INTRODUCTION

Often in manufacturing, visual inspectors are used to approve the correctness of a free form surface’s cosmetic or functional characteristics. While the human’s adaptive interpretation allows flexibility where standard vision systems fail, the human inspection process remains highly subjective and inconsistent between inspectors. This can be problematic for manufacturing due to the necessity that even the smallest variations in curvature or blemishes can result in a nonfunctional or irregular looking part \[1\]. The introduction of phase defectometry as an optical metrology technique can now give production facilities an objective view of their manufacturing process by imaging irregularities on the surface of free form parts \[2\]. Additionally, these facilities can achieve peace of mind that the once highly subjective process of visual inspection now has reliable repeatability.

PRINCIPLE OF OPERATION

Phase shifted deflectometry acts on the principle that one is observing the projection of a light pattern on the surface of a test piece instead of focusing on the surface of the part itself. By viewing the pattern, the observer is able to see alternate fringes or sections of the projected pattern. This differs greatly from technologies such as fringe pattern triangulation which rely on changes between lateral measurement points and cannot directly view the slope of the measured region. Additionally, by widening the view to the projected pattern the system is able to record this detail over a much larger area and perform these observations quickly.

The phase shifted deflectometry system adapted for visual inspection consists of a white light LED array that generates continuous illumination patterns. Computer numerically controlled positioning stages which move the part under test into optimum fields of view. Various cameras whose optical resolutions are matched to the limits of the defect sizes being looked for and whose pixel resolutions satisfy the Nyquist-Shannon sampling theorem. Finally, a high performance computing cluster is added and scaled accordingly to allow for any evaluation algorithms to be performed at the speed of image acquisition such that evaluation times meet the strict cycle times during production and 100% inspection can be achieved.

The system’s LED array produces a series of sinusoidal fringe patterns that are viewed by a camera as a reflection from the object under test (FIGURE 1). The series of patterns produced by the illumination element are shifted in phase from each other and recorded by the system.

FIGURE 1. Diagram of the phase deflectometry setup.

The resulting images that are acquired are then used to derive three fundamental images for image processing a synthetic grey image, a gloss image, and an inclination image.

RESULTS

The resulting images can now be used to objectify features on the part for inspection tasks such as completeness, or more importantly, detection of surface irregularities (FIGURE 2) \[3\].

First (FIGURE 2a), shows a grey scale image as typically seen by standard gray image systems, because the test piece is being viewed from one
specific vantage point, surface quality defects that are present are very difficult to notice. Therefore, if the surface is not observed from a particular angle it can result in slippage of a defect and is not uncommon if a visual inspector manipulates parts non-repeatedly and makes the “good or bad” decision very subjectively.

The second (FIGURE 2b), a ‘synthetic grey image’, is a very low noise image created by the synthesis of multiple phase shifted images. This image has homogeneous illumination which is widely independent from the shape of the part being tested. This image can be compared to typical gray scale imaging systems and is highly relevant when detecting edges and variations in color.

The third (FIGURE 2c), a ‘gloss image’, highlights areas of increased light scattering which are independent of the shape of the part under test. This image gives the distinction of gloss and brightness which is critical for proper detection of cosmetic defects or defects that exhibit an increase or decrease in scattering from the nominal surface. In this case the very superficial scratches that change the parts cosmetic appeal are noticeable.

Finally (FIGURE 2d), the ‘inclination image’ can be obtained from the phase information and used to determine any deviation in the nominal slope of the part. This image can be highly critical to functional evaluation and is necessary when detecting surface defects such as scratches. Additionally, the curvature of the part or its irregularities can be derived from this image providing further analysis of the type of defects observed on the surface. These defects include indentations, scratches, pimples, or other negative and positive defects. In this case a linear shaped dent which influences functionality is noticed on the part; this defect is very difficult to see in the gloss channel due to the specular nature of the ‘dent’ which resembles characteristics of the surrounding surface finish unlike a typical scratch that has a discontinuity in scattering characteristics from the surrounding surface.

CONCLUSION
The above method automates visual inspection and provides traceability for manufacturing processes which might be responsible for defects or surface irregularities that commonly occur in a precision manufacturing setting. This allows a manufacturer to achieve an objective analysis of defect detection and be confident that his production has minimal overkill or slippage.

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References