Renishaw touch-trigger probing technology

Rugged and flexible solutions for discrete point measurement on CMMs
Touch-trigger probe technologies

Resistive
- Simple
- Compact
- Rugged

Strain-gauge
- Solid-state switching
- High accuracy and repeatability
- Long operating life
Kinematic resistive probe operation

A trigger signal is generated on contact with the component surface and is used to stop the machine.

Three rods, each resting on two balls, providing six points of contact in a kinematic location.

A spring holds the stylus against the kinematic contacts and returns the probe to a seated position following contact between the stylus and the part.

The stylus ball is uniquely located, returning to the same position to within 0.00004 “ (1 micron).
Kinematic resistive probe operation

- Probe in seated position

All kinematics in contact

Motion of machine
Kinematic resistive probe operation

- Probe in seated position
- Stylus makes contact with component
Kinematic resistive probe operation

- Probe in seated position
- Stylus makes contact with component
- Contact force resisted by reactive force in probe mechanism resulting in bending of the stylus
Kinematic resistive probe operation

- Probe in seated position
- Stylus makes contact with component
- Contact force resisted by reactive force in probe mechanism resulting in bending of the stylus
- Stylus assembly pivots about kinematic contacts, resulting in one or two contacts moving apart
- Trigger generated before contacts separate
Kinematic resistive probe operation

- Probe in seated position
- Stylus makes contact with component
- Contact force resisted by reactive force in probe mechanism resulting in bending of the stylus
- Stylus assembly pivots about kinematic contacts, resulting in one or two contacts moving apart
  - Trigger generated before contacts separate
- Machine backs off surface and probe reseats
Kinematic resistive probe operation

**Electrical switching**

- Electrical circuit through contacts
- Resistance measured
- Contact patches reduce in size as stylus forces build

Close-up view of kinematics:

- Contact patch shrinks as stylus force balances spring force
- Resistance rises as area reduces \( R = \rho/A \)
- Elastic deformation

Section through kinematics:

- Current flows through kinematics
- Kinematics bonded to (and insulated from) probe body
- Kinematic attached to stylus

H-1000-8006-01-B Slide 9
Kinematic resistive probe operation

**Electrical switching**

- Resistance breaches threshold and probe triggers
- Kinematics are still in contact when probe triggers
  - Stylus in defined position
- Current cut before kinematics separate to avoid arcing
Factors in measurement performance

Pre-travel

• Stylus bending under contact loads before trigger threshold is reached

• **Pre-travel depends on** $F_C$ and $L$

• Trigger is generated a short distance after the stylus first touches the component

$$F_C \times L = F_S \times R$$

$L$ and $F_S$ are constant

$\therefore F_C$ is proportional to $R$
Factors in measurement performance

Pre-travel variation - ‘lobing’

• Trigger force depends on probing direction, since pivot point varies
  • $F_C$ is proportional to $R$
  • Therefore, pre-travel varies around the XY plane
Factors in measurement performance

Pre-travel variation - ‘lobing’

High force direction:
- $F_S$
- $R_1 > R_2$
- $F_{C1} > F_{C2}$

Low force direction:
- $F_S$
- $R_2$
- Pivot point

Pivot point
Factors in measurement performance

Pre-travel variation - ‘lobing’

• Trigger force in Z direction is higher than in XY plane
  • No mechanical advantage over spring
  • $F_C = F_S$
• Kinematic resistive probes exhibit 3D (XYZ) pre-travel variation
  • Combination of Z and XY trigger effects
  • Low XYZ PTV useful for contoured part inspection

Test data:

• ISO 10360-2 3D form
• TP20 with 50 mm stylus: 4.0 µm (0.00016 in)
Factors in measurement performance

Probe calibration
• Pre-travel can be compensated by probe calibration
• A datum feature (of known size and position) is measured to establish the average pre-travel
• Key performance factor is repeatability

Limitations
• On complex parts, many probing directions may be needed
• Low PTV means simple calibration can be used for complex measurements
• If PTV is significant compared to allowable measurement error, may need to qualify the probe / stylus in each probing direction
Factors in measurement performance

Typical pre-travel variation

Scale in µm

- XY plane

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<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Probe:</td>
<td>TP6</td>
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<tr>
<td>Stylus:</td>
<td>50 mm</td>
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<tr>
<td>Pre-travel variation:</td>
<td>3.28 µm</td>
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<tr>
<td>Trigger force:</td>
<td>15 gram</td>
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<tr>
<td>Repeatability (2 Sigma):</td>
<td>0.5 µm</td>
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</table>
Factors in measurement performance

Repeatability

• The ability of a probe to trigger at the same point each time

• A random error with a normal distribution

• For a given probe and probing condition, repeatability is equal to twice the standard deviation ($2\sigma$) of the normal distribution

• 95% confidence level that all readings taken in this mode will repeat within $\pm2\sigma$ from a mean value
Factors in measurement performance

Hysteresis

• Error arising from the direction of the preceding probing move

  • Maximum hysteresis occurs when a measurement follows a probing moves in opposite directions to each other in the probe’s XY plane

  • Hysteresis error increases linearly with trigger force and stylus length

  • Kinematic mechanism minimises hysteresis
Factors in measurement performance

Ranked in terms of importance

Repeatability
- Key requirement of any trigger probe
- Fundamental limit on system measurement performance
- Hysteresis contributes to measurement repeatability

Pre-travel variation
- Can be calibrated, provided all probing directions are known
- Measurement accuracy will be reduced if probe used in un-qualified direction and PTV is high
- Increases rapidly with stylus length

Hysteresis
- Small error factor for probes with kinematic mechanisms
Kinematic resistive probe technology

Simple electro-mechanical switching

- Resistive probes use the probe kinematics as an electrical trigger circuit
- Pre-travel variation is significant due to the arrangement of the kinematics
Kinematic resistive probe characteristics

- Extremely robust
- Compact
  - Good part access
  - Suitable for long extensions
- Good repeatability
  - Excellent performance with shorter styli
  - Low contact and overtravel forces minimise stylus bending and part deflection
- Universal fitment
  - Simple interfacing
- Cost-effective
- Finite operating life
  - Electro-mechanical switching
TP20 stylus changing probe

Concept

• Direct replacement for TP2
  • Ultra-compact probe at just Ø13.2 mm
• TP20 features fast and highly repeatable stylus changing
  • Manual or automatic
  • Enhanced functionality through extended force and extension modules
TP20 stylus changing probe

Benefits

• Reduced cycle times achieved by fast stylus changing without re-qualification
• Optimised probe and stylus performance with seven specialised probe modules
• Easily retrofitted to all Renishaw standard probe heads (M8 or autojoint coupling)
• Compatible with existing touch-trigger probe interfaces
• Metrology performance equivalent to industry proven TP2 system but with greater flexibility of operation
TP20 stylus modules

Optimal measuring performance

• Seven specialised probe modules allow optimisation of stylus arrangement for best accuracy and feature access in all user applications

• Module attaches to probe body via a quick release, highly repeatable kinematic coupling

• Module range covers all forces supported by TP2

• 6-way module replaces TP2-6W
Comparative module and stylus lengths

- Soft materials
- General use
- Longer or heavier styli
- Grooves and undercuts
- Reach up to 125 mm (5 in)
Strain-gauge probe technology

- **Solid state switching**
  - Silicon strain gauges measure contact forces transmitted through the stylus
  - Trigger signal generated once a threshold force is reached
  - Consistent, low trigger force in all directions
  - Kinematics retain the stylus / not used for triggering
Strain-gauge probe operation

Force sensing

- Four strain gauges are mounted on webs inside the probe body
  - X, Y and Z directions, plus one control gauge to counter thermal drift
- Low contact forces from the stylus tip is transmitted via the kinematics, which remain seated at these low forces
- Gauges measure force in each direction and trigger once force threshold is breached (before kinematics are unseated)
Strain-gauge probe operation

Low lobing measurement

Scale in µm

- Trigger force is uniform in all directions
  - Very low pre-travel variation

<table>
<thead>
<tr>
<th>Probe:</th>
<th>TP7M</th>
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<tbody>
<tr>
<td>Stylus:</td>
<td>50 mm M4</td>
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<tr>
<td>Maximum variation:</td>
<td>0.34 µm</td>
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<tr>
<td>Sensitivity:</td>
<td>HIGH</td>
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</table>
Strain-gauge probe operation

Lobing comparison

• Plots at same scale

Strain-gauge
XY PTV = 0.34 $\mu$m

Kinematic resistive
XY PTV = 3.28 $\mu$m
Strain-gauge probe characteristics

High accuracy and repeatability
- Probe accuracy even better than standard kinematic probes
- Minimal lobing (very low pre-travel variation)

Reliable operation
- No reseat failures
- Suitable for intensive "peck" or "stitch" scanning
- Life greater than 10 million triggers

Flexibility
- Long stylus reach
- Suitable for mounting on articulating heads and extension bars
- Stylus changing available on some models
TP7M strain-gauge probe

Concept

• 25 mm (1 in) diameter probe
• Autojoint mounted for use with PH10M PLUS
  • Multi-wire probe output
TP7M strain-gauge probe

Benefits

• Highest accuracy, even when used with long styli - up to 180 mm long ("GF" range)

• Compatible with full range of multi-wired probe heads and extension bars for flexible part access

• Plus general strain-gauge benefits:
  • Non-lobing
  • No reseat failures
  • Extended operating life
  • 6-way measuring capability
Uni-directional repeatability

Test results from five probes
Test results from five probes
TP200 stylus changing probe

Concept
• TP2-sized probe, with strain gauge accuracy
• Stylus changing for greater flexibility and measurement automation
• 2-wire probe output (like TP20)

Benefits
• Long stylus reach - up to 100 mm long ("GF" range)
• Match stylus to the workpiece using high-speed stylus changing
  • Improve accuracy for each feature
  • No re-qualification
• Manual or automatic changing with SCR200
• Compatible with full range of heads and extension bars
TP200 stylus modules

Optimal sensor performance

- 6-way operation $\pm X$, $\pm Y$ and $\pm Z$
- Two types of module:
  - SF (standard force)
  - LF (low force) provides lower overtravel force option for use with small ball styli and for probing soft materials
- Detachable from probe sensor via a highly repeatable magnetic coupling
- Provides overtravel capability
- Suitable for both automatic and manual stylus changing
- Module life of $>10$ million triggers
Trigger probe measurement performance comparison

- **Unidirectional repeatability**
- **ISO 10360-2 2D form**

The graphs show the performance comparison for different probe lengths (Stylus length) for TP20, TP200, and TP7M.
Renishaw touch-trigger probing technology

Thank you for your attention…