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An optical flatness measurement system for medium-sized surface plates

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This paper describes the work to develop a parallel beam scanning system (PBSS) for the noncontact measurement of surface flatness of such medium-sized surface plates, as sheet metals, sheet-moulding compound (SMC) plates, and glass plates, which are difficult to measure by traditional methods. The PBSS consists of a He–Ne laser source with good pointing stability, a scanner to create divergent scanning beams, a large aplanatic meniscus lens to convert the divergent beams to parallel beams, a linear stage to drive the testpiece to each sampling position, a screen for the projection of reflected beams from the tested surface, and an image-processing unit to analyze the projected image. Because of the out-of-flatness of the surface, the straight line formed by the incident parallel beams will be distorted and magnified on the screen as it is reflected from the surface. A charge-coupled-device (CCD) camera is employed to capture the image of the distorted line each time, and proceeds in line-by-line sequence. With the proposed mathematical model, the three dimensional (3-D) flatness data of the testpiece can be converted from the input image data and analyzed by the least-squares method. Experimental results by the use of this system have shown good agreement with the results obtained from a coordinate measuring machine (CMM). Because of the limit of the meniscus lens, the workpiece size is within 200 mm in width. © 1997 Elsevier Science Inc.

Keywords: surface plate; flatness measurement; scanning system

Introduction

The definition of flatness error of any surface plate has been specified in many different standards on the geometric tolerance,[1–3] which relates to the geometric quality of products. Many technical methods have been proposed for measurement of surface flatness according to the size and the quality of the surface to be inspected. For big surface plates, such as granite tables, the flatness measurement can be carried out using an electronic level,[4,5] autocollimator,[6] or laser interferometer.[7] For small surfaces, such as gauge blocks and mirrors, the flatness error can be measured by interferometry.[8] However, for medium-sized plates all the above methods are not applicable, because the plate is distorted by the weight of the instrument placed on it, or its size is too big for the interferometer field of view. Some traditional methods that might be used for the flatness measurement of surface plates include the projection of grid patterns[9] and the digitizing with low-force linear transducers.[10,11] The former cannot provide sufficient resolution and sensitivity, while the latter is time consuming and requires an expensive positioner, such as precision X–Y table, or coordinate measuring machine (CMM).

Other researchers have shown that, with the scanning light technique, the surface quality of sheet-moulding compound (SMC) plates can be

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Precision Engineering 21:102–112, 1997
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655 Avenue of the Americas, New York, NY 10010

0141-6359/97/$17.00
PII S0141-6359(97)00067-6