Factors affecting measurement uncertainty in industrial CMM work

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Abstract

Customer satisfaction requirements and keen competition typical of today’s markets make reliable quality systems a must in industry. Stringent quality assurance programs are required, capable of ensuring consistency of manufacturing performances. Proactive quality management implies less time spent in inspection, as preventing production of faulty items is a more cost effective policy than weeding out defectives. Flexibility and speed of operation, crucial in order to obtain a competitive lead, require both reliable measuring systems, and methods. Analysis of main factors affecting measurement variability, and defining an approach to assess reliability of measurement systems, such as Coordinate Measuring Machines (CMM), were aimed at in a program carried out within an industrial environment. Measurements of complex parts often exhibit uncertainties exceeding substantially reasonably expectations, according e.g. to stated Maximum Permissible Error – MPE (ISO 10360-2:2001). Furthermore, checks of geometric tolerances often exhibit larger discrepancies than those pertaining, for example, to measurements of length or diameter (see e.g. Aggogeri et al., 2008). Origins of trouble may be traced to constraints such as tight time schedules, leading operators to increase probe speed, and cut down both frequency of probe qualification and part soaking time, in order to reduce overall measurement task cycle time.

The case considered, concerning experimental evaluation of measurement variability on a CMM, entailed unraveling a fairly complex pattern of effects. The investigation, aimed at identification of major components of uncertainty in verification of geometric tolerances, concerned a platform, object of previous studies (see e.g. Aggogeri et al., 2008). Measurements were carried out by qualified operators in the certified metrological laboratory of an automotive component manufacturer, supplying precision parts and subassemblies to leading European automakers. Key parts undergo 100% CMM inspection, according to standard company policy. The measurement process was investigated with an (originally) balanced design, aimed at estimation of effects on measurement variability of probe speed, probe qualification and piece temperature. Probe speed and qualification process affect part flow in a critical way. By increasing the former by 30% and dispensing with the latter at every batch change, production rate may be increased by as much as 5%. If piece temperature effect on measurement variability does not exceed given limits, CMM may be placed right on the production line, thus avoiding shuttling parts to and from metrological laboratory, and related soaking time. While the study focuses on an example pertaining to automotive supply chain, the methods applied lend themselves to application in other sectors as well.

Factors were considered at two levels; two quantitative, namely probe speed (0.9 and 1.2 mm/s), piece temperature (19 and 23 °C), and another qualitative, probe qualification (Y, N) indicating whether qualification is performed immediately before every measurement task as specified, or dispensed with altogether. Six tolerance verification tasks were considered, namely four concerning position (concentricity) and two orientation (perpendicularity), specification limit for all being 0.100 mm. Two different probes with spherical tips were used, one 4 mm dia. on a 50 mm stylus and another 5 mm dia. on a 80 mm stylus, according to features inspected.
Exploratory data analysis (Tukey, 1977) highlighted the effect of systematic probe qualification prior to task on measurements, particularly in terms of reproducibility and repeatability, owing to geometrical tolerances and their references being located on different sides of the piece. In the light of these considerations the effect of the factors and their interactions were assessed, showing among others a sizable effect of speed on measurement variability only when the probe has been qualified. Main effects are summarized in Figure 1 (a), temperature however plays a substantial role too, as shown in Figure 1 (b). Contrasts are also depicted in the normal probability plot of Figure 1 (c), according to the method proposed by Johnson (1964).

Final considerations highlight the importance of factor selection, trials layout and exploratory data analysis in industrial investigations, leading to identification of major effects, and their implications, affecting the all important bottom line.

![Figure 1](image)

Figure 1. Main effects of quantitative factors (temperature and speed) on measurement variability (a), and relevant interaction (b); contrasts shown on a normal probability plot according to Johnson’s method (c).

**Bibliography**


