A Novel Method for Rapid Part Inspection and Verification

The University of Bath, Uk
V.Dhokia@bath.ac.uk

Abstract

Metrology is fundamentally important to every manufacturing sector. The ability to determine manufacturing quality issues rapidly results, in-part, to overall profitability. There are a number of different quality control methods used, which include coordinate measuring machines (CMM) and conventional dedicated gauging. Conventional hard gauging methods consist of using precision-machined fixtures to verify that parts are within tolerance. This is highly inflexible with the inability to adapt rapidly to changes in part design. Renishaw Plc, a world leading precision engineering company, have developed a method for versatile, automated and thermally stable gauging directly at the manufacturing interface, with the ability to provide full certified part inspection without the need for custom fixturing. This paper illustrates the concept of this new device, Equator, and its ability to significantly enhance the present state-of-the-art manufacturing process chain, when compared to conventional gauges for in process measurement. For verification of this process a modified NAS979 test part was machined and inspected using the Equator system.

1 Introduction

Inspection and related measurement issues are vitally important for every type of manufacturing industry. There are different inspection methods used to assess parts, including CMM’s [1], spindle-mounted inspection probe systems on machine tools [2], and specific part dependent gauging [3]. Traditional gauging methods are predominantly used for in process measurement. Parts come off a production line, are quickly run into the gauge and using the reference master part to datum, the process deviations are quickly understood. This technique is inflexible because for each different part a custom gauge is required. Datum surfaces as references are needed for every measurement; as a result the gauge fixture requires hard ground datum locations for accurate part positioning. The consequences of this are additional costs and time associated with each specific gauge and any design changes. CMM’s differ
in that they establish datums on the part, unlike with gauging. On a CMM, due to increased mobility measurements are taken around the part, to establish relationships to datums, using analysis software. A CMM is certified to function correctly over its working volume in specific environments, but because thermal variation can directly affect the CMM and part geometry, measurements are typically trusted and certified only in the temperature-controlled environment.

2 The Renishaw Equator concept
Renishaw’s Equator functions as a gauge using the master / measure technique to take into account thermal deviations. However, datums are established on the part removing the need for dedicated fixturing. Unlike with a CMM, which is calibrated volumetrically, the philosophy behind Equator is to calibrate each system for each specific part without the need for dedicated datuming or fixturing. Furthermore the technique can be repeated meaning that the same Equator gauge can be used for many parts. This will lead to reductions in waste, cost and re-working, plus increases in productivity, whilst also providing comprehensive part inspection data and increased manufacturing process confidence.

2.1 The Equator process
The master part is first measured on a CMM as a pre-calibration step, and is then re-measured on Equator – a process termed Equator Mastering. The pre-calibration step allows any nominally representative production part to be used as the master part instead of requiring the production and maintenance of a precise ‘golden’ master part. The mastering process, which is essentially the same process used in conventional gauging, accounts for any thermal variation in the shop floor environment. The combination of the two process steps (calibration and mastering) means that absolute accuracy tied back to CMM certified inspection of the master can be exported onto the shop floor. This process guarantees inspection of production parts that match the master part. Equator is turned into a dedicated gauge through the calibration and mastering process. In addition the Equator mastering process can be repeated on as many production parts as required. The result is a temperature stable, versatile yet dedicated shop floor gauge that can react to part design changes as simply as modifying a measurement program. The use of a CMM to certify the process by use
of dedicated master parts, combined with the robust Equator gauge placed next to the machine tool, provides close process control in any manufacturing environment.

3 The experimental setup

A modified national aerospace standard test part, B-NAS979 was machined and measured as a master part on Equator with the generation of a master file. The part was subsequently re-measured a number of times. By re-measuring the same master part on Equator following a mastering step, all deviations from nominal dimensions can be used to assess the repeatability of the inspection system (see figure 1).

Figure 1: Equator repeatability testing

The second test demonstrated the full Equator process (figure 2). The master part was first calibrated on a CMM and then mastered and measured on Equator. Subsequent parts were then inspected on Equator, which used the master and calibration information and ensured true measurement relative to CAD nominals. The part was then compared against CMM measurements and the results are illustrated in figure 4.

Figure 2: The Equator process

4 The results of Equator testing of B-NAS979

Figures 3 and 4 provide examples of the results achieved from the two tests, which show the repeatability of the measure process and the full Equator process.
5 Conclusions and the future vision

The concept of Equator is to provide a gauging device, next to the machine tool in the thermally unstable shop floor environment without the need for dedicated fixturing. This paper presents a paradigm shift where measurement capability is integrated on a complete traceable scale on a production line that, in terms of accuracy and repeatability, is comparable to conventional gauging, with CMM certification and traceability. The vision of Equator further extends towards complete process control and ultimately zero-defect manufacture as it has the capability of interpreting measurements and feeding required offsets back into the process, thus providing closed-loop manufacturing capability, with full part traceability.

References