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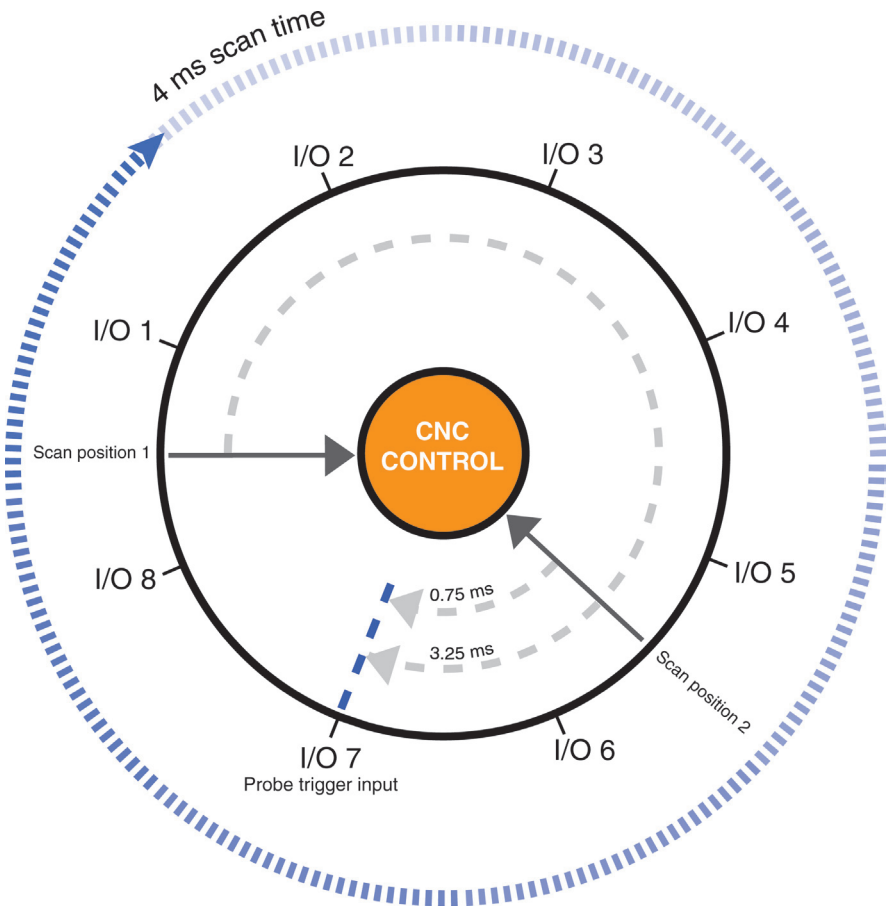
One-touch versus two-touch probing strategies

CNC scan-time and measurement uncertainty

The biggest influence on the repeatability of a probing system is the process by which the machine recognises and acts on the probe trigger input. This is a characteristic of the machine and its controller. Commonly, the probe trigger signal is just one of a large number of inputs to the CNC which are interrogated in turn. The time taken for the programmable logic controller (PLC) to look at all of its inputs sequentially is called the scan time (which can be in the order of 4 ms for a typical controller fitted with a standard probing input). Consequently there could be a delay of between 0 ms and 4 ms before the controller reacts to the probe trigger signal. During this period, the machine keeps moving at the gauging velocity. This delay is neither predictable nor repeatable, otherwise it could be calibrated out and not affect measurement repeatability. The probe trigger signal will be acted on by the controller at an indeterminate point in time between zero and the full scan time (see figure 1).



Example: If the probe triggers at scan position 1, there will be a 3.25 ms delay before the trigger signal is recognised by the machine tool control. If the probe is driven at 3000 mm/min, it will move 0.162 mm in this time. If, however, the probe triggers at scan position 2, the trigger signal will be recognised 0.75 ms later. This will result in the probe moving 0.037 mm, a difference in measurement of 0.125 mm.

Uncertainty of repeatability = scan time × gauging velocity

For this example uncertainty is 4 ms × 3000 mm/min = 0.2 mm

Figure 1: CNC scan time and its effect on uncertainty of repeatability

On machines with a scan time of 4 ms the variable delay in the machine acting upon a trigger signal cannot be ignored as, at 3000 mm/min, such a machine could travel up to 0.2 mm. The uncertainty in measurement repeatability is directly proportional to the gauging velocity, as shown in figure 2.

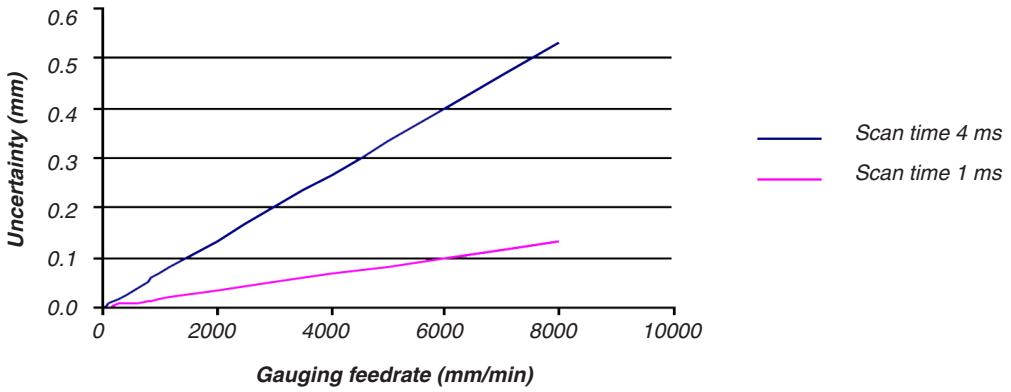


Figure 2: uncertainty = gauging velocity x response time variation

Many modern controllers include a direct input for the probe's trigger signal often referred to as a skip input (this can be standard fitment or may be a cost option depending on the controller type). On such controllers, the probe trigger signal is effectively read immediately and the current axis position is 'latched' upon receipt of this signal. Controllers which incorporate this type of probing input have response times of 0.2 ms (200 µs) or better. Using this scan time figure, again at 3000 mm/min, the machine could travel an additional 0.01 mm (uncertainty). Some direct input controllers are specified as having response (scan) times as fast as 0.004 ms (4 µs). Such a controller, again probing at 3000 mm/min would produce an uncertainty of measurement of less than 0.0002 mm (0.2 µm).

Probing strategies

There are two basic probing strategies generally used to find the positions of surfaces being probed: one-touch or two-touch. A one-touch probing cycle is one in which the probe starts at a given distance away from the surface and moves towards it at the gauging velocity until the trigger is acted on by the controller. The probe then stops and returns to the start position. The axis positions, at the moment of trigger are stored within the CNC for calculating the surface position. As described above, the repeatability uncertainty will increase (degrade) in line with gauging velocity.

A two-touch probing cycle is more complex than a one-touch strategy. From the start position, the probe contacts the surface at a relatively high feed rate until the trigger is acted on by the controller. The probe then stops and is moved back away from the surface by a set small distance (known as back-off distance) and a second measurement takes place at a slower gauging velocity. A slower feed rate is selected for the second touch to guarantee an optimum repeatability of measurement even on those controllers with slow scan times. This second trigger position is stored within the control for calculating the surface position (see figure 3).

A one-touch routine with a gauging velocity of 3000 mm/min was found to have a cycle time of 0.254 seconds. The equivalent two-touch routine, with an approach speed of 3000 mm/min and a gauging velocity of 30 mm/min, had a cycle time of 0.444 seconds, therefore introducing an extra time requirement of 0.19 seconds. However, the uncertainty of repeatability for a one-touch cycle on a machine with a 4 ms scan time is 0.2 mm, whereas uncertainty for the equivalent two-touch routine is only 0.002 mm. Considering cycle time is made up of many moves, this small increment in time taken for a touch move can be justified as it achieves 100 times improvement in measurement certainty.

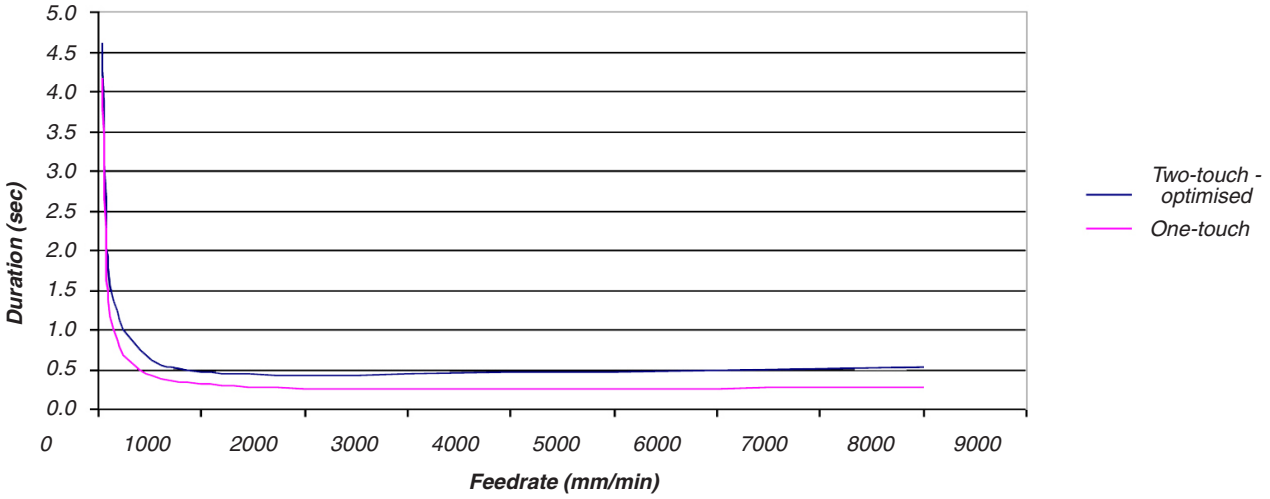


Figure 3: single surface gauging cycle times - one touch verses two touch

Minimising cycle time is, of course, an important consideration. More information about how to optimise cycle time without compromising metrology performance can be found in module TE413, *Optimising measurement cycle time*.

Despite the extra cycle time required for two-touch probing, when operating a machine without a direct input for the trigger signal it would be prudent to use two-touch probing in order to achieve a level of uncertainty within the order of magnitude of the probe's repeatability. **Consideration of the scan time is critical when determining whether two-touch probing is necessary for acceptable metrology performance. In many cases, the corresponding improvement in measurement repeatability and accuracy will be worth the extra milliseconds of cycle time required for two-touch probing.**

Conclusions

- Machine tool scan time has a significant effect on measurement uncertainty during on-machine probing.
- Metrology performance of any given probing cycle should be the primary consideration in its set-up and implementation. A short cycle time is an important but secondary objective.
- One-touch measurement cycles should be used with extreme caution on machines without a direct input for the probe trigger signal because the uncertainty of measurement will be proportional to gauging velocity.
- A two-touch probing strategy will yield good metrology irrespective of CNC control options.
- Most existing and new machine tools will be fitted with a CNC control system with a scan time of 1 ms to 4 ms. On these machines, one-touch measurement cycles need to be used with extremely conservative feed rates to achieve reliable metrology. The resultant cycle times will be far longer than the equivalent two-touch routine in order to achieve good metrology.

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