Aesthetic surfaces created with the Electron Beam texturing technology

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ABSTRACT

The final surface topography of galvanized steel sheet is obtained through skin passing using textured rolls. Electron Beam Texturing (EBT) is one of the well known techniques available today to texture the working rolls. This technology distinguishes itself from others in that it allows a fully deterministic lateral pattern of craters yielding a superior forming and painting performance. Recently, an innovative and fascinating potential with EBT has been developed. In particular, it has become possible to imprint any image (e.g. in bitmap format) on the working rolls in which the difference in roughness produces the visualisation of the picture. Thus, the system can be compared to a giant laser printer where the ink dots are replaced by EBT craters of different dimensions. Obviously, this creates a vast amount of applications ranging from quality labelling (logo's, watermarking) to purely aesthetic and decorative surfaces. In this paper, this new functionality of EBT is discussed in detail and the results of some preliminary trials with hot dip galvanized material are presented.

1. Introduction and concept

In recent years, it has become a major point of interest to offer galvanized steel products with specific and innovative surface functionalities. In this work, we focus on the creation of aesthetic metallic coated steel surfaces exploiting the possibilities of Electron Beam Texturing (EBT). This is a well known technique used to texture work rolls for sheet metal production [1]. As schematically shown in Figure 1, this process uses an electron beam (3) gun to generate local melting of the roll surface. As the roll is placed in a vacuum chamber (1), oxidation of the molten material is prohibited allowing a better adherence of the rims to the surface. The high frequency (up to 200 kHz) electromagnetic focusing system (2) is synchronized with the rotating and transverse shifting movement of the roll.

Compared to other existing technologies, EBT allows a fully deterministic pattern of craters with well defined dimensions and distances between the craters, a feature that leads to superior forming and painting performance [e.g., 1]. Recently, the texturing process and control has been further optimised and it was decided to extend the new operating system with the possibility of creating pre-defined images on work rolls. By changing the roughness in a fully deterministic way, one can visualize any desired pattern on the rolls. Although the principle of this new concept is relatively simple, the implementation in production environment is not so straightforward and requires the latest state-of-the art electronics. The grey levels of the targeted image (e.g., supplied in a *.bmp file) are translated into different e^--gun control parameter sets. The machine can be compared to a giant laser printer where the ink dots are replaced by craters of different dimension (mainly depth, see below). In principle, 16 different grey levels or 'colours' can be converted in 16 different roughness levels). A lateral image resolution of 100 µm is obtained. Once the patterns are printed as intended on the rolls, they can be transferred to the galvanized steel sheet during the skin pass.

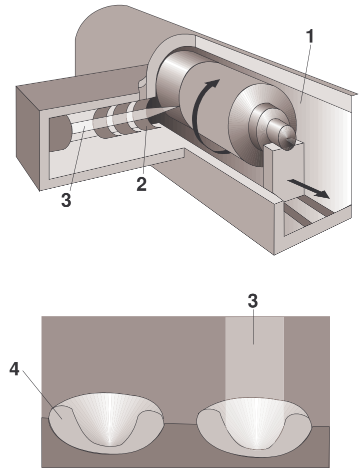

Figure 1: Working principle of the Electron Beam Texturing process

Today, few technologies are capable of generating pre-defined images or patterns on steel sheet in a fast, affordable and perfectly reproducible way. An isolated example is the use of etched rolls (e.g. in a stainless steel mill), but this technology has a few severe shortcomings including a high texturing cost and these rolls are very susceptible for damage in the mill. Another possibility is to make use of the interference effect of multiple EBT patterns (e.g. tandem and temper mill textures), leading to a visible macroscopic Moiré effect. However, it is nearly impossible to create any pre-defined image by this effect and to guarantee the required reproducibility. The present paper will clearly demonstrate the potential to use EBT for producing aesthetic (metallic coated) steel sheet with patterns as desired ('custom made products'). The first feasibility trials are very promising and show a wide range of applications. Generally, it gives the opportunity to produce aesthetic and decorative steel surfaces making flat steel products an appealing material for designers.

Initially, the above concept has been verified by considering only two grey or roughness levels by changing the depth of the EBT craters (controlled by the intensity of the e^--beam) while keeping the distance between the craters constant. In this case, both roughness levels are obtained by the EBT process, i.e. all areas of the roll were textured. Alternatively, instead of lowering the intensity according to the contours of the image, one can choose to completely switch off the e^--gun in certain areas leaving these untouched during the texturing process. The surface in these particular regions of the roll will remain very smooth (rolls are normally ground before texturing) resulting in an increased roughness difference and thus a higher contrast in the images. In the framework of some first feasibility trials both options have been implemented. The results of these preliminary trials are described in the next section.

2. Results from feasibility trials

For a first trial, a skin pass roll was textured with two different images, the Arcelor logo and a regular aesthetic pattern of stripes, see Figure 2. As explained above, the contrast in these images was obtained through the creation of areas with different depths of the EBT craters. In this particular case, the difference in depth is of the order of 10 µm. Subsequently, the textured test roll has been applied at the skin pass of the cold rolling mill at Sidmar on a non-skinned hot dip galvanized coil. The first important observation was the excellent transfer of the images onto the surface of the steel strip leading to a good visual and aesthetic aspect with a very clear impression of the images. This demonstrates **the possibility to indeed produce well defined images on steel surfaces by this technology**.

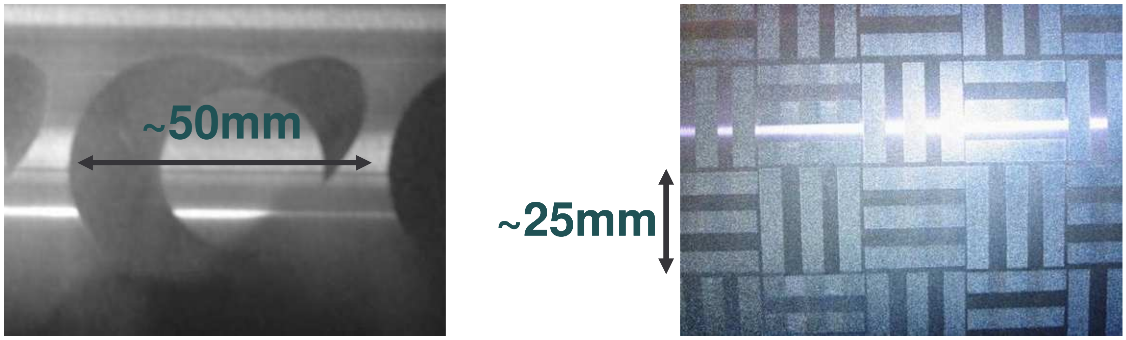

Figure 2: Images on the first test roll (logo and pattern of stripes)

Several laboratory tests and characterizations have been performed on these first industrial samples. An example of a 3D roughness measurement (with a stylus instrument) of the logo is given in Figure 3. An interesting and important result is shown in Figure 4: a 2D profile is extracted from the 3D scan, running over the different areas. Clearly, the average height of the profile inside the logo is equal to the one outside the logo, thus it is only the amplitude of the roughness profile that varies when moving from one zone to another. A number of 2D roughness parameters (measured in the rolling direction) for both regions are summarized in Table 1. The determination of the mean roughness Ra reveals a difference of almost 3 µm between the two textures.

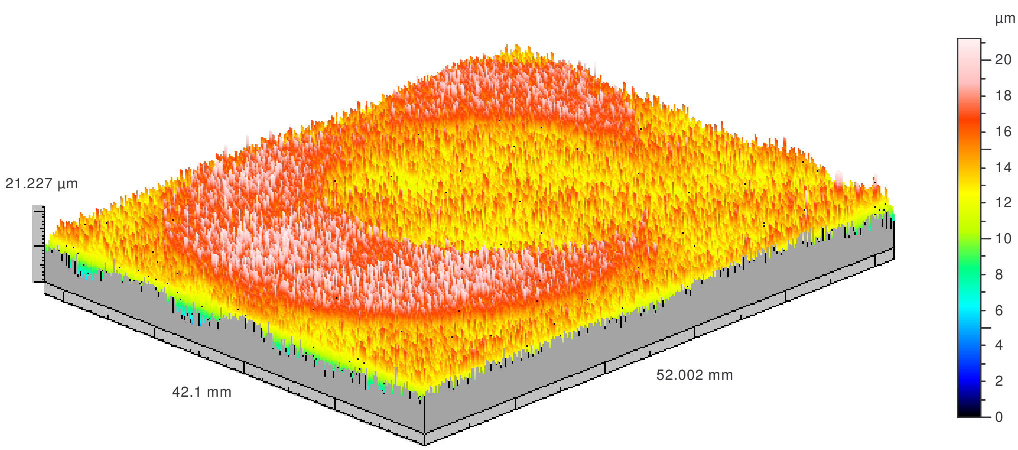

Figure 3: 3D stylus measurement of the Arcelor logo on a sheet sample from the first trial

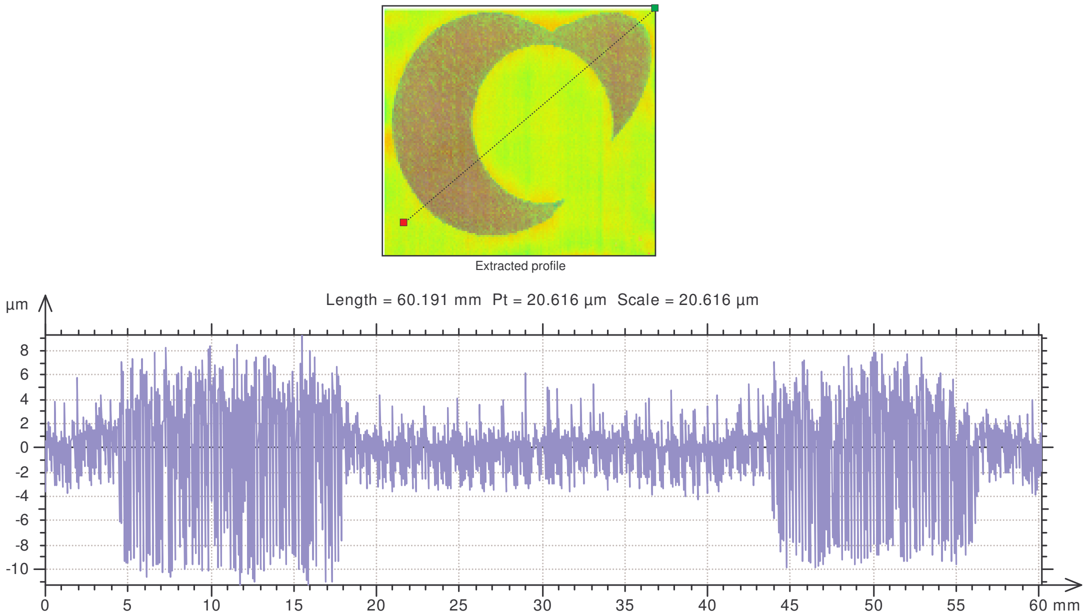

Figure 4: 2D profile (below) taken in a 3D scan (top) from the lower left corner to the upper right one (measurements on sheet).

Position	Ra (µm)	Rt (µm)	RPc (pks/cm)
Inside logo	4.05	21.2	53
Outside logo	1.28	9.9	80
Inside stripe	4.19	23.3	52
Outside stripe	0.99	8.1	71

Table 1: 2D Roughness parameters on steel sheet, determined in the two different roughness regions to create the image

Subsequently, we studied the performance of the material in and after forming operations with some Marciniak tests. It is observed that a typical pre-strain (for exposed panels) of about 3 % (in this case bi-axial deformation mode), does not reveal a deterioration of the visual aspect. In addition, no other problems during the forming operations due to the relatively high roughness differences have been experienced. Obviously, it can be expected that, for higher strains on the other hand, the shape of the images will be stretched so that the initial appearance may be modified.

An important issue for these innovative surfaces is the application of different coating systems and the effect on the final aspect of the surface. In some cases it might be appropriate to hide the image by covering it with a paint layer. In this way, it would be possible to apply **the idea of watermarking** or **quality label** on steel products. For aesthetic coil coated products, on the other hand, it would be more convenient to retain the visibility of the image after coating (typically thickness range of 15-25 µm). Analogously, when creating a specific aesthetic surface on the substrate, one intends to have the pattern still visible after applications of thin (µm range) layers applied to improve corrosion resistance, anti-fingerprint, etc. Laboratory tests have demonstrated that **several applications are feasible**. Application of transparent coatings like a thin organic coating or powder varnish shows that the images become even more expressed and the contrast between the two grey scales is amplified. Powder painting with a standard PE powder for the domestic appliances market, on the other hand, shows that with a normal layer thickness of about 70 µm it is easily possible to cover the Arcelor logo so that a watermarking becomes available. Going down with the coating weight to 40 µm shows that the pattern of stripes remains visible, even with an “intended” high orange peel aspect. In addition to these laboratory painting trials, a part of the test coil was industrially processed at one of the coil coating lines of Arcelor. Two different systems (with different colours of the top layer) were considered: a 15 µm system with a white top layer, and 30-35 µm system with a brown top layer. In both cases, the images on the steel substrate are still visible with the organic coating on top of it.

Recently, a second trial was launched in order to verify the above results as well as to test a number of other concepts. Firstly, a pair of skin pass rolls (top and bottom) was textured in this case with different bands (of about 300 mm width) each containing a specific image. For some patterns, three different roughness levels were required to print the image onto the roll. An important difference with the previous trial concerns the lowest roughness level used to yield the contrast in the images. As mentioned in the introductory section, this level can be kept extremely low by leaving the roll untouched instead of applying and EBT topography with shallow craters (and thus low roughness). Thus, in this case some well defined areas of the roll, according to the contours of the desired picture or pattern, will remain very smooth, increasing the roughness difference with the textured areas and, consequently, the contrast in the images. Another alternative that was tested was to create so-called ‘inverse’ images for which precisely the areas of the roll between the pictures are textured while keeping the initial low roughness surface inside the pictures (the first images were produced in the opposite way). In general, **the texturing for this second trial was very successful**, all possibilities as just explained were perfectly implemented and a good aspect on the rolls (with increased contrast) was obtained. For example, the attempt to have three grey levels required to have a print of the image shown in Figure 5 (illustration of a neuron with shadow) has been succeeded.

As for the initial trial, skin passing with these textured rolls leaves **a good imprint of the pictures** onto the galvanized steel surface. Currently, a full characterization of the samples is being performed in order to comprehend the effect of the presence of large non-textured regions on the rolls on the final contrast in the images on the steel sheet. This should lead to a better view of the most optimal conditions to produce these innovative products.

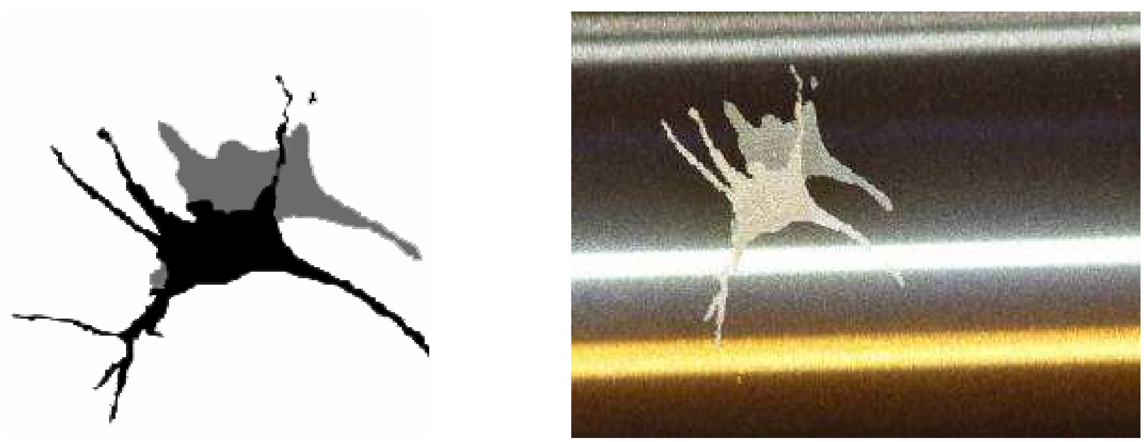

Figure 5: Illustration of a neuron with shadow (left) successfully printed on a skin pass roll (right) using EBT. For this image, three different grey levels were required.

3. Conclusions and outlook

Recent advances in the technology of Electron Beam Texturing make it possible to create pre-defined images and patterns on working rolls for steel sheet production. The outcome of the first feasibility trials with such rolls is very promising. It has been observed that the transfer of the patterns during the skin pass onto the hot dip galvanized steel surface is accurate and efficient. Future studies have to determine the texturing and rolling conditions that yield the optimal visual appearance on the steel sheet. The results of the first trial already indicate that the following approach will give satisfying surfaces: application of an EBT texture both inside as well as outside the images (with variation in crater depth). A possible alternative might be the concept of 'inverse' images, in particular for a non-continuous pattern such as logos, or more general individual images. As explained above, in this case there is an EBT topography in the areas between the images while the images themselves remain smooth. Finally, it is essential that the surface of the hot dip galvanized material before skin passing with the textured rolls is of high quality since the main target is to create aesthetic and decorative steel surface for exposed applications.

Preliminary tests with different coating systems have already demonstrated the multitude of possible applications. However, further research is required to completely assess the behaviour of the new surfaces in combination with existing or innovative coating layers (e.g. colouring the surface). Other aspects for future tests include phosphating, the application of high gloss powder coats, the corrosion resistance (blank and coated), the friction behaviour, etc.

4. References

[1] M. Vermeulen, A. De Boeck, S. Claessens, J. Antonissen, J. Scheers, *Sheet metal processing, texturing and coating methods in view of application manufacturing steps Robust Filtering applied to Sheet metal Surfaces*, Proceedings of 9th International Conference on Sheet Metal (SheMet 2001), p 3- 26, Leuven, KUL, 2-4 April 2001.

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