Hardness Testing and Image Analysis

Sponsored by Buehler Jan 31 2018

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Introduction

Hardness testing is an important characteristic in testing component properties, and, as a vital materials testing tool, this critical parameter can be performed and measured by numerous approaches and techniques. While certain hardness test types such as the Rockwell test will yield fast, single process results based on indentation depth, many of the usually used test types such as Knoop, Vickers, and Brinell, require a secondary process to establish the size of the indentation.

These secondary processes can be inefficient, time-consuming, and susceptible to subjective errors. One attained before.

Automatic Hardness Testing

Two of the most common hardness tests are Vickers and Knoop, used in micro and macro testing to establish material hardness based on measuring the size of a diamond-shaped impression left from an application of a specified force. The nature of the test typically shows a relatively light force, resulting in very small impressions that must be measured at the micron level. Traditional methods, still extensively practiced today, involve microscopes with objectives of variable resolution integral to the hardness tester, which manually measures through an eyepiece based on human interpretation.

Predictably, this is inefficient, time-consuming, and in today's fast-paced, extreme environment, progressively unacceptable. It is not uncommon for a technician to create and measure by eye numerous indentations during a day, with fatigue probably compromising the measurement process as the number of indents increase. Furthermore, there is a need to produce a complete analysis of a hardness traverse often consisting of over 15 indents each, typically several times on a single sample, and the need for advanced, automatic methods become obvious.

Over the past several years and progressively in the future, these manual processes have and will continue to quickly give way to automation in every aspect of the process. New methods are being created in material preparation, results interpretation and analysis, stage movement, and even reporting. One such technology being applied into many labs globally is automatic stage traversing and image analysis of Vickers, Knoop, and Brinell indentations.

An automatic hardness system typically has a fully controllable tester, including an auto-rotating or revolving turret and actuation in the Z axis either from the head/indenter housing or from a spindle driven system for both applying the indent at a predetermined force as well as for focusing the specimen. Add to this an automatic XY traversing motorized stage, a laptop or desktop computer with exclusive hardness software installed, and a USB video camera, and the result is a robust, fully automatic hardness testing system. After preliminary setup with samples and a stored program, it can be left alone to automatically make, measure, and report on an almost unrestricted number of indentation traverses.

Newer technology eliminates a lot of the hardware that in the past caused operational difficulties and cluttered workspace. For instance, the stage is moved through a virtual joystick, and on some systems, stage controllers are combined into the stage housing. Progresses in stage movement algorithms and mechanical design have made XY accuracy and repeatability better than ever, which are vital in precision traverse requirements, for example, case depth analysis.

Image Analysis

While image analysis is not a new concept, the technology continues to progress, greatly enhancing the process. For instance, camera technology has evolved from frame grabber, to IEEE Firewire, to USB, eliminating extra hardware while at the same time boosting camera resolution and field-of-view possibilities. The capabilities of existing and developing cameras, coupled with the processing capacity of today's PCs and continually enhancing software packages, have greatly enhanced the repeatability, accuracy, and dependability of automatic indentation reading.

All digital cameras possess pixel arrays. Each pixel can be either on or off. If a black and white image is projected on the pixel array, the pixels in the dark areas will be off and the light ones will be on. By counting the number off, the size of the dark spot on the image can be established, and then the image area. The size of any indent is used along with the indenter and applied force to define hardness value.

Automatic Traversing

Expanding productivity even more is the ability to utilize larger size XY stages capable of holding two, four, or even six samples at a time in an array of fixturing types. Pre-programed and saved traverses are opened, samples are aligned in holders, and with one click, the indentation, reading, and reporting of many traverses on each sample are started. Autofocus allays any problems of indent clarity because of Z position variation. Newer software even enables different scales, forces, and microscope objectives, between and within traverses.

Automated testing is also progressively advantageous for Rockwell hardness testing, predominantly in repetitive pattern requirements such as Jominy testing, where a number of bars can be completely tested and reported, unmanned after a single click of the mouse.

Other Applications

As in Knoop and Vickers testing, Brinell Testing by nature is a labor-intensive and manual process that, in its conventional state, necessitates constant human intervention and processing. Since the traditional Brinell test has a single, controlled test force made with a specified diameter tungsten carbide ball, the resulting impression must be optically measured (diameter in mm) to define the material hardness. This is usually performed using a low-power, hand-held microscope, a process that is both difficult and subjective. As in Knoop and Vickers, fatigue-induced errors from performing measurements repeatedly are common, and the process itself can be time-consuming and inefficient.

With many processes requiring 100% inspection and productivity based on quick results return, it is no surprise that a means to both hasten the process as well one that mitigates the possible manually induced errors is in demand. The technique that may be most appropriate is reliant on a range of factors including test time requirement, loading and unloading method, ASTM standards requirements and adherence, specimen geometry, material properties, and of course budgetary alignment.

When using a conventional Brinell floor or bench model tester that performs the indent portion of the test only, an alternative to the hand-held manual process involves using a hand-held digital camera that can efficiently and accurately measure the diameter of the impression automatically using image analysis methods. Consequently, it has become comparatively easy to measure Brinell indents through a camera. If a hand-held imaging system, which requires manual intervention is lacking in the preferred production, then a fully automatic, optical Brinell system can provide adherence to ASTM E-10 while allowing for completely automated optical testing.

A completely integrated automatic optical Brinell testing system can rapidly and accurately perform the whole Brinell test process in compliance with ASTM E10 including accurate indentation application, and providing an image analysis system to autofocus on, identify, and record indent size and hardness measurement. All of this, coupled with flexible user-friendly software, offers the operator extensive and an abundance of capabilities in producing tests, completing the analysis, and creating reports.

An operator only has to find the sample in the tester, and press the start button. Indentation is automatic just like the rotation of a revolver or turret style system that turns the measuring objective/microscope into position. The automatic focus and imaging process is then started and results are returned in as little as 20 seconds.

Past boundaries with regards to surface finish, preset calibration, lighting, as well as pixel sizing have been alleviated, and are continually undergoing development. The result is better ability and dependence on "letting the instrument do the work," contributing to considerable increases in consistency and throughput, while saving time for the operator to perform other responsibilities. With a fully integrated system, the labor-intensive, subjective, and error-susceptible process is almost eliminated and instead substituted with a considerably more accurate and productive process.

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Related ANSI Standards

ASTM B277-95(2012): Standard Test Method for Hardness of Electrical Contact Materials

ASTM C748-98(2015): Standard Test Method for Rockwell Hardness of Graphite Materials

ASTM E110-14: Standard Test Method for Rockwell and Brinell Hardness of Metallic Materials by Portable Hardness Testers

ASTM E18-16: Standard Test Methods for Rockwell Hardness of Metallic Materials

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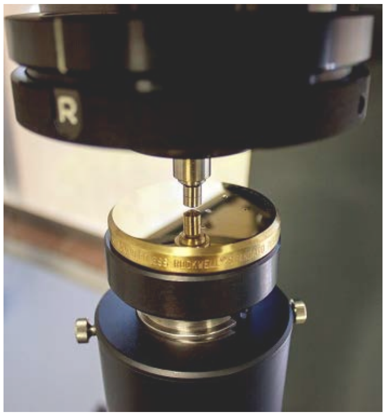

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