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An automated diamond turning facility

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Abstract
Key trends in manufacturing industries are increased automation, increased precision and miniaturisation. The authors have previously introduced the highly integrated μ_{for} ultra-precision machine tool concept This new paper reviews the performance of this machine operating in a fully automated fashion. This highly compact (0.6m x 0.6m x 1.1m) multi axes ultra-precision machine tool (1,2,3) enables workpiece loading from the top of the machine. Automation includes: diamond tool setting, workpiece handling and preparation, post process measurement and unloading. This paper provides details of a μ_{for} machine arranged as a production diamond turning machine. Its performance capability in regards form accuracy achievement is presented when operating using a fully automated production cycle. The manufacturing technologies introduced demonstrate for the first time an ultra-precision diamond machine tool operating in fully automated cycle.

Keywords: compact machine tools, ultra-precision, automation

1. Introduction

Diamond turning and micro-milling have become significant production processes. Automating these processes whilst achieving significantly sub micrometre accuracy and nanometrically smooth surfaces has proved difficult.

The Loxham Precision μ_{for} compact diamond turning machine represents a new era ultra-precision machine concept, see Figure 1. This highly compact machine has been designed and manufactured to offer ease of use and ease of automation properties. The machine is highly integrated and small at 0.7m x 0.7m x 1.1m including all motions and control systems and electronics. The machine operates on a single phase electricity supply and demands only pressurised air for its bearings lubrication. The vertical orientation of the machine and its novel motion configuration make it highly suitable for applying automation systems. At less than 500kg the machine is also very easy to reposition allowing the machine to be wheeled from one location to another. This portability enables production cell / lines to be revised without demanding lifting systems and long term planning.

This paper introduces technologies developed for the μ_{for} machine to enable effective automated diamond turning of complex shape optics. These include; surface preparations, loading the workpiece, centring the workpiece, tool setting, post machining measurement, automatic adjustment and if necessary error correction. Accuracy data to confirm functionality claims are presented.

2. Automated diamond turning cycle demands

Diamond turning is often applied to produce surfaces having a 1 - 10 nm RMS roughness range and surface form accuracy typically in the 10 – 100 nm RMS range. The workpiece substrates are often of low stiffness or brittle in nature, and have surfaces that are prone to scratching and surface damage.

Consequently, these sensitive substrates need to be handled with care and ensuring cleanliness between operations is essential to enable high form accuracy and damage free (scratch free) surfaces. Furthermore the tight tolerances require high levels of accuracy in regards workpiece positioning, tool setting and where needed post process measurement and error correction.

Figure 1. μfor automated diamond turning system

3. Automated diamond turning cycle description

A two axes robotic loading system is mounted on top of the machine See Figure 2. Added to the vertical axis is a workpiece holding device.

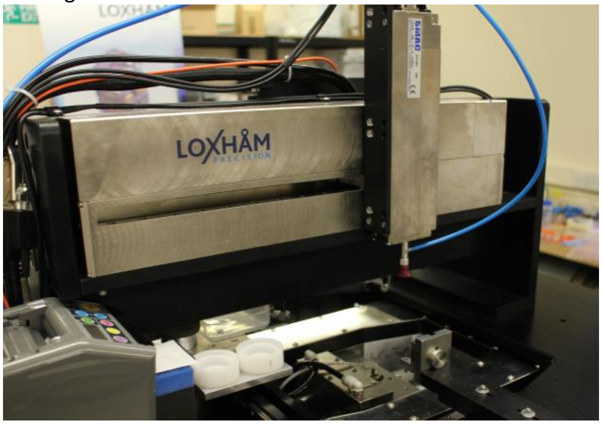

Figure 2. µfor automated load/unload robot

Workpieces can be brought to the machine via a simple "flex-link" conveyor. The robot system performs a number of preparation operations prior to loading the substrate onto the work holder chuck. After loading an automated high accuracy workpiece positioning sequence is performed that precisely locates the component into the machine. Workpieces can be located to < 0.001mm.

After precise work positioning is carried out diamond tools are checked for their exact tool positioning. This process is carried out by an optical tool system with image recognition and tool edge detection functions. The position of the optical tool system itself is tightly bound to the workpiece spindle axis of rotation. The close proximity and direct link of the tool position system and the workpiece spindle enables automatic X, Y and Z tool offset settings to be made with high accuracy. The optical tool system, shown in Figure 3, is brought into position by rotating the C axis workpiece spindle 90 degrees using the machines A axis, see Figure 4. The automated fashion of this process enables thermal drifts to be absolved between tool setting operations. A number of tool positions can be recorded and stored at any one time.

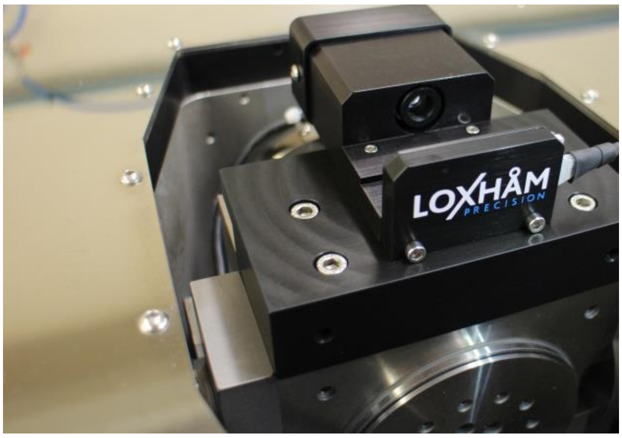

Figure 3. µfor optical tool setting system

After turning the workpiece is prepared ready for measurement. The X axis moves the workpiece under a specially devised optical measuring system that employs a dedicated optical probe mounted onto a vertical motion axis. Workpiece shape data is collected as departure from fiducial position as the X and Zm axes scans the prescribed shape of the workpiece. If form error is above tolerance then confirmation of tool positions can be automatically made, and if necessary an error corrected toolpath generated and performed.

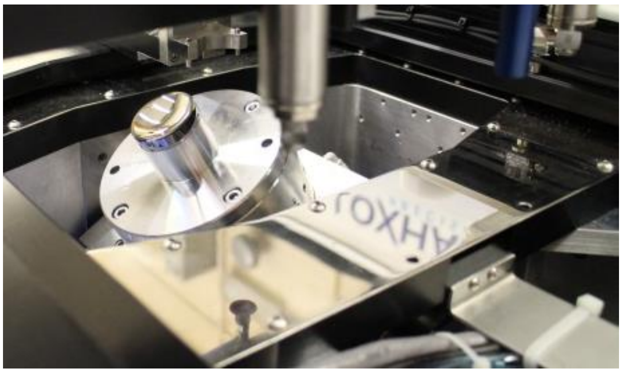

Figure 4. µfor A axis used to position tool set system

Typically, the produced surface will be well within specification at which point workpiece surface preparations are performed followed by the robot unloading the workpiece and loading of the next workpiece substrate.

Typical form accuracy achieved thus far using this fully automated process is in the range 10 – 25 nm RMS for workpieces in the 30 - 75mm range. Figure 5 shows result for a 32mm F1 part taken with a Fisba interferometer.

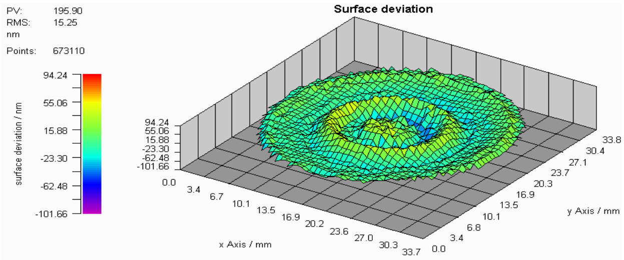

Figure 5. µfor automated form accuracy achievement (15nm RMS)

4. Conclusions

A new style highly compact diamond turning machine with low energy demands, low mass and low cost of ownership has been created.

Automation technology for this compact vertical oriented and highly integrated diamond turning system has been created and proven. The automated processes include those necessary to process and handle delicate substrates without damage. High specification of surface roughness and form accuracy has been achieved.

5. References

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