InsituTec Inc.

Precision In-process Solutions

The arrival of real-time, contact-based scanning systems for in-situ process monitoring: diameter measurement and roundness testing

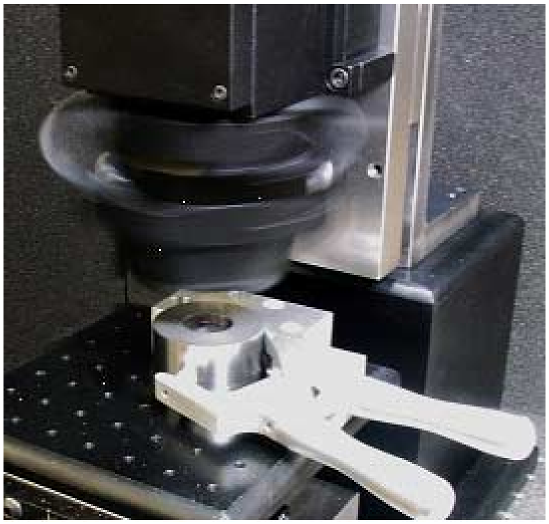
Shane Woody & Marcin Bauza
InsituTec, Inc., Charlotte, North Carolina 28213

Stuart Smith
Center for Precision Metrology, University of North Carolina, Charlotte, North Carolina 28223

Mark Malburg
Digital Metrology Solutions, Inc., Columbus, IN 47203

Abstract

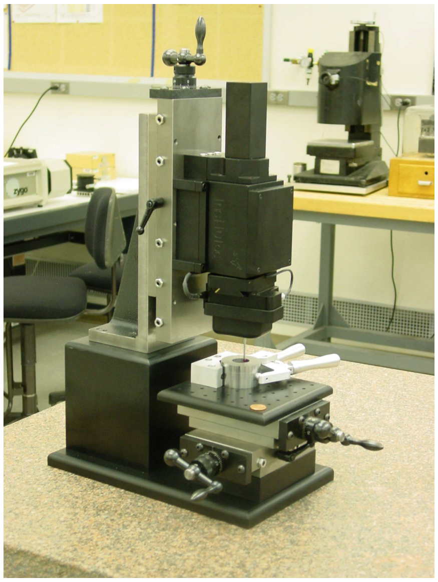
In a perfect world, manufacturers would have 100 % inspection using measuring machines with combined uncertainties considerably better than tolerance requirements on a part. One step towards this goal is to be found in the development of real-time, fast, contact-based metrology systems ruggedized for use in the manufacturing process Generally, manufacturing based metrology systems are categorized as non-contact (i.e. optical) or contact based measurements. Non-contact/optical based systems are routinely integrated into process lines due to fast response times for six sigma inspection. However, the trade-off with these systems are the limitations with measurement accuracy, most instruments are only capable of measuring upper surface features or features at a defined focal plane and the complex nature of the uncertainties encountered with non-reflective surfaces. Alternatively, currently available contact-based measurement systems can provide an accurate representation of the workpiece geometry but are inherently problematic for in-situ process control, mainly due to slow measurement cycle times. To counter this problem, a real-time roundness gauge operating at greater than 60 rpm (1 second per hole scan) with ± 0.2 μm measurement uncertainty has been developed to address roundness needs for in-situ process. This technology affectively represents a paradigm shift for roundness gauges and is poised to provide sufficient speed and accuracy for in-process application and may represent a trend towards robust, in-situ quality control of processes with six-sigma confidence.



InsituTec's Real-time Scanning System

Introduction

Historically, hand held gauges such as pneumatic and dial bore gages have been employed to provide the operator with 'go' or 'no go' inspection. While useful to determine if components are meeting tolerance specification for maximum or minimum diameters, this methodology does not provide quality control information that might enable diagnosis of process problems. As requirements on precision tighten, such parts require more reliability information related to form error and surface finish. For example, to obtain this information engine blocks are generally transferred to a temperature controlled metrology room wherein cylinder bores are measured using a laboratory roundness gauge. This operation is time consuming, adds expensive overhead for laboratories and potentially scrapped parts due to process control delays during which defective components are being manufactured. Consequently, to reduce the cycle times compared to similar laboratory instruments, roundness gauging and bore gauges as well as surface finish instruments are appearing on the shop floor. Nonetheless, these instruments are not rugged enough or fast enough to be embedded into process lines for 100% inspection.

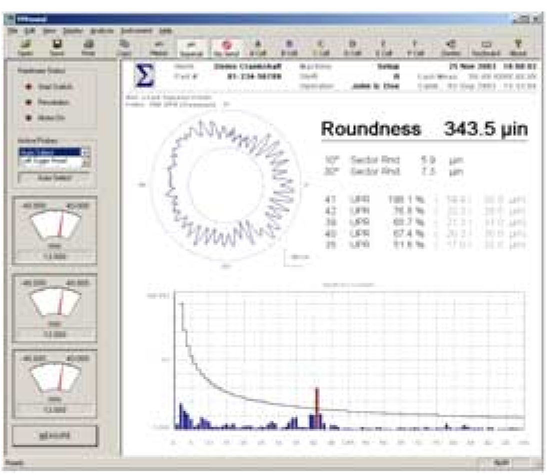


Scanning Probe Head Attached to Conventional Slideways

In automation processes, because of fast measurement times, optical vision systems emerged as a viable candidate to real-time measurement cycles. However, the tradeoff is accuracies of 5-8 micrometers are produced and form error below the top surface of an OD or ID component is challenging to measure, particularly with burrs or other poorly defined edge features. Although adequate for many processes, optical vision systems can not produce the necessary accuracy for many precision components such as hydraulic spool valves, roller bearings and i,c, engine cylinder liners where accuracies of better than 5 μm are essential for 100-300 mm diameter components For smaller components these accuracy requirements become progressively tighter. As previously discussed, current shop-floor contact based roundness gauging technologies provide better accuracies (i.e. typically 0.5-1.0 μm measurement accuracies) but are unable to provide fast response times for 100% inspection on high production cycles, often have no or slow data connectivity to a computer and are not easily embeddable into a process. One significant issue with some roundness gauges is the need for the component to be rotated while the scanning head measures about a null position to obtain form error. It is challenging to integrate such a system on an automation line where the component must be rotated as well as being aligned with respect to the roundness gauging. Because of the long measurement cycle, presently, it is more common (universal) that sampled components are measured and statistical process control (SPC) methods applied. Quite simply, in the absence of 100% inspection the manufacturing process can not ensure 100% defect-free parts.

One hundred percent inspection is desirable to reduce the scrap rate and provide zero defect components. The fundamental limit is that current measurement tools are too slow for the more demanding accuracy requirements and are not readily embeddable into the process line. Recently, a state of the art roundness gage has been developed by InsituTec Inc. to address this need for real-time form error measurement incorporating the latest in constant force scanning technologies. This gage has a patented nano-positioning technology that can be used in a variety of industrial “roundness” measurement and inspection applications such as roller bearing, cylinder manufacturing and connecting rods just to name a few. This particular device is expected to drive a paradigm shift towards manufacturing processes being capable of 100% inspection with superior shop floor accuracies and metrology scanning capability. The device is able to scan circular features with the following characteristics;

- Between 0.5-1 second for a complete roundness measurement
- Measurement accuracies better than ± 0.2 μm
- Adaptable probe heads enabling measurement of 8-60 mm diameter features
- Maintains programmable constant scanning forces to less than 50 mN
- Measures OD and ID components and returns diameter measurement relative to a ring gage master.
- Rotating scanning head and compact size is designed for ease of integration into a process line to measure features on arbitrary size workpieces.
- 300 point (extendable to 1024 points) azimuthal sample spacing
- Form error reconstruction



GUI Developed and Supplied by Digital Metrology Solutions Inc.

A second issue for real-time inspection is the rapid extraction and transfer of data to a host computer. This capability is provided in real-time with extraction of sensor parameters being carried out by digital signal processing (DSP). DSP modular systems can be considered as a dedicated computing system with real-time measurement of real-world processes with sufficiently powerful computational capacity to provide real-time control of measurement systems. For the roundness measuring system, the DSP based system multi-channel inputs and outputs at 16 bit precision (i.e. voltages can be read and generated with a precision approaching 1 part in 64,000) with update rates of up to 100,000 samples per second. The DSP has also proven to be a valuable tool for rapid data connectivity. Manufacturers may foresee that dedicated modular systems may be placed throughout the process line for the purpose of both measurement and control. Furthermore, DSP based metrology systems will provide the necessary precision computation and speeds to tag components, perform complex computation and administer process changes in order to provide complete defect-free components. One distinct advantage for 100% 'tagging' of components may arise in the bearing industry. For example, precision bearings characterized as Abec 7, Abec 9 or 'matching bearings' are often very expensive. One contributor to the cost is due to many of these bearings being manually measured and matched with corresponding bearings of similar precision. In order to minimize the costs associated with manual inspection, the bearings might be alternatively scanned for form error, 'tagged', and then automatically sorted into groups by precision.

Fixturing is another crucial component for rapid inspection tools. A rapid scanning system cannot be exploited if the setup time is lengthy. The roundness gage is configured to rotate the scanning head rather than rotating the work piece. . The low mass scanning head design of this device is compact and mounted to a spindle that is capable of rotating at 60-120 rpm. This generally is more desirable for the measurement of large components such as engine blocks that are difficult to move and, in particular, to rapidly rotate. The next logical step is to provide fixturing for the process line to center the feature with respect to the roundness gauge as well as level and clamp the component. One of the large uncertainty contributors for roundness gauges is the misalignment of the part which produces a relatively large uncertainty in 2 UPR. Generally, this may be less of an issue as long as the roundness gage is mounted and measured perpendicular to the work piece datum surface. The centering of the part is less critical as long as the roundness gauge stays within operating range.

In conclusion the need for 100% inspection is continually growing within manufacturing. Real-time contact based scanning systems are finally emerging in the metrology industry with the necessary accuracy and speeds for process capability and these systems are now being ruggedized for shop floor use. Furthermore, rapid extraction of precision data and parameters are readily available by employing DSP systems.

Contact us to further determine if this technology is suitable for your metrology application

InsituTec Inc.
(704) 503-6908
info@insitutec.com