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Topographical and ellipsometrical analysis of orange peel on polished steel surfaces

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1. Introduction

In recent years, many optical devices have been implemented to monitor finishing processes in case of industrial steel sheets, because their high accuracy, non-destructiveness and velocity significantly reduce the production costs. In particular, the functionality of surfaces can be predicted by a proper detection of defects. Such defects arise predominantly during finishing processes: e.g., for excessive polishing and pressure, and yield also a surface roughening with fine peaks and valleys best known as orange peel. In this contribution, the topography of orange peel on polished steel sheets is described through surface roughness parameters evaluated by applying a 3D interferometric microscope [1]. In addition, spectroscopic ellipsometry (SE) [2] is proposed as an alternative technique to determine the optical response of samples affected by orange peel.

2. Experimental framework

Although interferometrical microscopy and spectroscopic ellipsometry (SE) are both based on the interaction of light with rough surfaces, the operating principle differs crucially. Interferometrical microscopy, on one hand, detects the path difference of two light rays caused by the roughness of the analyzed surface and creates an interference pattern on a CCD detector, which in turn is evaluated pixel-wise for different lens or mirror positions. Based on the so-measured topography data, then surface parameters are calculated according to ISO standards. On the other hand, SE measures the change in polarization of light reflected or transmitted from a rough surface. Two ellipsometric parameters (Ψ and Δ) are obtained for a given wavelength of light and can be correlated to the surface topography.

3. Detection and Evaluation of Orange Peel

Firstly, surface topographies of polished steel sheets were evaluated using a phase-shifting interferometer. This device uses a narrow-band blue light source and employs a 10x Mirau objective lens that covers a field of view of 1270 µm x 950 µm. In order to increase the area of analysis, multiple measurements were stitched together up to a total area of 4.72 cm x 3.54 cm. Fig. 1 shows the appearance of orange peel on polished steel surfaces. The images show differently pronounced orange peel of two degrees identified as strong and week.

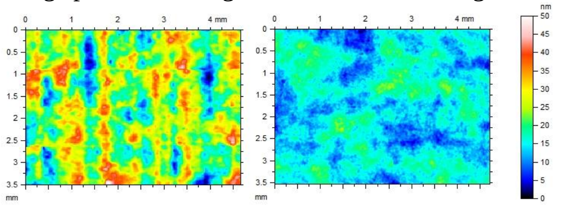

Fig. 1 Strong (left) and weak (right) orange peel on polished steel surfaces

The degree of orange peel can be determined by calculating surface parameters [3] with proper low-pass filters (0.8mm cut-off wavelength). In Table 1, representative height, functional and spatial parameters are given.

Table 1 Evaluation of orange peel

Surface parameters	Strong	Weak
Sq: Root mean square height (ISO 25178)	7.1 nm	3.4 nm
Sk: Core roughness depth (EUR 15178N)	12 nm	5.2 nm
Str: Texture aspect ratio	0.11	0.574

From Sq and Sk it is inferred that two degrees of orange peel can be distinguished by relating the amplitude of peaks and valleys and there spatial distribution on the surfaces. In addition, it can be deduced from Str that the structure of strong orange peel has a preferential direction. Moreover, the pseudo-dielectric function <ε>, calculated from the measured ellipsometric parameters (ψ, Δ) shows qualitative good correlation with the degree of orange peel in the range of photon energy 1 eV to 2.5 eV.

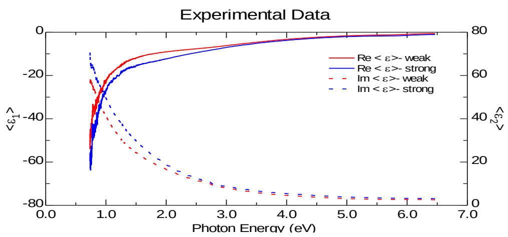

Fig. 2 Optical response of samples

4. References

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