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Surface topography evolution through production of aluminium offset lithographic plates

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ABSTRACT

The topographies of cold rolled, alkaline etched and electrograined specimens of AA1050 alloy have been examined by scanning electron microscopy, and ultra-low-noise inteferometry with data analysis by TalyMap software. The objectives of this work were to trace the topographical history contributing to the roughness parameters of fully convoluted, electrograined surfaces, to investigate the differences in pit shapes produced under different conditions and to explore their effect on the fluid retentive properties of the aluminium substrate. The analysis of 3D parameters, such as S_a, S_{sk}, S_{tr}, S_{al}, S_{dr}, S_{ku} and S_v/S_z, disclosed the changes in typical topography from topography of rolling lines, with transverse tearing, to the topography of highly populated pits. Pit volumes were calculated after partitioning the surface by depth, using S_k functional parameters to define bearing area thresholds. Through this combined approach, simple functional void volume parameters and analysis of cross-sections at the top of the deepest layer (S_{vk}) were sufficient to differentiate important features visible in plate topographies where roughness parameters had previously failed. Whilst amplitude parameters were sufficient to distinguish tearing or scallops after alkaline etching, the features of electrograining, such as double pit structures and shallow lateral pit development, were separated using analysis of S_k functional parameters, where the tips of deep pits that occupy the S_{vk} layer revealed pit shape and were excellent indicators of the quality of the macroscopic electrograined surface.

1. Introduction

In lithography, an image on a plate is transferred to paper on a printing press [1] through the separation of ink and water [2,3] at discrete oleophilic image areas (dots) and hydrophilic non-image areas on the plate. The water–ink balance on the press, an essential parameter relating to the quality of the print, depends on several factors including plate roughness [4,5]. Deliberate roughening of the plate surface is engineered during production, where the aluminium coil is subjected to chemical cleaning or etching and then to an electrograining process [6–10] that provides the required surface convolution through development of pit structures on the surface. After roughening, the coil is anodised and, before cutting into individual plates, it is coated with a 1 μm thick heat or light-sensitive oleophilic organic coating [11–14]. Prior to use, the image is produced, for example on the positive plate, by selective removal of organic coating from non-image areas, exposing the underlying hydrophilic, anodised aluminium surface.

It has been established that the engineered roughness of the aluminium substrate is important in understanding the durability of a printing plate during its life to which the adhesion and wear of the organic coating are critical [15–17]. Therefore, the pit geometry that constitutes the roughness is important to the production of the plate and on-press performance of the anodic and organic coatings [18,19]. In modern computer-to-plate laser technology [20,21], it is advantageous to produce a shallow topographical profile on the electrograined plate. This shallow profile reduces the scattering of the laser beam used to expose the image on the organic coating [22] and allows application of a thinner coating, with consequent reduction of exposure time to the laser.

Since the height range of the topographical profile of the electrograined aluminium substrate is greater than the combined thicknesses of the anodic film and the subsequently applied organic coating, quantification and optimisation of surface roughness are important steps in achieving desirable printing properties for the lithographic plate. Testing of plates with different pit sizes [23] has confirmed that a compromise is necessary in pit design: acceptable pits are sufficiently large to allow the necessary fluid retention for good printing, but sufficiently small to enable fine resolution to be achieved. The topography is used for simple differentiation between successful and unsuccessful electrograining as well as

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Nomenclature

Amplitude profile parameters ISO 4287

- R_a arithmetic mean deviation of the assessed profile
- R_{sk} skewness (asymmetry) of the assessed profile
- R_t total height of the profile on the evaluation length
- R_{pm} maximum profile peak height within a sampling length
- R_v maximum profile valley depth within a sampling length
- R_z maximum height of the profile within a sampling length

Profile functional parameters based on the linear material ratio curve (ISO 13565-2)

- R_k kernel roughness depth (roughness depth of the core) is the efficient roughness of the profile, without taking into account the elevated peaks or the very deep valleys
- R_{vk} reduced valley depth (roughness depth of the valleys) characterises the depth of the valleys below the kernel zone of the profile, R_k
- R_{pk} reduced peak height (roughness depth of the peaks) characterises the height of the peaks above the kernel zone of the profile, R_k
- R_{mc} inverse material ratio is the height (from the mean plane) at a given material ratio
- Mr_2 lower material ratio
- Mr_1 upper material ratio

Height areal parameters ISO 25178

- S_a arithmetical mean height. Mean surface roughness
- S_p maximum peak height is the height between the highest peak and the mean plane
- S_v maximum pit height is the depth between the mean plane and the deepest valley
- S_z maximum height is the height between the highest peak and the deepest valley
- S_{sk} skewness of the height distribution is third statistical moment, qualifying the symmetry of the height distribution
- S_{ku} kurtosis of the height distribution is fourth statistical moment, qualifying the flatness of the height distribution

Spatial areal parameters ISO 25178

- S_{al} auto-correlation length is the horizontal distance of the autocorrelation function (tx, ty) which has the fastest decay to a specified value $s = 0.2$
- S_{tr} texture-aspect ratio is the ratio of the horizontal distance of the autocorrelation function (tx, ty) which has the fastest decay to the horizontal distance which has the slowest decay to a specified value $s = 0.2$. If the value is near 1, the surface is isotropic with the same characteristics in all directions. If the value is near 0, the surface is anisotropic with periodical topographical features

Hydrid areal parameter ISO 25178

- S_{dr} developed interfacial area ratio is the ratio of the increment of the interfacial area of the scale limited surface within the definition area over the definition area. The developed surface indicates the complexity of the surface by the comparison of the curvilinear surface and the support surface. A completely flat surface has $S_{dr} = 0\%$

Areal functional parameters based on the linear material ratio curve (ISO 13565-2)

- S_k kernel roughness depth (roughness depth of the core)
- S_{vk} reduced valley depth (roughness depth of the valleys) characterises the depth of the valleys below the kernel zone of the profile, S_k
- S_{pk} reduced peak height (roughness depth of the peaks) characterises the height of the peaks above the kernel zone of the profile, S_k
- Sr_1 upper material ratio
- Sr_2 lower material ratio
- S_{mc} inverse areal material ratio is the height (from the mean plane) at a given areal material ratio
- A_{vc} area of the surface at threshold on the level of the S_k layer
- A_{vv} area of the surface at threshold on the level of the S_{vk} layer

Functional volume parameters ISO 25178

- V_{vp} the void volume, ml/m^2, and percentage of void volume, %, in the S_{pk} layer in relation to the material volume
- V_{vc} core void volume of the scale limited surface, ml/m^2, or percentage of core void volume, %, in the S_k layer in relation to the material volume
- V_{vv} pit void volume of the scale limited surface, ml/m^2, and percentage of void volume, %, in the S_{vk} layer in relation to the material volume
- $V_{vf} = V_{vc} + V_{vv}$ the functional retentive volume of the voids, ml/m^2
- S_{mvr} the total closed volume of the voids, ml/m^2. This is the total volume of void of the surface obtained by measuring the space between the points of the surface and an imaginary horizontal plane at the maximum altitude of the surface.

Others

- V_{vd} the minimum volume of the deepest pits (ml/m^2)
- V_{vs} volume of typical pits where the volume of the deepest pits is ignored (ml/m^2)
- N_{pt} population density of pit tips (μm^{-2})
- d_t mean equivalent diameter of pit tip (μm)
- D_p mean pit diameter (μm)
- v_f mean functional volume of the pit (μm^3)
- N_p population density of pits (μm^{-2})
- h mean pit height (μm)
- d mean equivalent diameter of pits (μm)
- a mean pit area (μm^2)

for optimisation, although patents generally use unsophisticated descriptions of target values for mean pit mouth diameter, centre line roughness or maximum difference in height [24,25].

The 2D roughness of electrograined surfaces has been measured by line profilometry [26,27], and later in 3D by both stylus and atomic force microscopy [28]. Line profilometry revealed that surfaces with strikingly different morphologies had different combinations of centre line roughness, R_a, and skewness, R_{sk}. From this base, roughness targets and electrograining conditions may be selected, but limited explanation is available on how these parameters relate to pit shape or distributions. Conversely, the 3D study deduced the independence of surface area from R_a and maximum difference in height, R_t, then emphasised the need to ascertain