Ball screws are routinely used for a wide range of applications. These include aircraft control surfaces, landing gear, precision machine tools, automotive steering and numerous other applications.

In this Application Note we consider the challenges involved in measuring Ball Screws, outline the limitations of traditional methodology methods and detail the solutions provided by the Form Talysurf® PGI NOVUS system and Metrology 4.0 software.

Challenges

1. Ball screw contact points

A key reason for axial inspection of ball screws is to prevent performance issues after assembly of the ball screw, ball nut and associated components. In a typical Ball Screw assembly, the key issue is how and where the ball sits on the Gothic arch profiles. The consequence of not controlling this often leads to tight spots in the final assembly.

Problems such as tight spots can usually be prevented by monitoring the following characteristics: Gothic arch form and radius, contact points, axial surface finish, pitch and pitch circle diameter (PCD) - all of which are typically well-specified on the design drawing. The consequence of not controlling this often leads to tight spots in the final assembly.

2. Accurate alignment of the thread

For accurate measurement of form along the thread using a surface profilometer, it is crucial that the ball screw is correctly aligned to the measurement axis. Any misalignment will introduce measurement errors as the stylus will not track the intended path.

A further challenge is in aligning ball screws which do not have a plain cylindrical shaft on which to do the alignment. This means it is necessary to align on the thread itself, highlighting the difficulty found with conventional profilometers in positioning the stylus accurately on the thread, particularly if the land areas are small.
3. Measurement on both sides

Measurements are needed on both sides of the ball screw, in order to fully characterise PCD and other parameters. The relationship of both sides is key to its functionality.

Such measurements are typically done on a profilometer using a ‘dual-bias’ gauge and double-sided stylus. Accurate measurements of diameter (e.g. PCD) can only be achieved on a stable measurement platform where the relationship between the two tips and system coordinates are precisely known and where the gauge is accurately aligned. Conventional profilometers do not address these issues.

Solutions provided by Form Talysurf® PGI NOVUS and Metrology 4.0

1. Identifying the contact points

Key functional issues can be determined quickly with the use of Form Talysurf® PGI NOVUS and Metrology 4.0 software. Axial measurements of the thread profile, combined with Helix Angle Correction (Figure 3), establish the true ball fit in the gothic shape (Figure 4).

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**Reduce cycle time with Helix angle correction**

Helix angle correction allows an axial measurement to be taken along a thread profile and transform it so that it represents a measurement taken perpendicular to the thread angle.

This allows for tolerancing of the profile as it is usually defined in the design drawings. It greatly reduces cycle time for inspection as the complete ball screw can be measured in one trace.

![Figure 3 - An axial measurement along the axis of the part can be simulated to represent a measurement taken perpendicular to the thread angle.](image)

**Find contact points automatically using Metrology 4.0 software with gothic arch analysis**

The ball is fitted to the Gothic profile. The information of the ball contact points can be displayed. Pitch, radius, and PCD can also be determined.

Ball screw manufacturers get a valuable insight into how the ball screw will function the analysis will highlight any issues that will affect performance and lifetime of the part.

![Figure 4 - Analysis of Pitch, Gothic arch, PCD from two axial measurements.](image)

* A ball nut can only be measured in this way.
2. Correct alignment gives true profiles

It is important to capture the true profile of the ball screw. To ensure this, the component should be correctly aligned to the instrument axis. This is particularly important for small diameters.

The system achieves this rapidly by use of high accuracy (Y and rotary) stages with an automated alignment routine. The Y-stage and rotary stage are used to determine the crest positions at each end of the ball screw and rotate it by the correct amount. This increases accuracy, repeatability, reproducibility and throughput as there is no operator interaction required.

Accurate ball screw measurements can only be achieved following correct alignment.

Alignment methods to match the scenario

Alignment method 1: Outer shaft section - The Y stage and rotary stage is utilised to measure both ends of the component. From these two measurements the angular rotation of the crests can be determined. The rotary stage is then adjusted to align the component to the measurement axis. The automatic lift lower on the PGI NOVUS gauge allows for fast movement over the component without the need of moving the column.

Alignment method 2: Align on threads with the use of Metrology 4.0 PCS - The revolutionary Part Co-ordinate System (PCS) that is available in Metrology 4.0 software allows exceptionally precise control of the Form Talysurf® PGI NOVUS stylus. With this new approach to instrument moves and full control of the stylus tip position, it is possible to move the stylus exactly where required onto the very small land areas on the thread. This is done through creating a new origin and axes on the part itself (a PCS), relating back to the design drawing.

3. Dual bias measurement capability - both sides of the component with one set-up

The ball screw’s upper and lower surface can be inspected in one measurement process. The Form Talysurf® PGI NOVUS has dual bias capability that gives 20 mm of gauge range and a resolution of 0.2 nm. The built-in gauge calibration allows for accurate measurements of form, surface finish and diameter from one automated routine. The measurement of a ball screw will require all of these.

The Taylor Hobson calibration artefact allows normal bias calibration, reverse bias calibration and a unique tip to tip calibration. The latter ensures accurate diameter measurements as it calculates the vertical distance of the tips as well as the stylus tip offsets in the X and Y direction. The offset values are used to ensure the tip is on the crest of the component (see Figure 5).

Measurements are needed on both sides of the ball screw. This enables the critical analysis of PCD. The relationship of both sides of the component is key to the functionality of the part. After the gauge has been calibrated by the automated routine, form and surface finish measurements can be carried out on both sides of the component.

Figure 5 - When measuring diameter, it is critical that the tip is on the crest of the part. Metrology 4.0 software can automatically offset the component to ensure this requirement is met.
Results

User defined analysis templates can be automatically applied to the measurements as part of the analysis program. Analysis of Gothic arch form, contact points, radius, axial surface finish, pitch, pitch circle diameter (PCD) can be displayed to the preference of the user. Once a template has been saved it can be used on every measurement conducted afterwards. Pass/fail criteria can be set that gives a full indication whether a part has met tolerance or not.

![Figure 6 - Contour template showing surface finish, form, gothic arch analysis, pitch, PCD and tolerances.](image)

Summary

Form Talysurf® PGI NOVUS and Metrology 4.0 software provide the ultimate solution for axial measurements on a ball screw. The key challenges for ball screw measurement are fully met through the hardware and software capabilities. The large gauge range and low resolution provide accurate measurements of form and radius on the gothic profile, the automatic stages ensure correct alignment of the component and the dual bias gauge provide profiles on both sides of the component. In addition to the measurement, Metrology 4.0 analysis provides the key information in a clear, fully user defined format.