Optimisation Of Measuring Strategies in Coordinate Measuring Technique

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Abstract

The guidelines for supporting software for optimal measurement strategy choice have been presented. The system of typical measurement tasks classification has been built. Each task has been characterised by determining the possible measurement strategies set. The conditions of performing measurements as well as the specific features having the possible influence on the measurement strategy have been taken into consideration. The example of steering gear case has been presented.

1. Introduction

The measurement strategy in coordinate measuring technique includes a lot of aspects. The best-known ones are the issues concerning probing strategy; it means the problems referring to the number and distribution of measurement points. In most cases it is better to increase a number of measuring points and use equal distribution to cover the whole area of the workpiece being measured [1, 4]. A lot of many other influences should be included in the measurement strategy. They depend on the available equipment and CMM software (for example the kind of probe head, probe autochange system), workpiece (the shape and dimensions limit the possibilities of placing the workpiece in measurement volume, form and position deviations increase the measurement uncertainty) and these are the limitations. Many aspects of measurement strategy depend on the operator. These are for instance: configuration of styli, stylus length, the diameter of ball-ended stylus tip, the weight of stylus, CMM working parameter (e.g. movements' speed), filtration parameters and first of all the measurement procedures being used. The proper designing of the measurement process depends on the skills of the operator.

The measuring uncertainty in coordinate measuring technique may be the limitations or be one of the optimisation criterions. At present three approaches to evaluate the measurement uncertainty are used [1, 2]: the method of virtual CMM, comparison method and the method using the formulas for error E of indication of a CMM for length measurement.

2. Catalogue of measurement tasks

The authors made an effort to elaborate the software supporting the designer of measurement process. For this purpose the catalogue of typical measurement tasks was worked out. The structure of this catalogue might be presented in the hierarchic form. The structure is presented on Fig. 1.

The starting point is the kind of the measured feature (dimension, position deviation, form deviation). Next more detailed descriptions follow. In the example presented on Fig. 1 they are as follows: the kind of dimension (internal, external, distance, other), for the internal dimensions its closer description (cylindrical hole, conical hole, slot) and finally for cylindrical hole – the name of the measured feature: the diameter. Next in classification the following details are taken into consideration: dimensions or the dimensions' proportions of measured workpieces, the manufacturing accuracy, other simultaneously existing requirements etc. In the example on Fig. 1, the holes have been classified as the „long" and the „short" ones (the criterion of classification is the ratio between their diameter and length or the length exclusively), then – as small and big ones (the criterion is the diameter), then – as those of the typical and high manufacturing accuracy, then – tolerated with or without envelope condition and finally from the point of view of the additional requirement (the existence of form tolerances and their combinations). The examples of simple measurement tasks are presented on Fig. 2.

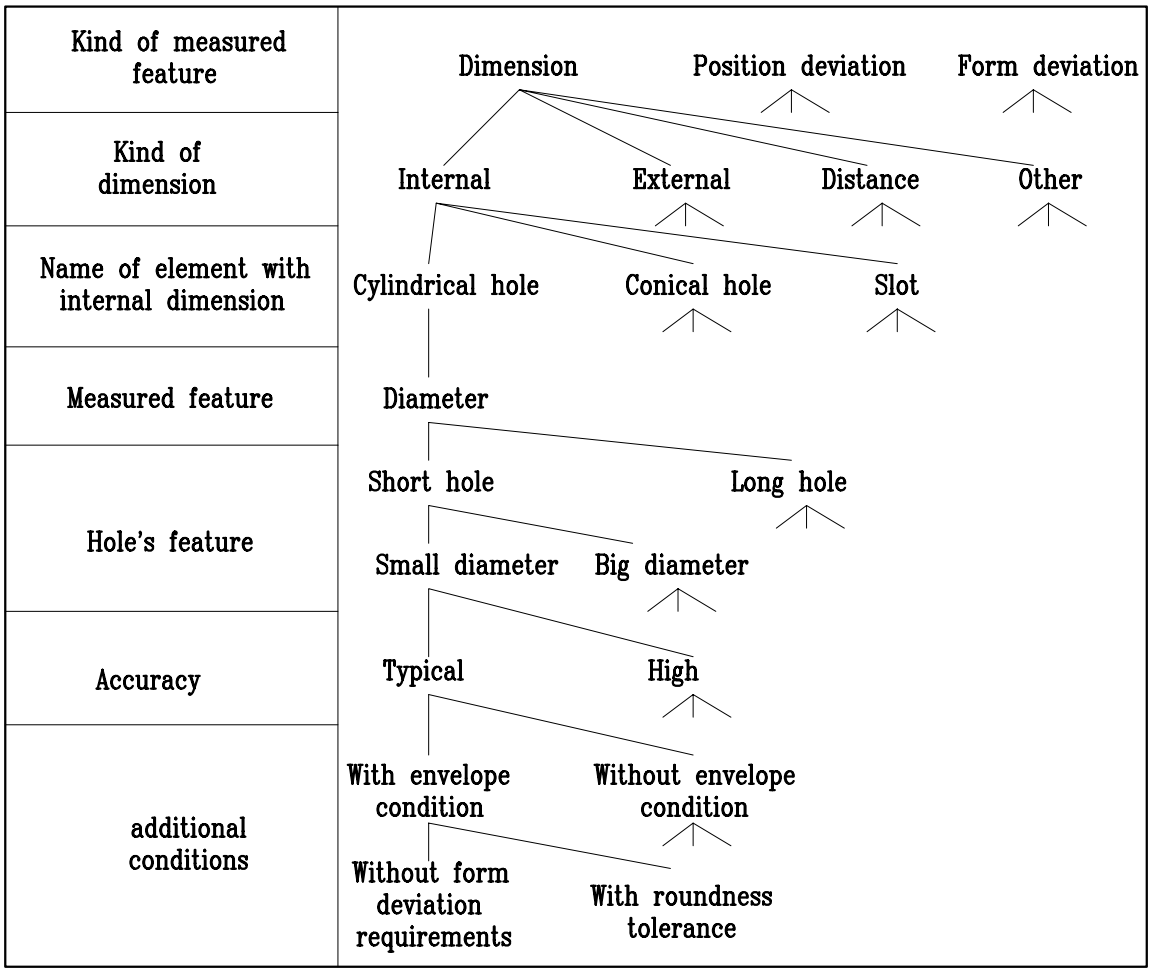

Fig. 1. The structure of catalogue of typical measurement tasks

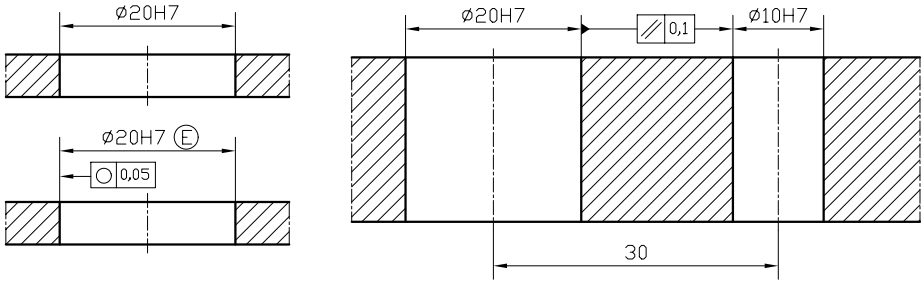

Fig. 2. The examples of measurement tasks

3. Measurement strategies

Each measurement task has been characterised by determining the set of possible measurement strategies. This set consists of standard measurement procedures offered by CMM's software and the special procedures resulting from specific needs or operator's skills.

As the example for the measurement task „the diameter measurement of cylindrical hole" to define standard procedures the following aspects have been taken into account:

- CMM's software offers two standard commands: „measure circle" and „measure cylinder",
- in both cases the results may be calculated using different substitution elements: Gaussian, maximum inscribed and Chebychev,
- in the case of using the command „measure circle" the probing points may be taken into calculations according to one of the two algorithms: probing points are projected onto best fit plane

built from these points and then the substitution circle is calculated or the probing points are projected onto the plane determined by the operator and then the substitution circle is calculated,
- the standard probing strategy assumes equally distributed probing points covering whole area of measured workpiece.

For the same example from the specific operator's need point of view the following possibilities have been taken into account:
- the operator may repeat the command „measure circle" in a few cross sections (in the purpose of the later calculation of axis's straightness),
- in the case of high accuracy requirements it is possible to carry out the measurements using the comparison method. First the calibrated ring gauge having the diameter close to the diameter of the measured hole is measured (the ring gauge is located in the same place and in the same position, the same configuration of styli is used). The difference between the measurement results and the calibrated value of ring gauge is treated as a systematic error and is eliminated from the results of the later measurements. In this method it is also possible to take into account the distribution of probe head errors,
- the traditional measurement of the local dimension (two points measurement according to the fundamental tolerancing principle) in coordinate measuring technique may be simulated by the measurement of circle in non-equal distribution of probing points, e.g. 6 points as shown on Fig. 3,
- due to the lack of access to whole area the special probing strategy might be used.

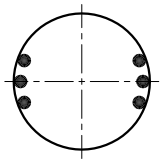

Fig. 3. Probing strategy for simulating two points measurement on CMM

In table 2 the possible procedure for measurement task: „short cylindrical hole diameter, with small diameter, typical accuracy, without envelope condition, with roundness tolerance" have been presented.

Table 2. Measurement strategies for measurement task „short cylindrical hole diameter, with small diameter, typical accuracy, without envelope condition, with roundness tolerance"

Measurement procedure	Quindos command	Substitution element
Standard measurement of hole as circle	Measure circle	Gauss Chebychev
Simulation of two points measurement	Measure circle	Gauss
Measurement of hole as circle with projection of probing points onto the determined plane	Measure plane + measure circle	Gauss Chebychev

4. Measurement uncertainty

Measurement uncertainty depends on many factors, whose origin is ascribed to CMM, measurement conditions, workpiece being measured and operator, strictly speaking the measurement strategy implemented by operator. The term „measurement strategy" consists of: the measurement procedure, the probing strategy, and the location of workpiece in CMM's volume, styli configuration. Due to many factors having influence on measurement uncertainty and to obtain the possibility of measurement uncertainty evaluation before the measurement for each measurement task so called standard measurement strategy has been defined. One of possible measurement strategy (in theory the best one), typical probing strategy and the other typical parameters (e.g. CMM working parameters) have been used. Similarly the typical conditions of performing the measurement were defined. The remaining probing strategies are characterised by the values of systematic errors (bias) casued by the departure from standard strategy.

5. An example

The above mentioned assumption have been tested on following example:

1. the measurements are carry out on CMM MicroXcel 765 CNC with Quindos programming system and PH9 probe head,
2. the additional equipment is sensor TP200 with modules allowing for the styli change,
3. the measurements are carry out in following temperature conditions: room temperature 20±2°C, the gradients in the CMM surrounding max 2°C,
4. the workpiece is a steering gear case (Fig. 4); a special attention refers to hole ϕ35H7.

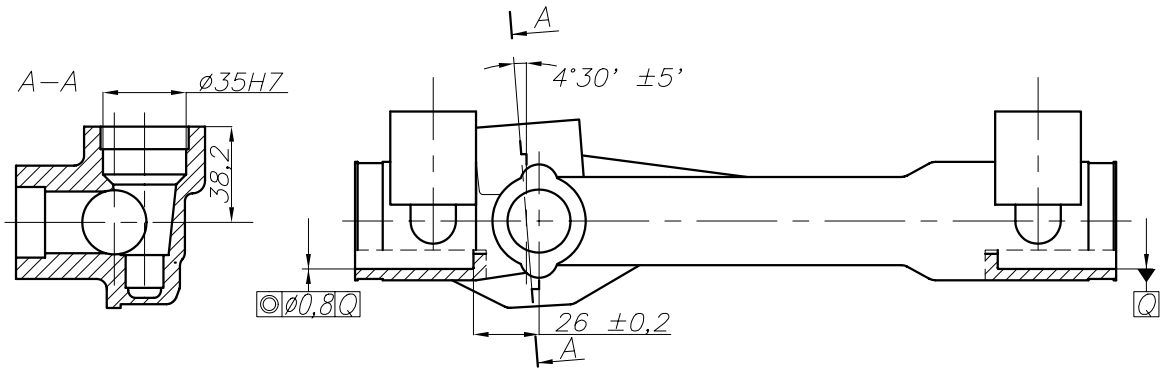

Fig. 4. The draft of design drawing of steering gear case

For the above mentioned measurement task the standard strategy is as follows: hole axis – vertical, probe head PH9 with angle of azimuth A = 0° and elevation E = 0°, stylus length 20 mm, tip diameter ϕ4 mm, hole is measured with projection of probing points onto the determined plane, probing strategy: for plane – 4 equally distributed probing points, calculation type – Gaussian substitute plane, for hole – 6 equally distributed probing points, calculation type – Chebychev substitute circle.

Due to the shape and dimensions the workpiece should be located in measuring volume in such a way, so its primary axis should be parallel to the CMM's x axis, and in reference to this, the axis of the measured hole forms the angle 4,5° to the CMM's z axis. Consequently to measure the hole it is necessary to use stylus with big diameter of tip or to change the angular orientation within hole measurement. For the probe PH9 the angular step is 7,5°. To measure remaining geometric feature the longer styli and small diameter of tip are required.

As the optimal solution following guidelines have been obtained:

1. from the point of view of measurement uncertainty: stylus with ruby tip ϕ6, stylus length 20 mm, stylus extension 40 mm, angular orientation of probe head determined by the angle of azimuth A = 0° and elevation E = 0°. Probing strategy: 6 equally distributed points,
2. from the point of view of measurement time: stylus with ruby tip ϕ2, stylus length 20 mm, stylus extension 40 mm, angular orientation of probe head determined by the angles of azimuth and elevation A_1 = 0°, E_1 = 0°; A_2 = 90°, E_1 = 7,5°. Probing strategy: 6 equally distributed points (each 3 points measured by separate probe head angular orientation).

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