

**Precision has always  
been our second nature...**



## **Triskelion Ultra Precision Tactile Probe System**



# Triskelion | Ultra Precision Tactile Probe System

## 1.1 Introduction

IBS Precision Engineering has developed an new ultra-precision touch probe system, the Triskelion probe. This probe system is suitable for point measurements as well as scanning. Its excellent measuring uncertainty and full 3D measurement capabilities make this probe suitable for ultra-precision 3D metrology. Possible applications include 3D ultra-precision (*micro-/nano-*) CMMs as well as on-machine metrology on machine tools.

## 1.2 Probe concept

A schematic representation of the probe concept is shown in figure 1.1. The stylus is elastically suspended by means of flexures. The stylus is attached to these flexures via a rigid body; this body contains target discs which serve as measurement targets for the capacitance sensors. During deflection of the probe tip, the capacitance sensors measure the displacements of these target discs; the displacement of the probe tip can thus be determined.

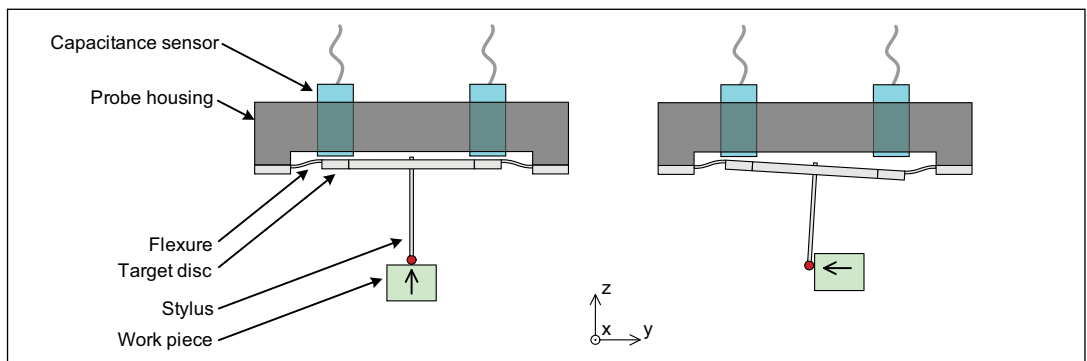


Figure 1.1: Schematic representation of probe concept

Figure 1.1 shows the working principle of the probe system for deflection of the probe tip in vertical and sideways direction. Note that this is a 2D simplification, the actual design features three flexures and three capacitance sensors, allowing deflection in full 3D, while the deflection of the tip is also measured in x-, y- and z-direction.

The suspension of the stylus is realized by means of a monolithic metal suspension foil. This foil contains both the flexures and the three-legged body which connects the flexures to the stylus. The thickness of the flexures is reduced to achieve the desired (low) stiffness of the suspension and to ensure that elastic deformation takes place in the flexures and not in the three-legged body or in the stylus. At the end of each flexure, circular target discs serve as the targets for the three capacitance sensors.

Figure 1.2 shows a CAD model of the realized probe-system. For this design, a stylus length of 8.5 mm is applied, with a  $\varnothing$  0.5 mm spherical ruby probe tip. The following section will discuss the most important design features of the realized probe system.

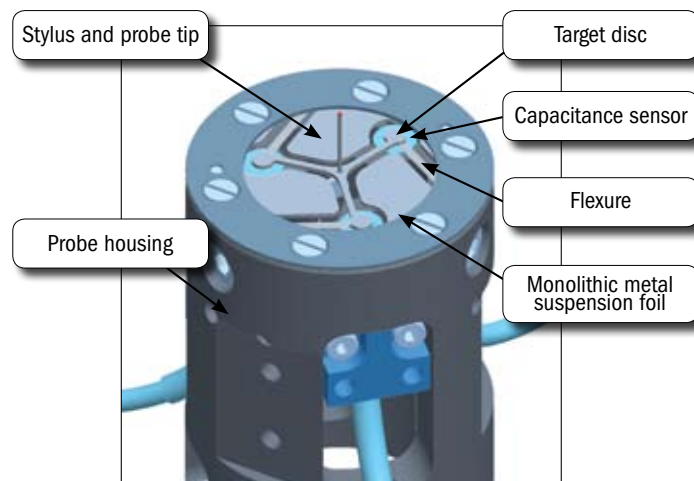


Figure 1.2: Ultra-precision touch probe system

## 1.3 Design features

### 1.3.1 Low contact force

When the contact force between probe tip and work piece surface is too high, there may be a risk of damaging the surface. For the probe design shown in figure 1.2, this contact force is limited by selecting a sufficiently low stiffness for the suspension of the stylus. A stiffness of 70 N/m was realized, which results in a typical probing force of 0.5 mN or less.

### 1.3.2 Low collision force

Other than the 'static' contact force, the impact of the probe tip colliding with the work piece can also cause surface damage. Although this can be reduced by applying low probing velocities, this is generally not desired as measurement times may increase.

A more efficient way to reduce the collision force is to minimize the suspended mass of the system. For the probe system discussed here, the suspended mass was reduced to 160 mg.

### 1.3.3 Large measurement range

The measurement range of the probe system is a critical parameter for the control of the CMM: after a probe trigger has been detected, the CMM axes should reach a standstill within the measuring range of the probe system. If this is the case, simply adding the measured probe deflection to the position measurements from the machine axes will yield the measurement point coordinates. The measurement range of the new probe system is more than 10  $\mu\text{m}$  in all directions.

### 1.3.4 Probe tip size

The long-term stability of the probe system has been optimized by applying low-expansion materials. The complete probe body and the elastic suspension are made from invar<sup>®</sup>. The stylus is made from tungsten carbide. In addition, the probe system is assembled from only a minimum number of parts, without adhesives or other potentially instable assembly techniques.

### 1.3.5 Low replacement costs

Products may have small features, such as narrow ridges or small holes, which cannot be measured with a large probe tip. Reducing the probe tip size greatly increases the measurable area of such work pieces. For this probe system, spherical ruby tips with radii between 0.08 and 0.25 mm can be applied. IBS Precision Engineering is currently developing a miniaturized version of the Triskelion probe system, which has a spherical tip with a radius of only 36  $\mu\text{m}$ .

### 1.3.6 Robust design and low replacement costs

As the suspension of the probe is made from metal, the probe system is quite robust and will not break upon touch.

The most expensive part of the probe is the measurement system; because the three capacitance sensors can be re-used, even when the more fragile parts of the probe system have been damaged, replacement costs of a damaged probe are relatively low.

## 2. Calibration and application

Figure 2.1 shows some results of the sensitivity calibration of the probe system, which give a good indication of the measurement uncertainty of the measured probe deflection. The measurement result presented here shows the measurement errors in 3D for a tip deflection up to 5  $\mu\text{m}$ .

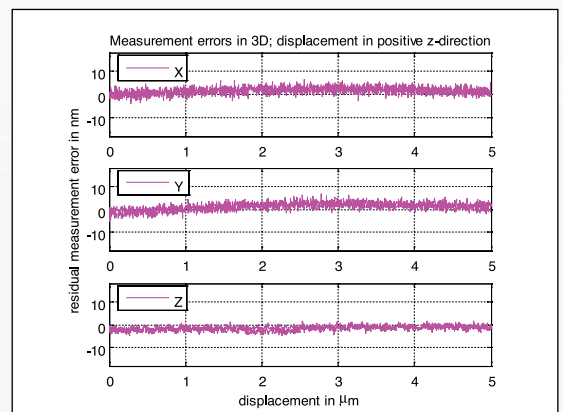
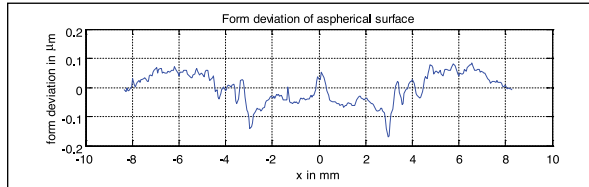
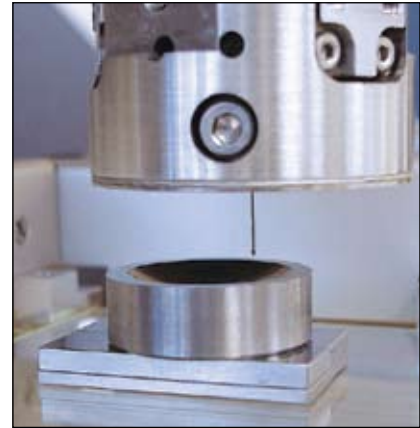


Figure 2.1: 3D Measurement errors for probe tip deflection up to 5 $\mu\text{m}$

Figure 2.2 shows a photograph of the probe system during measurement of an aspherical mould insert. For this measurement, the probe system was integrated in an ultra-precision CMM. The form error of the measured mould insert is also shown; this is the residual after subtraction of the theoretical asphere. No data filtering was applied.



Residual form error of measured profile

Figure 2.2: Measurement of aspherical mould insert

### 3. Summary

The design characteristics of the pre-prototype are summarized in the table below.

Ultra precision touch probe	
Stylus length	8,5 mm*
Stylus ball radius	250 µm*
Moving mass	160 mg
Probing stiffness	70 N/m Isotropic
Typical measuring force	< 0.5 mN
Measuring range X, Y	+/- 10 µm
Measuring range Z	+ 10 µm
Measurement resolution	3 nm
Measurement errors in 3D for probe deflections up to 5 µm (k=2)	< 15 nm
*Other stylus lengths and tip sizes are available upon enquiry.	

Table 3.1: Design parameters of realized ultra-precision probe system

At the cutting edge of accuracy