Conoscopic holography meets on-line metrology challenges

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New methods extend the range of conoscopic holography for quality control in manufacturing by offering longer working distances, more efficient signal processing, and better resolution.

Modern manufacturing requires on-line methods for testing every part. To stay competitive, manufacturers need a metrology system that can detect surface defects, measure dimensions, give fast feedback, and add to knowledge about the process. In addition, the system must be versatile, reliable, inexpensive, and easy to set up. Finally, the system must be able to work in real time in the often difficult conditions on the process line. These requirements are a great challenge to metrology science.

Conoscopic holography (CH)\(^1\) works well for this purpose.\(^2,\,3\) Unlike normal machine-vision systems that provide only 2D images of a part, CH provides depth information. This common-path interferometric technique is based in the double refraction property of uniaxial crystals, and offers high-precision measurements with a wide range of standoff distances. The system obtains an image of interference fringes when a laser beam is reflected off a part and passes through the crystal. One can calculate the distance to the part from the frequency of the obtained fringes. Optimet Optical Metrology (Jerusalem, Israel) develops and manufactures devices based on this patented technology, providing high-resolution point and line measurements for a variety of ranges and standoff distances.

Some industrial applications, however, require even larger standoffs and apertures due to environmental conditions. Often these industrial applications do not need absolute measurement values: relative distance variations are sufficient for detecting surface defects or for ascertaining flatness and other shapes. We collaborated with Optimet to develop a variation of the method (see Figure 1) that includes a small triangulation and uses the phase information of the fringes.\(^4\) This solution improves resolution more than 10 times. It also allows standoffs as long as 700–1200mm, depth ranges as great as 50mm, and apertures as large as 200–320mm. This sensor can record profile distance maps with a depth resolution of 0.1mm from a distance of 700mm, or 0.24mm from 1200mm (see Figure 2).

We are addressing some additional issues to improve CH technology, including the important matter of signal processing. Because the system must analyze many signals in the frequency domain, this process limits the acquisition rate. We developed new algorithms—based on the application of phase-shifting interferometry methods over a single frame—to retrieve the phase information and cut processing time by more than two orders of magnitude.

Another weakness of CH is its relatively poor resolution. The resolution is limited by speckle noise, which is an inherent problem in systems that use coherent-light illumination and triangulation.\(^5\) Several attempts have been made to filter the obtained signals,\(^6\) but they result in loss of resolution due to averaging. We addressed this problem by lowering the coherence of the laser source by placing a rotating diffuser behind the laser. In our experimental system, we saw a notable enhancement, and obtained resolutions up to \(\pm 7\mu m\) for standoffs of 500mm and up to \(\pm 2.3\mu m\) for standoffs of 300mm.

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Figure 2. One industrial application requires on-line detection of surface cracks in hot steel slabs (at temperatures above 500°C) with a 1200mm standoff. Shown above is the external view of the inspection system. Below are images of the crack as it appears in a hot slab (gray level) and in a cold one, and the surface map obtained by the on-line system.

In addition to the conventional uses of frequency-based CH sensors, our research suggests that a new range of applications for phase-based CH sensors will be able to address many of the industrial problems posed by on-line dimensional inspection.

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References

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