6.7. A Novel Detection and Classification System Based on a Deflectometric Method for Specular Surface Microdefects

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For an enhanced quality control analysis of specular surfaces like automobile coatings and high quality lenses the deflectometric scanning method offers an accurate and cost-effective solution. Similar to Phase-Shift projection the evaluation of the color amplitude and curvature of the test surface calculated from the raw image data of the sensor CCD-cameras allows the discrete determination of the position and structure of lacquer micro defects. The geometric analysis of the local curvature and color amplitude carried out in this thesis provides the basis for the acquisition of the correct raw data. An improvement by novel image processing steps in real-time, like preprocessing and feature extraction represents the second part of this work. Finally, we present a novel approach of the well-known supervised learning algorithm, support vector machines, which classifies the defects and determines the error cause.

Conventional surface inspection methods like simple Image Analysis or Phase-Shift-Interferometry have to face a tradeoff between the essential parameters, i.e., detection accuracy and costs. The deflectometry[1] provides the ability to calculate the local curvature κ as a key figure for defect recognition and the color amplitude p as a basis for an enhanced classification for large inspection areas and with the desired accuracy and time-effort. Furthermore, the analysis of this data with image processing algorithms increases the accuracy (defect radius $\leq 10\mu m$) of the measurement setup. The classification is decisive in terms of finding the cause of the particular micro defect. Therefore, a suitable measurement setup aims at determining κ and p, processing the image data to suitable defect results and classifying those in terms of size, shape and color to given defect groups. In principle, classical image processing and neural classification tools can be used to determine the defects. However, for the considered system in our contribution these will not meet the specifications given by the automotive industry in terms of accuracy and speed. Therefore, a real-time in-line system with high sensitivity and accuracy is required.

The deflectometric sensor system presented in this contribution utilizes a robot with a light source (TFT) to project 4 Phase-Shift sinusoidal profiles and a sensor camera-setup to measure the light intensity reflected by the specular surface (Fig.1). Furthermore, a computational system is attached to calculate the curvature and amplitude with combined Fourier-Analysis, Phase-Reconstruction and determination of the fundamental forms in the Weingarten-Matrix[2]. The amplitude and curvature images are highly superimposed with noise and inhomogeneous background light. Therefore, they are processed with fast adaptive image reconstruction techniques (Fig.2). With these results we use multigrid pattern recognition methods like spectral Phase-Switching and conclude the analysis with an adaptive threshold generation[3] (Fig.3). The generated defect regions are further analyzed with Support Vector Machines (SVM) as most significant method to determine the defect class (small/large inclusion, filler, scratch, crater and dent) (Fig.4). The tradeoff between process-time and classification rate is considerable as depicted in Figure 5. In our contribution, we provide a prototype setup consisting of an industrial robot with projection screen and CCD-sensor attached, novel adaptive image processing techniques and classification algorithms based on SVM. We are able to detect six important defect types ($r < 10\mu m$) with a detection accuracy of 96% and a classification rate of 99% in real-time. In conclusion, this particular sensor system can provide significant improvements in terms of process-time, accuracy and cost-efficiency generated by deflectometry enhanced by image processing and classification algorithms (Fig.6).

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