Optical Reference Profilometer with Improved Thermal Stability

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The optical reference profilometer (1) utilizes a $\lambda/20$ reference mirror and a metrology frame to create, what is essentially a contact Fizeau interferometer. A Fizeau interferometer measures height deviations of the part under test from a reference surface. In interferometry, this deviation is measured in fringes. Instead of using fringes, the optical reference profilometer uses a laser distance measuring interferometer coupled with an air-bearing stylus to provide the deviation measurement from the reference flat. The separation between the part under test and the reference must be constant during the measurement. In order to maintain a constant seperation, a metrology/metering frame is used. The basic metrology frame connects the part and the reference flat, and it consists of three super-invar rods, a super-invar base plate. The optical reference is mounted on top of the three rods with the optical surface facing down toward the test part. This frame is placed kinematically on top of an x-y roller-bearing translation stage, which moves the frame and test part under the air-bearing stylus assembly.

The benefits of this system are discussed in more detail in a previous paper (1), so only a short summary of these benefits will be given here. The main benefit of this design is the de-coupling of the z-axis motion of the stage from the part-reference separation. The measurement of any point on the test piece is the relative distance between the part and the optical reference. This distance is held constant by the three metering rods. Any z-axis motion errors of the stage cannot change this distance; therefore the measurement is insensitive to this error. This feature enables the use of a roller-bearing stage instead of a more expensive air-bearing stage.

The second benefit of this design comes from the mechanical separation of the stylus assembly from the metrology frame. Because the stylus rests (approx. weight 0.1g) on top of the part being measured, only the relative distance from the part to the reference flat is measured. This makes it possible to use an aluminum bridge to hold the stylus assembly instead of an athermalized support structure.

In an attempt to increase the long-term stability of the previously described system (1), a series of mechanical upgrades have been implemented. The data measurements taken by the first generation system were over a short time period and on low slope parts, so thermal expansion errors in the x and y positions were not significant. However, for longer runs (3-5 hours for example) this expansion can have a very large effect. The second-generation machine reduces these effects by adding a special metering rod network to couple the lateral positioning interferometers, used to monitor the x and y positions of the test part, to a defined test part center. This network also helps reduce deadpath errors and overall air path lengths because the cube interferometers for the DMI can now be placed closer to their respective stage mirrors. The metering rod network references the x and y positions on the part relative to the system center reducing the thermal sensitivity of the part position. Because the stylus assembly is mechanically independent from the frame-stage combination, it is possible for the location of the center of the stylus to shift in x or y from the system center during a measurement cycle. Therefore, it is necessary to monitor the x and y position of the stylus assembly relative to the system center. The stylus position is also referenced via this metering rod network. This makes it possible to correct for any lateral position shifts the stylus may experience.

The addition of the stylus position monitoring system is still in the development stages; therefore the results presented will be made with the x-y lateral positioning reference structure only. The stylus position monitoring system presented will contain theoretical effects on the measurement accuracy of the system.

References

[1] S. Clark, M. North-Morris, J. Greivenkamp, " Stylus Profilometer with an Optical Reference", in *Optical Fabrication and Testing Technical Digest*,OSA, 1998, vol. 12, p 155-156.

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