Application of Phase Measurement Deflectometry Method in Transparent High-Reflection Materials

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Transparent and highly reflective materials have special physical and optical properties and are widely used in various fields such as optics, automotive, and aerospace. Ensuring their surface shape accuracy is crucial. There are two main measurement methods for transparent high-reflection materials. The complex optical properties of transparent high-reflectivity materials are ignored in point scanning methods, including coordinate measuring machines and profilometers, and have low measurement efficiency. Spraying diffuse reflective powder on the surface to be tested to alter the complex optical properties of transparent high-reflectivity materials is another method. After changing the optical characteristics, the measurement is achieved using grating structured light, line structured light, and other methods. However, this measurement method has a complex process and requires cleaning of the powder after the measurement is completed, which has significant limitations. The phase measurement deflectometry (PMD) method is a deflection measurement method based on visual principles, widely used in measuring the surface shape of highly reflective surfaces. The use of the PMD method to measure transparent high-reflection materials does not require changing the optical properties of the surface of the test piece and uses its reflection characteristics to complete the surface measurement. Therefore, the PMD method has superiority in measuring transparent high-reflection materials. However, due to the multi-layered reflective surface of transparent high-reflectivity materials, the images collected using traditional PMD methods often suffer from signal aliasing, which will affect the accuracy of the measurement. Therefore, traditional PMD methods are no longer applicable. Discretization of stripes is a method to solve signal aliasing, but this method requires a larger number of stripes, which reduces measurement speed. By using more stripe images with different periods, parasitic reflections can be eliminated from an algorithmic perspective. However, this method also relies on projecting additional images, and the algorithm complexity is high and time-consuming. Therefore, we propose a novel phase deflection measurement method suitable for transparent high-reflection materials, which discretizes the characteristic fringes and uses a single-frame phase calculation method to obtain phase information. By using binocular cameras to capture one image each, the surface shape measurement of transparent high-reflection materials can be completed, which has the advantages of high measurement accuracy and fast speed. This measurement method is applicable to transparent high-reflection materials with uniform thickness and moderate curvature, as well as ordinary high-reflection surfaces. In this study, this method was used to measure the Head-up-Display (HUD) and automotive glass. In the future, this method can be applied to the measurement of high-reflectivity or transparent high-reflectivity materials in fields such as architecture and aerospace.