalvanizing, deep drawing and ED-painting. Electrogalvanizing was performed in the production line yielding zinc layers of approximately 7.5 µm. Deep drawing was done according to the Marciniak method [5] with an total elongation of about 3 % in order to avoid the formation of Lüders lines. ED-painting was carried out in a lab scale apparatus using a typical OEM product for car bodies with 18-20 µm layers thickness. Moreover all wavescan measurements were performed parallel and perpendicular to rolling direction in order to be aware of anisotropic influences.

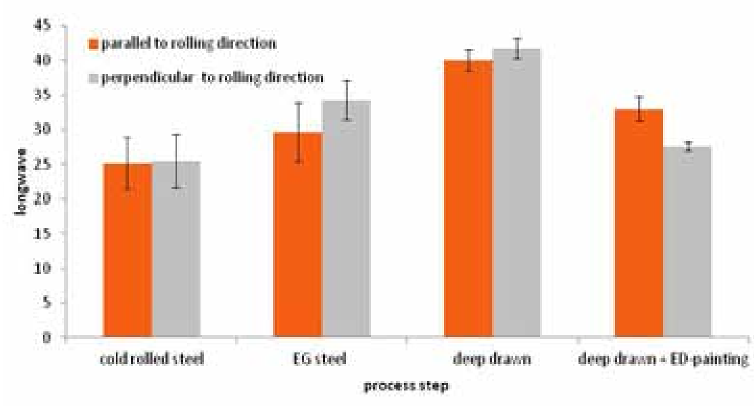

Fig. 6: Waviness characteristic of a steel surface throughout the processing chain.

3.2 Influence of hot dip galvanizing process on the surface waviness

As shown in Fig. 3, hot dip galvanized steel sheet is produced using a processing route different from electrogalvanizing. Access to skin pass rolled HDG surfaces is only possible in galvanized state. Thus the effect of hot dip galvanizing on the longwave parameter was studied by removing the zinc layer with hydrochloric acid (10 %) from a HDG steel sheet for outer panels (DX57; Ra=1,05 µm; RPc= 85 /cm, 0,75 mm). A comparison of results is given in Fig. 7.

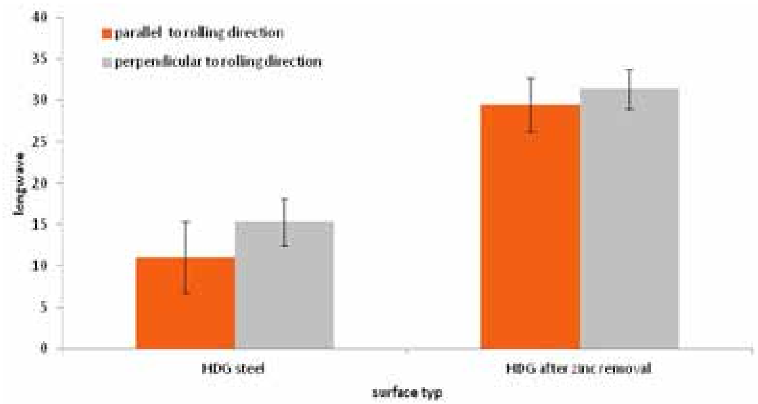

Fig. 7: Comparison of HDG surface waviness before and after zinc removal.

3.3 Influence of the curing orientation after ED-painting

To verify the possible influence of the curing orientation after ED-painting, similar samples of EG steel sheet were ED-coated in vertical position. The curing orientation was varied, while curing parameters were kept constant (180 °C, 20 min). Fig. 8 shows the longwave values from wave-scan measurement with tape. Additionally, the corresponding Wsa(1-5) values obtained by tactile measurement according to [3] are given in Fig. 9.

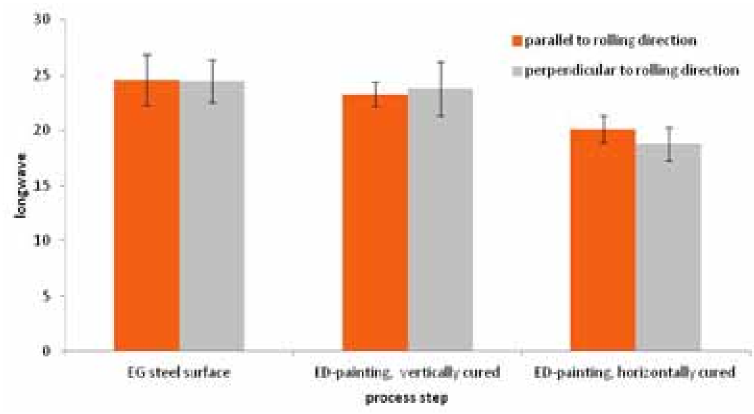

Fig. 8: Influence of curing orientation of ED-painting on surface waviness (wave-scan method).

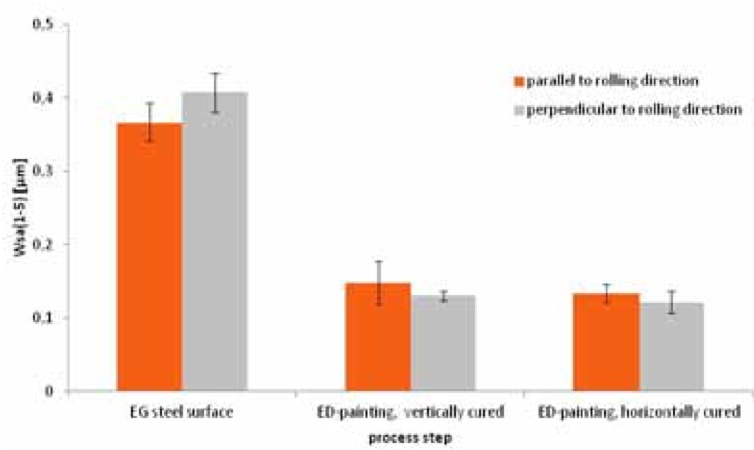

Fig. 9: Influence of curing orientation of ED-painting on surface waviness (tactile method).

4 Discussion

The main processing steps of sheet steel and car production were analyzed regarding their impact on the longwave parameter derived by wave-scan. All measurements were done parallel and perpendicular to the rolling direction, but no significant influence of the measuring direction was observed. Thus the propagation of the longwave parameter is isotropic in x-y direction.

The electrogalvanizing step was found to slightly increase in surface waviness (Fig. 6). In contrast hot dip galvanizing (Fig. 7) was found to level out the original waviness of steel substrate by molten zinc.

A significant increase of the surface waviness was found after deep drawing (Fig. 6). As the Marciniak method is designed to ensure frictionless biaxial stretch forming the increase in waviness has to be discussed in terms of localized inhomogeneity in material flow.

After ED-painting almost no surface roughness could be measured anymore (Tab. 2) while the original waviness of the substrate was reproduced quite well in case of vertically cured ED-paint. Similar to hot dip galvanizing horizontally cured ED-paint shows a tendency to level out the substrate waviness (Fig. 8).

Utilization of tactile methods to assess the propagation of surface waviness seems to be limited to metallic surfaces since measurements on ED-paint have given no reasonable results (Fig. 9).

5 Summary

The longwave parameter obtained by the wave-scan method is an important standard for car manufacturers to evaluate the optical quality of the paint finish. The aim of our investigation was to enable this method for measurements on unfinished surfaces. This would help to estimate the effect of single steps of the processing chain on the waviness before spray painting.

Using wave-scan and high gloss tape the effects of electro and hot dip galvanizing, forming, ED-painting and ED-paint curing orientation were analyzed regarding their impact on the longwave parameter. It was found that forming increases the waviness while hot dip galvanizing or curing in horizontal orientation level out surface waviness to some extent. Tactile methods to assess waviness yielded questionable results on ED-painted surfaces.

References

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