Application note A143: New software to reduce set-up time for grinding and diamond turning

PGI – X offset compensation

New software to reduce set-up time for grinding and diamond turning

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"The new AAU software from Taylor Hobson has increased our capability to manufacture high accuracy Infrared optics with enhanced diffractive analysis capabilities."

Tim Olsen (Dir. Of Engineering) Janos Technology

Introduction

Diamond turning is often used to manufacture high quality aspheric elements used in optical assemblies in telescopes, lasers, video projectors and numerous other systems and devices. Diamond turning is a multi-stage process. In the final stages of the manufacturing process, a diamond tipped lathe tool is used to achieve sub-nanometre level surface finishes and sub-micron form accuracies.

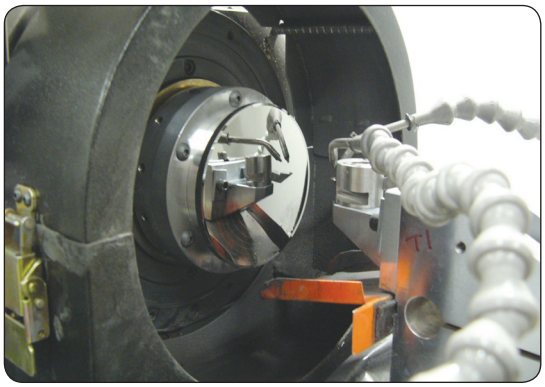

Figure 1: Diamond turning machine

Recent developments at Taylor Hobson have led to the availability of a new Aspheric Analysis Utility (AAU) software package. This not only provides the form error of aspheres and diffractives, but also calculates the X-offset and tool radius error which are common and frequent problems in the diamond turning process.

In addition to this X-offset analysis feature, Taylor Hobson and Precitech have developed software that enables the machine and metrology to communicate with each other. This enables automatic correction of the X-offset and tool radius errors, providing a significant reduction in set-up time and improved process performance.

Survey

Ten diamond turning customers in America were approached with a survey to determine the effect of Taylor Hobson's X-offset and radius error compensation capabilities. The average savings on set-up time are 330 hours per year. The larger benefit will be the scrap / rework reduction due to the X-offset compensation for the effects of the temperature drift in the diamond turning process.

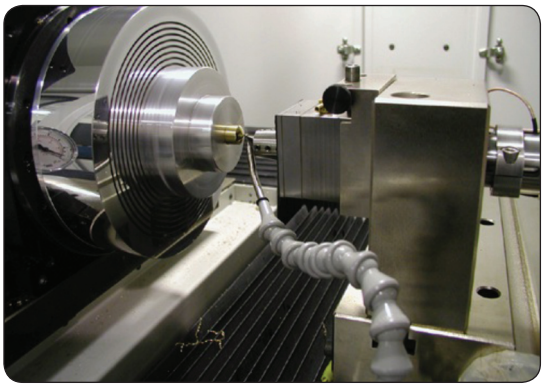

Figure 2: The fast tool Servo system enables the diamond turning of surface structures such as micro prisms, lens arrays, torics and off-axis aspheres with departures up to 1000 microns

Challenges

One of the largest causes of down-time in diamond turning and CNC generating is the set-up of a new cutting tool.

Traditionally a set-up requires a spherical set-up piece to be placed on the machine and cut. This is then measured on an interferometer to evaluate the X-offset error in the part as well as the tool radius error.

X-offset errors

X-offset errors are caused by a misalignment of the machine's X-axis and the spindle's rotational axis.

Any time a new tool is set-up it needs to be accurately aligned to the spindle axis. This alignment of the X-axis can drift over time due to the effects of temperature.

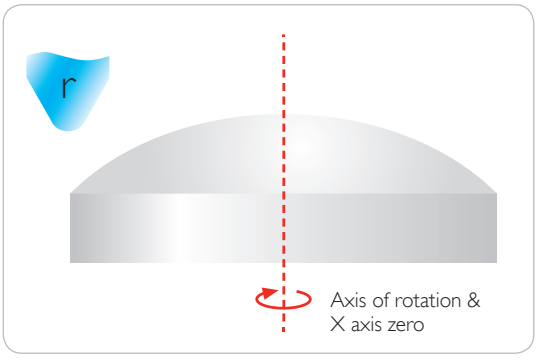

Figure 3: Axis aligned

Radius errors

The radius error is caused by not having accurate enough information of the diamond tool's radius.

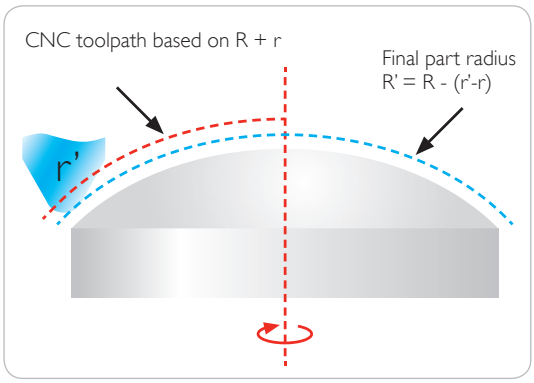

Figure 4: Tool radius error

Problems with spherical set-up piece

The spherical set-up part will not have exactly the same slope or sag as the asphere and thus will not represent errors which may be seen in the actual part.

The Z position of the spherical surface in the machine will usually be at a different Z position than the actual part. This can cause a shift in the X-axis based on spindle tilt relative to the Z-axis.

After spending an hour or two aligning the spherical set-up piece to the X-axis and changing fixtures, it is very possible that the actual part may still have an X-offset error.

Measurement and analysis using a standard interferometer relates form-error normal to the surface (along the circumference). Diamond turning machines generally cut normal to the Z-axis. This difference can cause an over-hit or under-hit based on this cosine error and a need for multiple iterations to get close to the desired alignment.

The fixturing to hold the set-up sphere will often be separate from the actual part fixture. This can require a substantial amount of time to change fixtures for set-up and then back again for the part, especially on critical applications where the fixture needs to be cut to match the back of the lens.

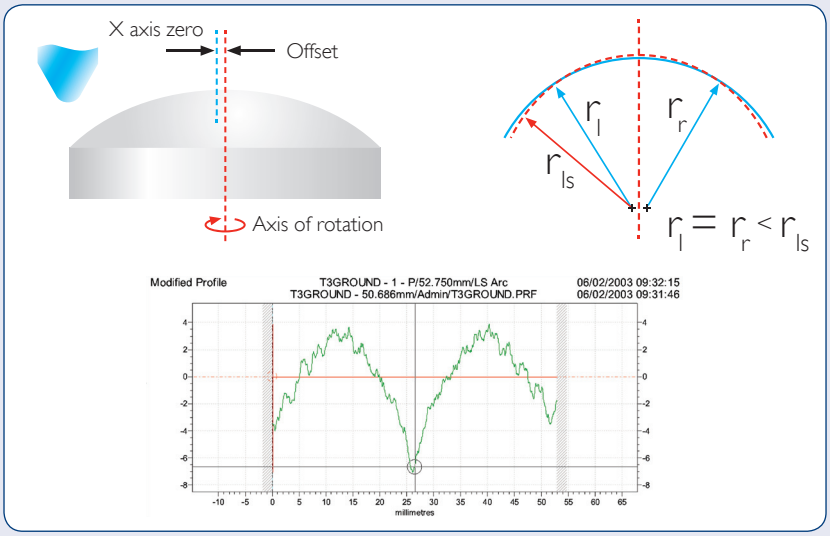

Figure 5: Axis misaligned: short of centre

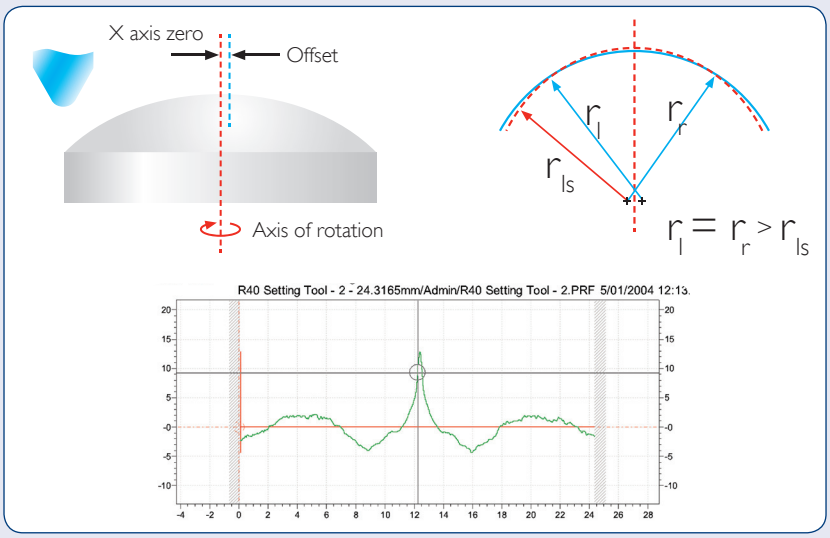

Figure 6: Axis misaligned: over centre

Old solution

It generally takes a few iterations of cutting and measurement to achieve proper alignment of the X-axis. An X-offset error will corrupt a radius measurement. It is common practice to iterate a few cuts to first correct for the X-axis offset and then iterate more to correct the tool radius

The accuracy and sensitivity will be specific to each part. Most parts need to have alignment better than 1 µm to achieve sub-micron form-error on the lens.

The average total down time for customers ranges from 0.5 hr to 2 hours:

- Change from part fixture to set-up fixture
- Possible changing of interferometer set-ups
- Iterate through cutting and measurement
- Set-up the part fixture again
- Potentially need to re-cut the part fixture in more challenging applications

New solution

New developments from Taylor Hobson Ltd. and Precitech Inc. now give the ability to measure the X-Offset/ Tool Radius as well as automatically correct for it from the direct measurement of a production asphere. The new process can reduce set-up time, improve throughput and reduce the amount of scrap and reworks required.

Data can be directly feed back into the Precitech controller for automatic correction without the need to re-program.

Set-up time reduction

- Quickly and deterministically correct for X-offset and tool radius for new set-ups.
- With large parts, correction can still be done with fast rough cut.

Improved process performance

- Quick feedback to the machining process allows a user to keep up with the X-axis drift over time due to temperature. This improves form error repeatability
- Reduction in scrap and rework, saving additional cost

Estimate of residual error after correction

- Advanced algorithm calculates what the residual form-error will be after the X-offset and radius error are corrected
- This knowledge lets the operator know if X-offset and radius error correction will enable a process that meets specification, or if the tool needs to be replaced, etc

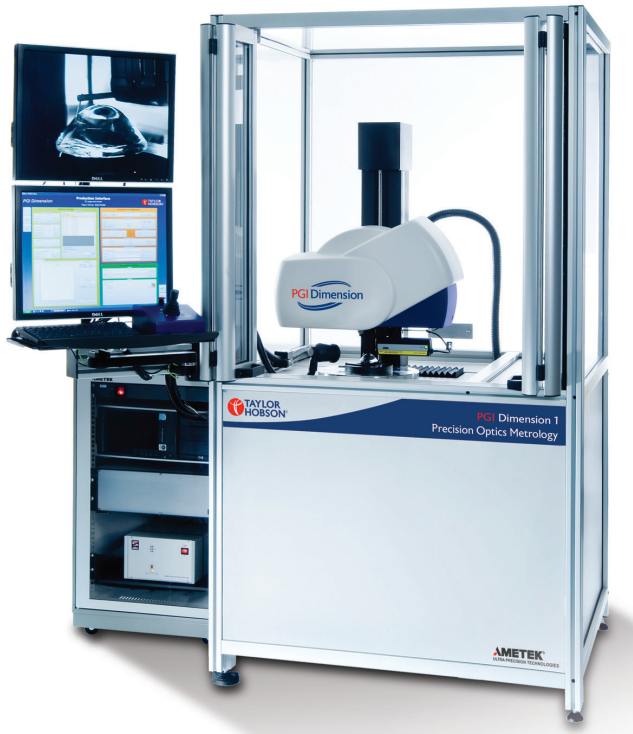

Figure 7: PGI Dimension for process improvement

Figure 8: Nanoform 250 ultra precision for diamond turning

Results

The diagrams below show a real customer example set-up of a high departure asphere. In this example, the Pt value has been reduced from 5.6886 um to 0.1717 um in a single correction. This not only shows a clear improvement in the process, but in the accuracy of the algorithms' initial estimate compared to the measured result after correction.

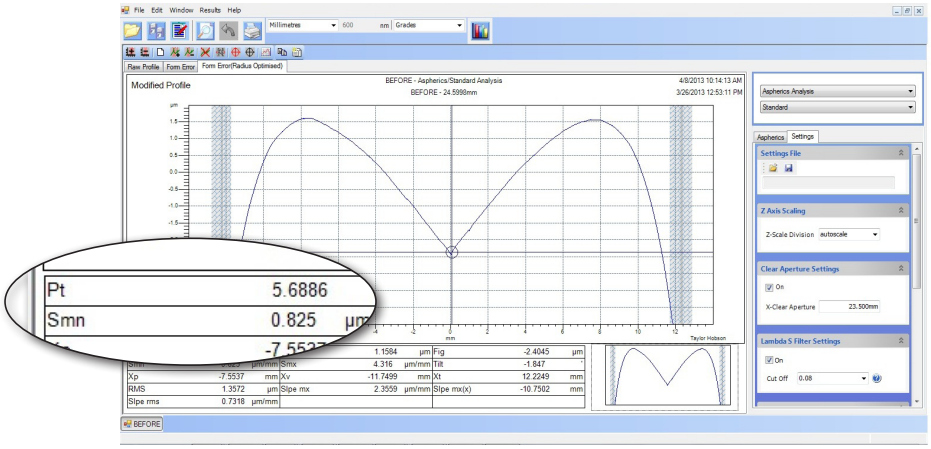

Figure 9: Measured form error before correction

Figure 10: Calculated form error with theoretical X-offset

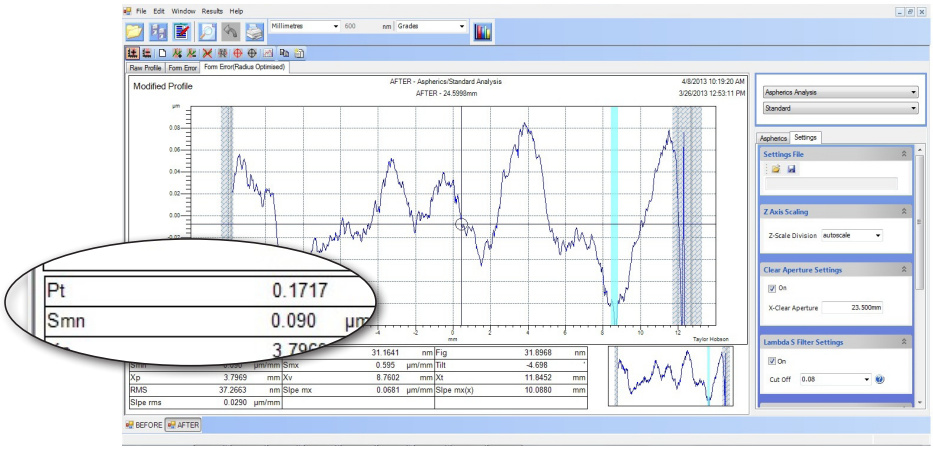

Figure 11: Measured form error after actual X-offset

Conclusions

This new development adds a fast, accurate and easy to use ability to keep the diamond turning and grinding process in check. This is through the automatic X-offset error knowledge and compensation capability, improving throughput and scrap / rework.

Overall benefits include:

- Set up time reduction
- Improved process performance and yields
- Automatic feedback to the manufacturing process

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