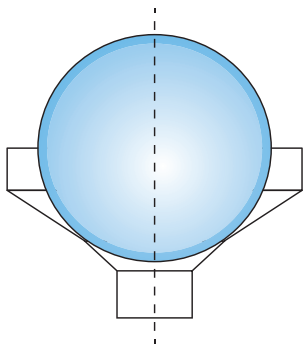


Application note A146: Fuel injectors

Coherence Correlation Interferometry (CCI)

High speed 3D cone measurements

Yang Yu, PhD



Ball location on seat

Introduction

Valves are important components for the modern high pressured fuel injections and hydraulic systems that power cars and other vehicles. The usual functional surface in a valve is a conical surface and a mating convex part such as a sphere. To lower emissions and increase the efficiency of vehicle engines, the tolerance of valve seat roundness is desired to be very tight, usually to the order of submicron. In addition, injector seat roughness, injector cone angle and straightness also play an important role in the hydraulic system. These parameters are critical to control the injection pressure in order to produce fine atomisation of the fuel leading to better and cleaner combustion.

In a single measurement the CCI delivers

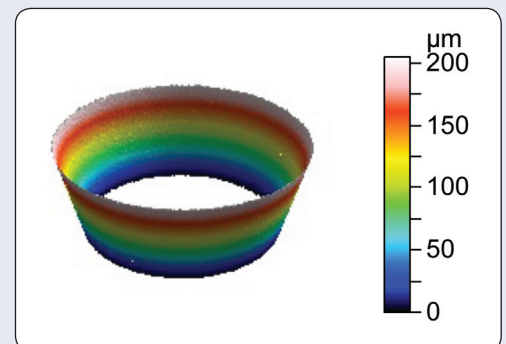
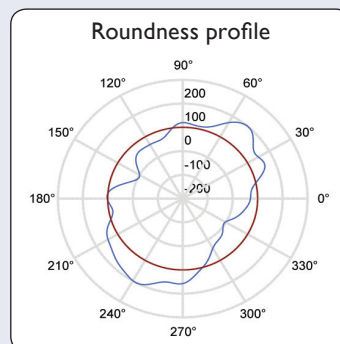
- Multiple roundness
- Accurate cone angle

Also available

- Roughness
- Straightness

Advanced metrology – CCI

Coherence Correlation Interferometry (CCI) instruments provide advanced 3-dimensional non-contact surface characterization. The technique is fast and accurate and provides a high resolution 3D image together with analysis that includes 3D roughness, 3D form analysis and 2D profile measurements. The conical seat is a key feature of modern fuel injectors. Using the CCI roundness and 3D data fitting it is now possible to accurately determine the cone axis and measure key parameters such as cone angle, roundness and roughness in a single measurement, eliminating setup errors and saving time over traditional contact techniques. This can be achieved without the need for a high cost fixture. In this application note, we provide some examples of the injector cone measurements using the newly released CCI Roundness. Some roundness correlation test results between the non-contact CCI Roundness and the new model of high precision Talyrond instrument are also shown in this note.



Fully automatic production batch inspections are possible now!

Coherence Correlation Interferometry (CCI)

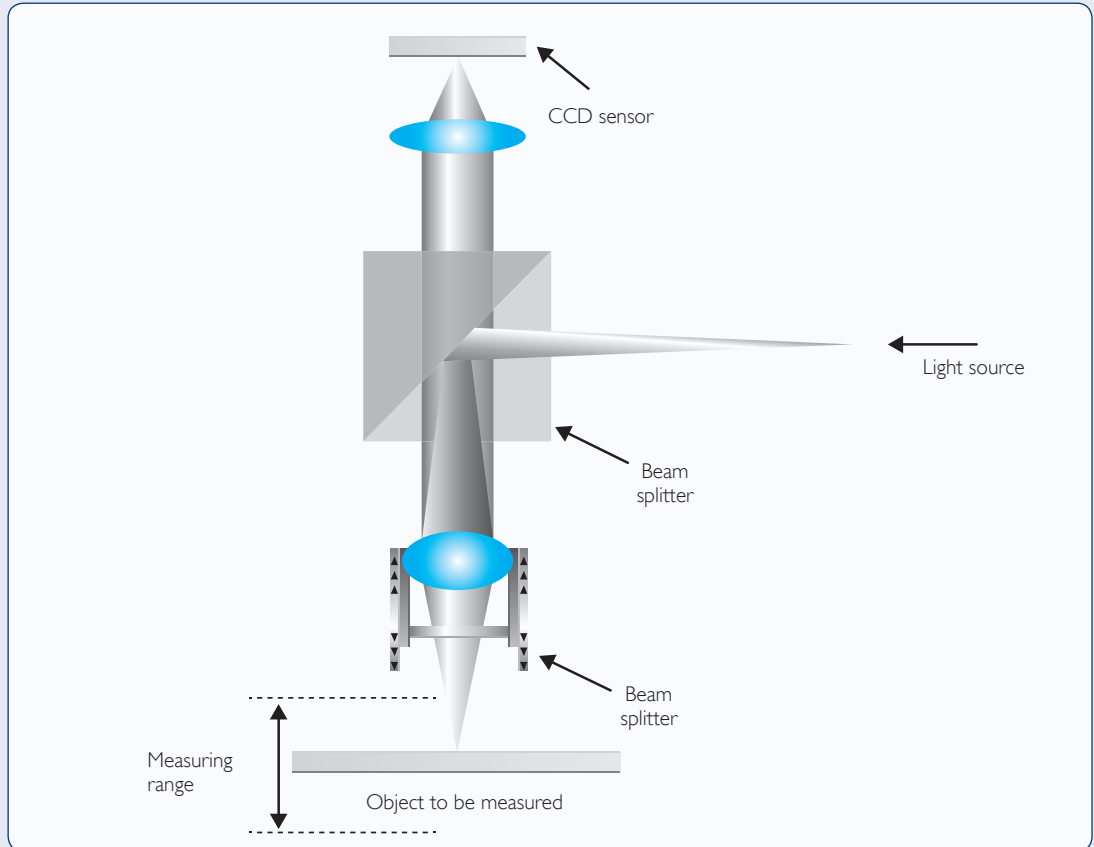


Figure 1: Schematic of a scanning interferometer system

“The wide variety of industrial applications mean that Coherence Correlation Interferometry is increasingly important”

Dr Mike Conroy, Business Development Manager, Taylor Hobson Ltd.

A schematic of a scanning interferometer system is shown in Figure 1. Light from the light source is directed towards the objective lens by the upper beam splitter and the light is then split into two separate beams by the lower beam splitter.

One beam is directed towards the sample and the other is directed towards an internal reference mirror. The two beams recombine and are sent to the detector. As the interferometric objective is scanned in the z direction, interference occurs when the path lengths of the two beams are the same. The detector measures the intensity, taking a series of snapshots as the sample is measured.

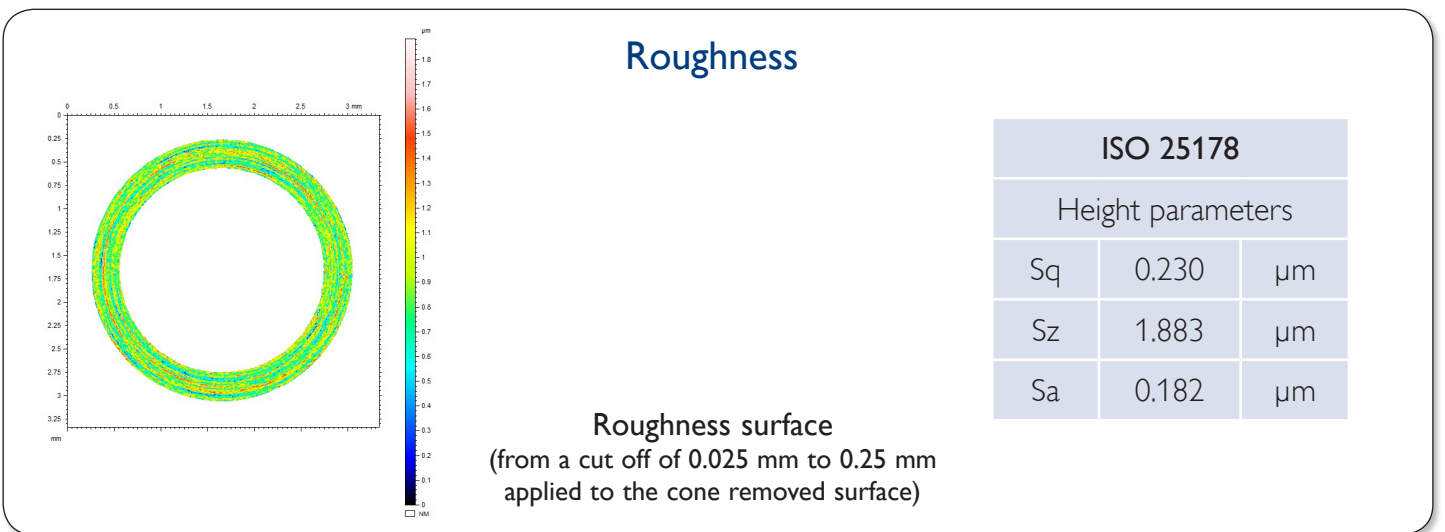
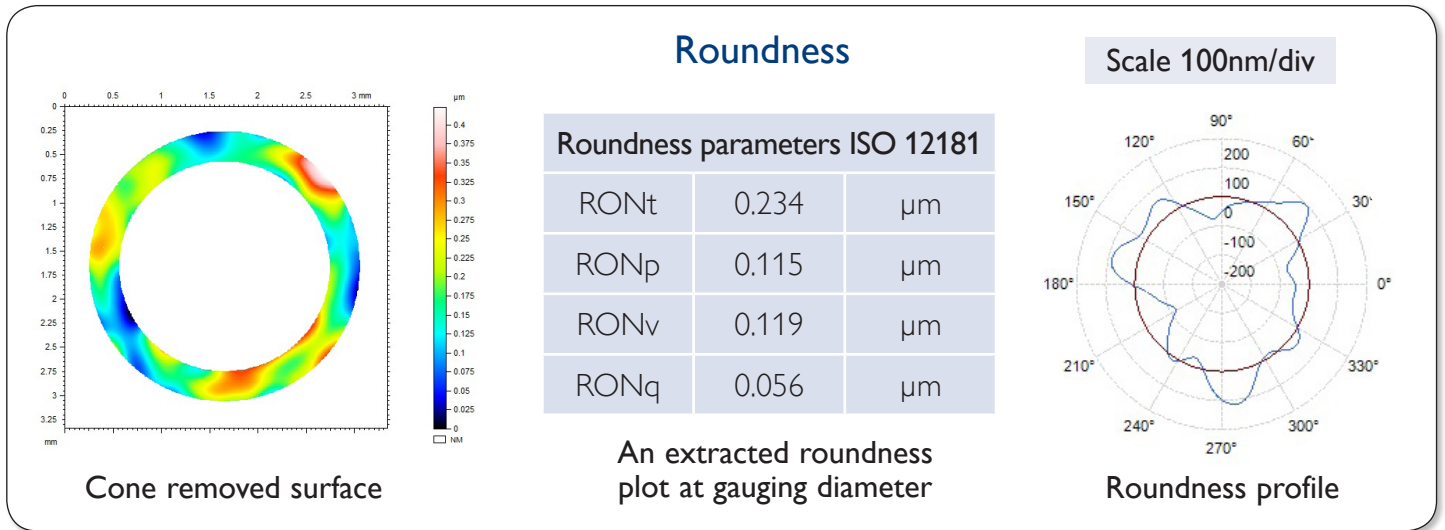
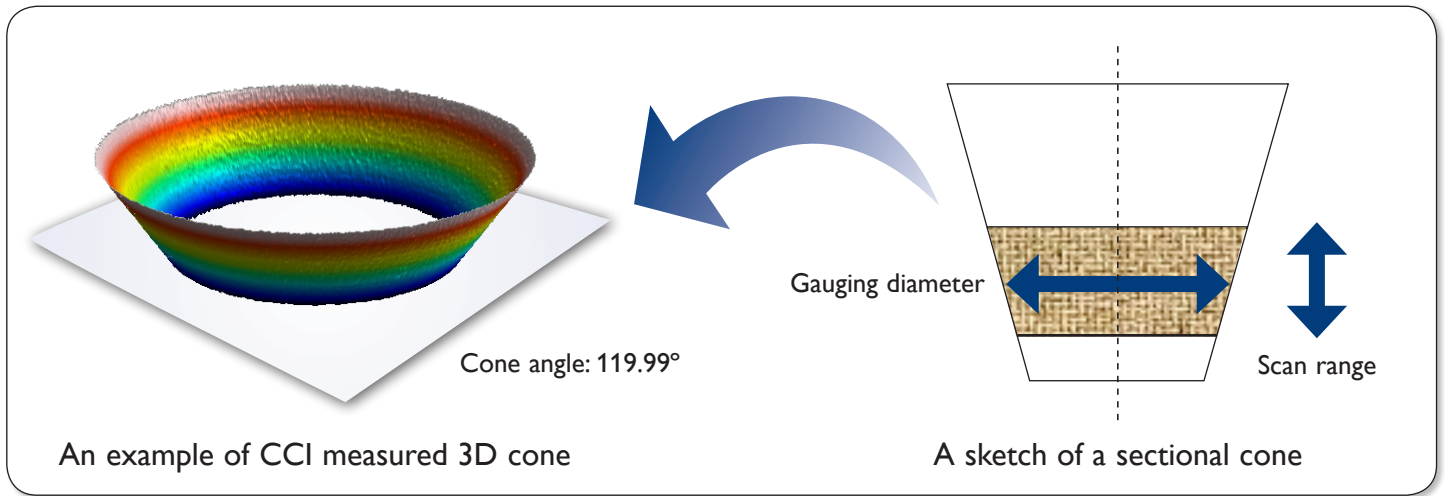
This creates an intensity map of the light being reflected from the surface, which is then used to create a 3D image of the surface being measured. Different techniques are used to control the movement of the interferometer and also to calculate the surface parameters. The accuracy and repeatability of the scanning white-light measurement are dependent on the control of the scanning mechanism and the calculation of the surface properties from the interference data.

Coherence Correlation Interferometry is becoming increasingly important for measurements in many applications, providing:

- Fully automatic non-destructive measurements
- Accurate and quantitative characterization of surfaces
- Sub-angstrom resolution regardless of the scanning range used
- Fast and convenient sample loading and set-up
- Capability of measuring a wide range of materials
- Highly repeatable measurements
- Roughness and step-height analysis in one measurement

Non-contact 3D measurement

Fully automated 3D measurement and analysis, over the whole seat contact region

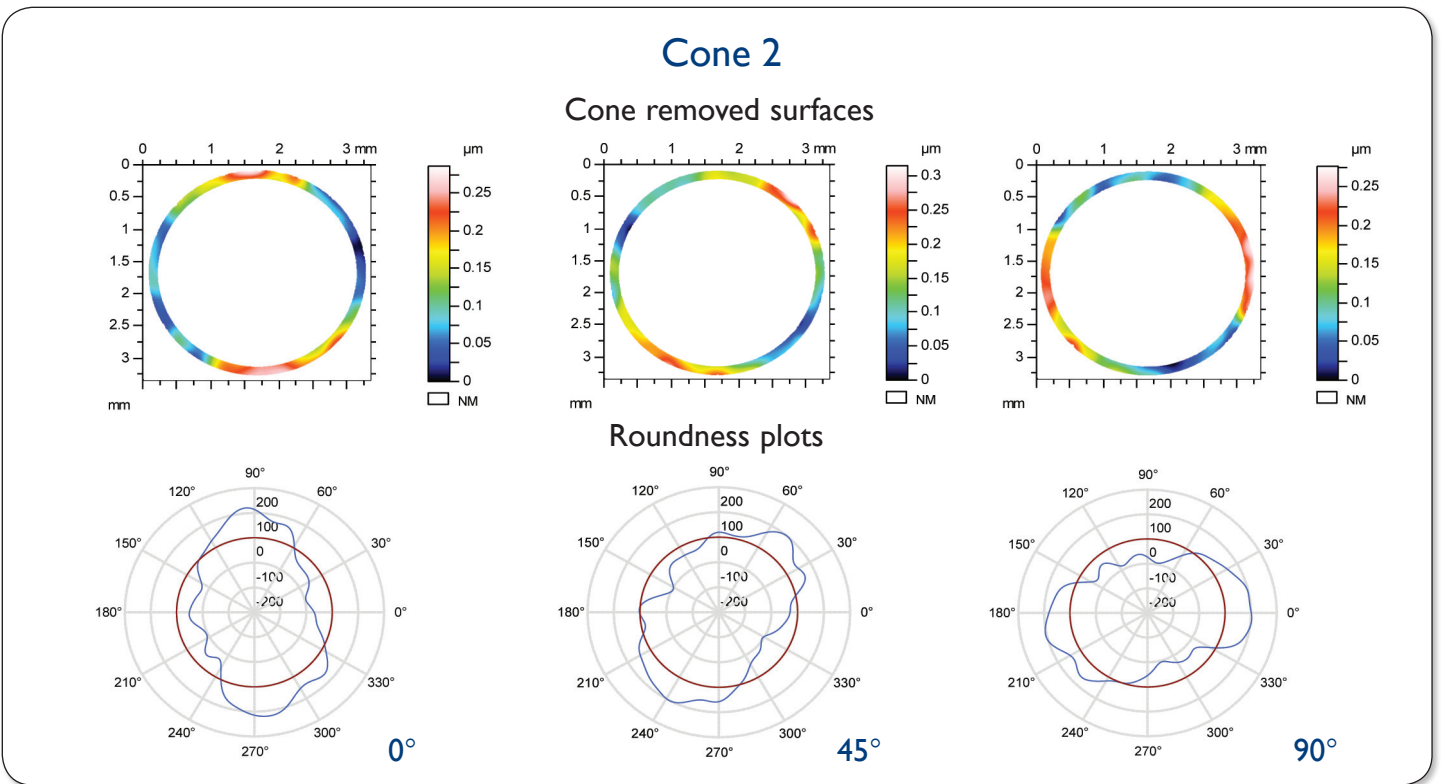
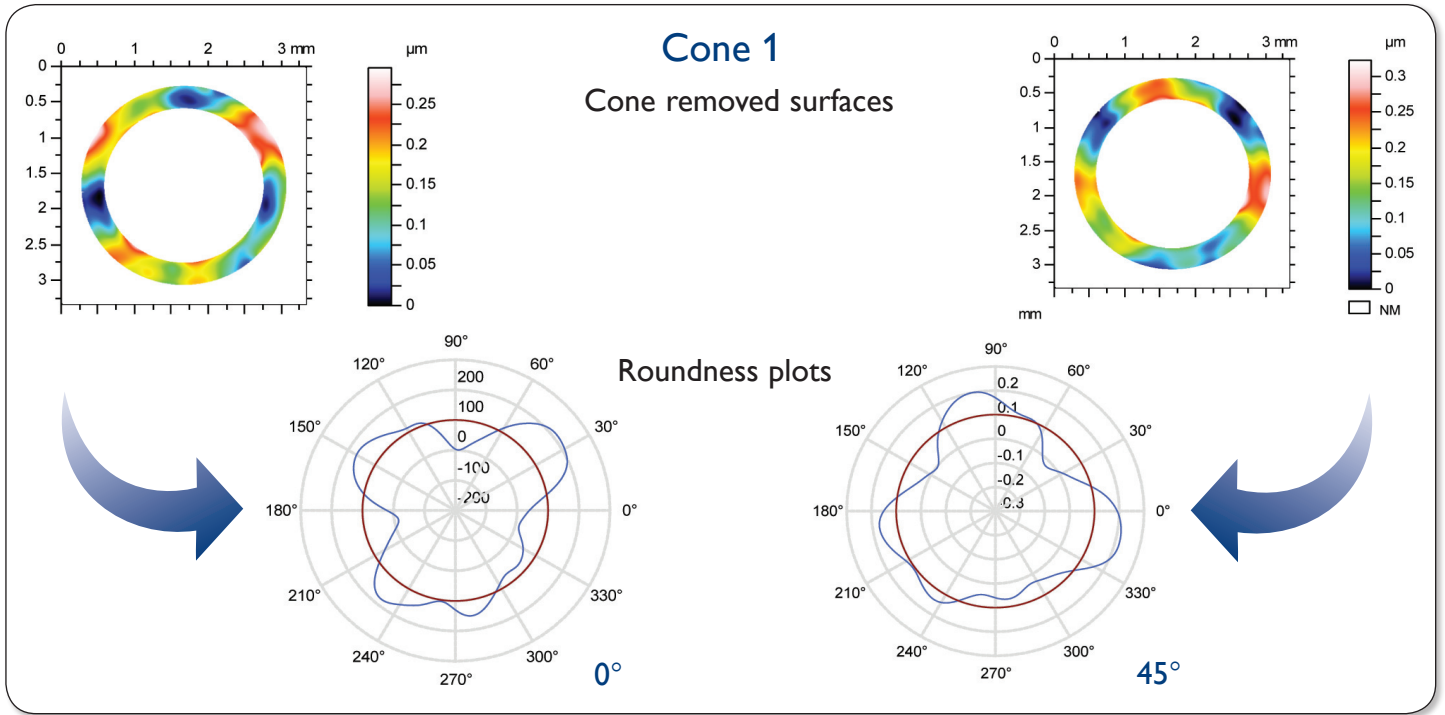


One measurement multiple analysis provide all the desired parameters such as seat roundness, cone angle, roughness and straightness, which gives greater inspection flexibility so as to improve process control.

Full injector cone inspection and excellent process control!

Examples showing reproducibility

Two injector cones were investigated using CCI at different rotation angles. See below for the corresponding cone removed surfaces and roundness plots at gauging diameters



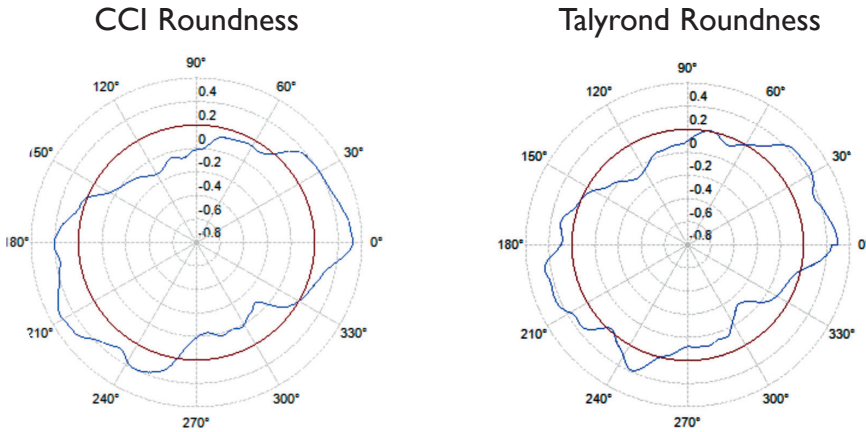
Almost identical roundness plots were obtained at different angle positions. It indicated that CCI roundness can offer accurate roundness results with minimum system errors.

Correlation studies – CCI Roundness and stylus instruments

Correlation study 1 – Roundness (CCI and Talyrond)

Ten cones with different finishes were investigated using CCI Roundness and high precision Talyrond instrument in this study.

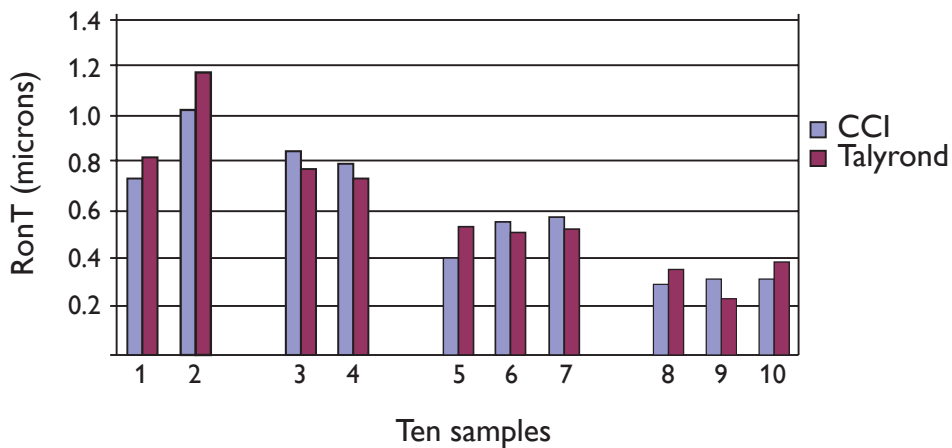
Roundness plots



Scale 0.2um/div

LS/ 1–50upr

An example of roundness comparison between CCI and Talyrond instruments (120 degrees)

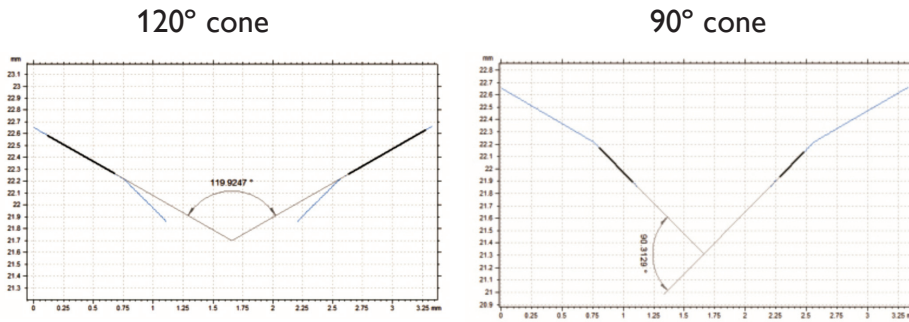


Good correlations can be clearly seen from the roundness plots and the chart, which proves CCI roundness results are trustable and can be used to identify process difference.

Correlation study 2 – Cone angle (CCI and PGI)

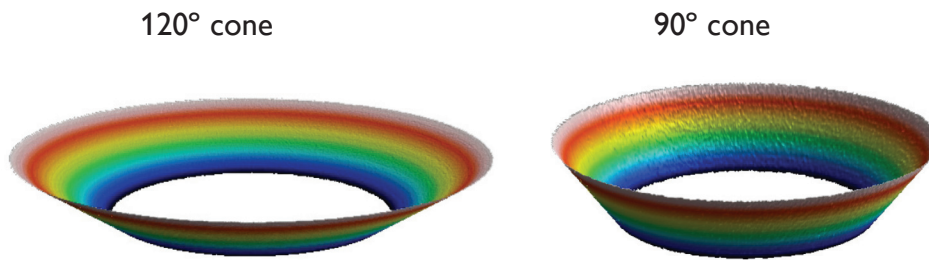
Ten 120° cones and ten 90° cones were investigated using a CCI Roundness and a Talor Hobson patented PGI (Phase Grating Inteferometry) instrument in this study.

PGI



Examples of PGI data

CCI



Examples of CCI data (3D cones)

CCI / PGI angle difference

Cone angle (°)	Average difference (°)
120°	0.014
90°	0.021

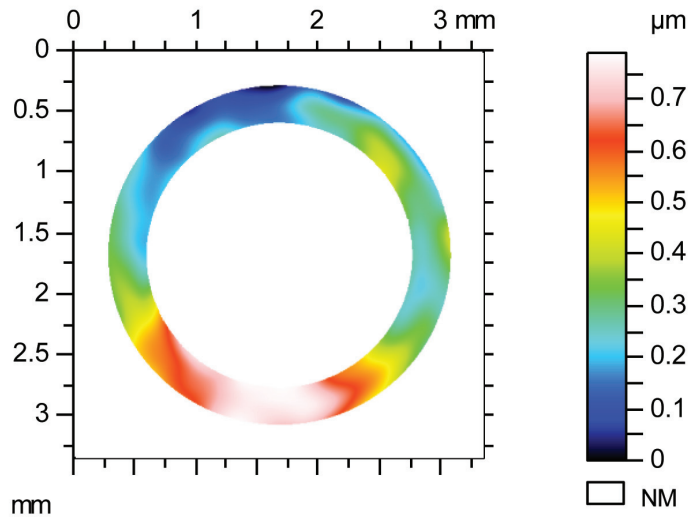
Excellent correlations from different cones with cone angles between a CCI Roundness and a high precision PGI stylus profiler indicated that CCI Roundness provides precise cone angle results and enables full inspection can be carried out in production.

Multiple roundness analysis at different gauging diameters from a single 3D dataset

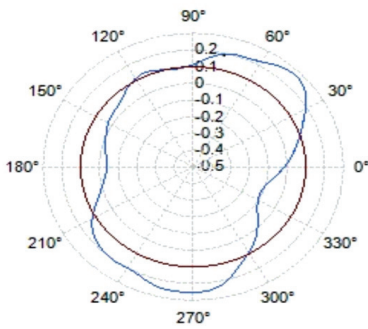
CCI Roundness is capable of carrying out roundness analysis from one 3D dataset at different radius, multiple roundness plots at different gauging diameters can be easily compared to identify the problem of measurement as consistent roundness plots at different heights are expected to be obtained considering the machine processes.

Multiple roundness plots at different heights

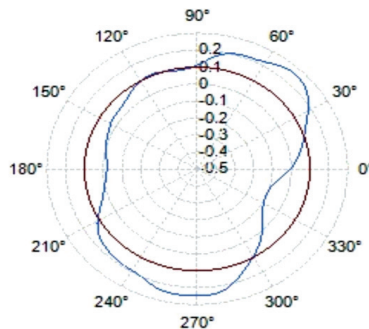
Roundness – cone removed



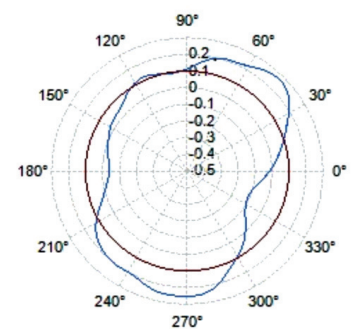
Roundness plots



Gauging diameter – 2.3 mm



Gauging diameter – 2.4 mm



Gauging diameter – 2.5 mm

Scale 0.1µm/div

LS/ 1–50µr

Identical roundness plots obtained from CCI Roundness analysis indicated that CCI provides accurate form information.

Repeatability tests

The tests were carried out on a 120° injector cone using CCI Roundness, 100 times repeat measurements were made on the cone.

	Cone angle (°)	Ront (µm)	Roughness Sa (µm)
Average value	120.043 ± 0.004	0.375 ± 0.010	0.252 ± 0.0022

Good repeatability test results were obtained from all the key parameters such as roundness, cone angle and roughness. It further proved that CCI Roundness is a reliable and trustable cone inspection tool.

Conclusions

Non contact CCI Roundness is a suitable metrology tool for process control of injector cones in production. It can provide high-density 3D data instead of profile traces. All the key parameters can be obtained from one single 3D measurement in a few seconds. It is capable of performing its function rapidly and accurately, whilst assisting with quality control of the systems.

References

1. A. Bankhead et al, Interferometric Surface Profiling, GB2390676, 2004



Taylor Hobson UK

(Global Headquarters)
PO Box 36, 2 New Star Road
Leicester, LE4 9JD, England

Tel: +44 116 276 3771
taylor-hobson.sales@ametek.com



Taylor Hobson France

Tel: +33 130 68 89 30
taylor-hobson.france@ametek.com



Taylor Hobson Germany

Tel: +49 611 973040
taylor-hobson.germany@ametek.com



Taylor Hobson India

Tel: +91 80 67823200
taylor-hobson.india@ametek.com



Taylor Hobson Italy

Tel: +39 02 946 93401
taylor-hobson.italy@ametek.com



Taylor Hobson Japan

Tel: +81 36809 2406
taylor-hobson.japan@ametek.com



Taylor Hobson Korea

Tel: +82 31 888 5255
taylor-hobson.korea@ametek.com



Taylor Hobson China Beijing Office

Tel: +86 10 8526 2111
taylor-hobson.beijing@ametek.com



Taylor Hobson China Shanghai Office

Tel: +86 21 58685111-110
taylor-hobson.shanghai@ametek.com



Taylor Hobson Singapore

Tel: +65 6484 2388 Ext 120
taylor-hobson.singapore@ametek.com



Taylor Hobson USA

Tel: +1 630 621 3099
taylor-hobson.usa@ametek.com