Optimisation Model of Measuring Strategy on CMM

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Abstract. *An attempt to formal description of the procedure of optimisation of measuring strategy on CMM was made. A set of feasible solutions, constrains and objective function were defined. Chosen steps of optimisation were described. An example of documenting of measuring strategy was given.*

Keywords: coordinate measuring machines, measuring strategy, optimisation

1. Introduction

The set of feasible solutions as well as the optimization process of measuring strategy for measurement tasks carried-out on coordinate measuring machines can be presented in the shape of graph-tree (Fig. 1).

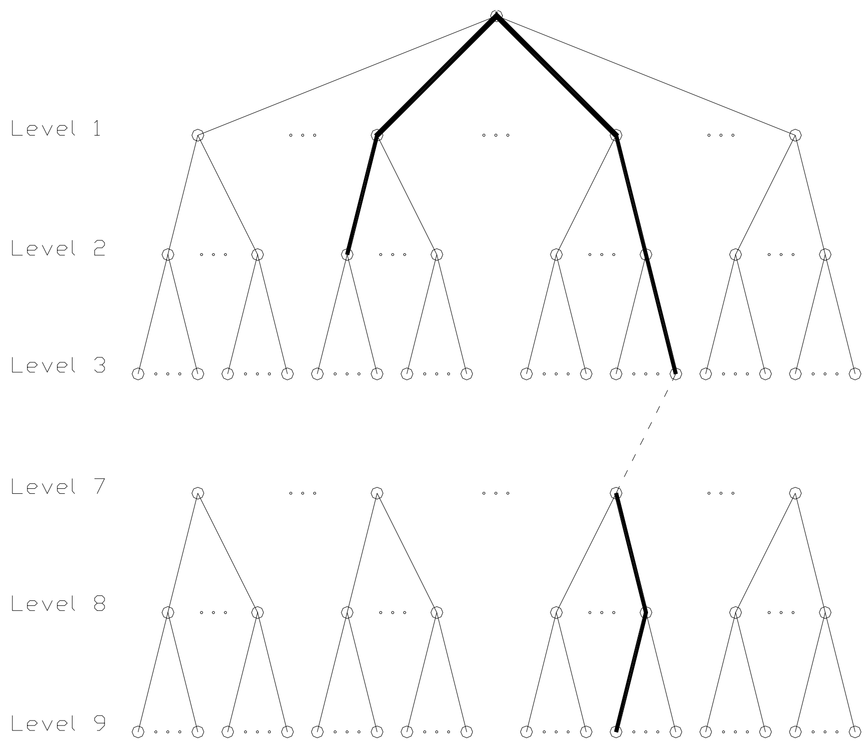

Fig. 1. The process of design the optimal measuring strategy. On the consecutive levels there are: 1 - the choice of measuring machine, 2 - the determination of placement of workpiece, 3 - the design and manufacturing of mounting tools, 4 - the design of measurement run as well as the configuration of styli, 5 - the choice of the kind of operator, the kind of geometrical feature, the criterion of fitting and the probing strategy, 6 - the elaboration of measurement results, 7 - the analysis of repeatability of measurement results, 8 - the estimation of measurement uncertainty of major feature, 9 - the validation of part program. Bold lines of the graph show which attempts of solution were made and which attempt was successful.

The size of set of feasible solutions is very big, but in practice only some branches are analyzed. The operator of measuring machine plays a role of expert, who has to carry-out the optimal decisions, at least in his own opinion. The possibility of verification of his decisions is obvious, but one has to remember that the time required for that, makes the process of measurement design longer.

The optimisation criterion is usually the cost of measurement per one workpiece and the main factors influencing this cost are time of creating the CNC program, setup time as well as the time of measurement one workpiece and their number. The optimization process runs in few stages and on each stage there is a possibility to return to any previous stage.

2. Choice of kind of operator and probing strategy

The choice of kind of operator, the kind of geometrical features, the criterion of fitting and probing strategy are based on knowledge and experience of operator in the field of coordinate measurements and manufacturing technology in use. The knowledge of manufacturing technology in the area of typical form deviations of workpieces is necessary to choose the appropriate kind of operator. The use of ideal or optimal operators is usually very difficult, because there is no appropriate procedures in CMMs' software. The choice of operator determines the use of appropriate kind of geometrical feature (e.g. the hole can be measured as circle or cylinder) and the fitting criterion (e.g. Gauss or Chebychev).

The example of choice of kind of operator was depicted on Fig. 2.

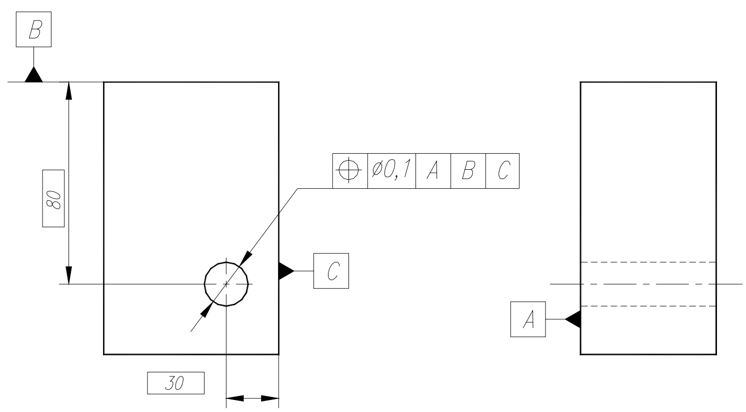

Fig. 2. An example of choice of kind of operator

For the workpiece presented on Fig. 2 the ideal operator requires the use of fixtures in the form of the spatial square gauge to define the datums' system [1]. After placing the workpiece in such a fixture, the probing is performed on the planes of the fixture. Next, the measurements of hole in some cross-sections using the geometrical feature "circle" are performed. In such a case the special procedure to elaborate the measurement results has to be elaborated. The circles' centre-points have to be projected on primary datum and for this points the minimum circumscribed circle with given nominal coordinates of centre-point has to be calculated.

The simplified operator will define the coordinate systems basis of measurement of three planes of the workpiece with Gauss fitting criterion and then will use typical procedures of cylinder measurement and position calculation. As a result of this simplification the measurement of the position will not cover straightness and perpendicularity of the hole's axis.

3. Elaboration of measurement results

After the measurements have been finished the calculation of relations among measured features follows. The calculated relations are linear and angular dimensions and geometrical deviations (form, orientation, location and run-out). In this stage the measuring report is also defined. This report contains usually not all features, but only the significant ones, actual and nominal values, tolerances etc. The important element of this stage is the analysis of obtained values, what shall enables to find the errors done by CMM's operator and by CMM's software. Sometimes some fragments of elaboration the measurement results have to be done outside the CMM's software, especially when the software of CMM is poor or the measurement task is very complicated.

4. Analysis of repeatability of measurement results

The evaluation of measurement uncertainty is very important element of whole measurement process. In coordinate measurement the reliable evaluation is not easy, so the analysis of repeatability of results can be good tool. The workpiece shall be measured many times with dismounting after each measurement. To evaluate the repeatability the statistical module of software can be used.

5. Validation of measurement program

The standardization in the geometrical product specification (GPS) gives the appropriate tool for unambiguous communication among designer, manufacturing engineer and the CMM's operator. Some firms appreciate the significance of unambiguous documentation and define the details concerning the measurement strategy. The ambiguous interpretation of design requirements still too often exists in practice. The experience of authors shows that the only way to avoid misunderstandings is the detailed documentation of measuring strategy for customer. It is especially important for research laboratories with accreditation.

The example of documentation of measuring strategy for the workpiece from Fig. 3 is described next. The reason for that is to avoid misunderstanding in interpretation of specifications on the drawing. The primary datum A is a plane. It was measured in three points with given nominal coordinates (20,110), (–40, –30) and (40,–60). This plane defines the y axis and zero point on it. Secondary datum B is the centre-point of circle ϕ6. This circle was measured in 4 points equally distributed on circumference. The calculation uses Gaussian criterion. The circle defines the zero point for z and x axes. The tertiary datum C is the circle ϕ19 measured in 4 equally distributed points on circumference, criterion of fitting is Gaussian circle. The datum B defines x axis. The x axis is included in A plane, as is rotated by nominal angle 67° around the datum B respectively to axis defined by datum B and C.

The tolerance zone in reference to datums A and B is the zone limited only by two circles with centre-point in point B covering symmetrically the theoretical centre-point of toleranced circle. No requirements in second direction has been defined. The example from Fig. 3b shows that the workpiece must be counted as good despite of a great distance of the hole's axis from the theoretical position.

The tolerance zone of profile any line is limited by envelope of circle with diameter equal to tolerance value and its centre-points are placed on nominal line. In analysed case the profile any line tolerance has only datum A. It means that this tolerance refers only to form (does not refer to orientation and location), so the calculation the value of deviation is done after the best-fit of actual and nominal line has been completed. If the software of CMM does not have such a possibility, a special software has to be developed.

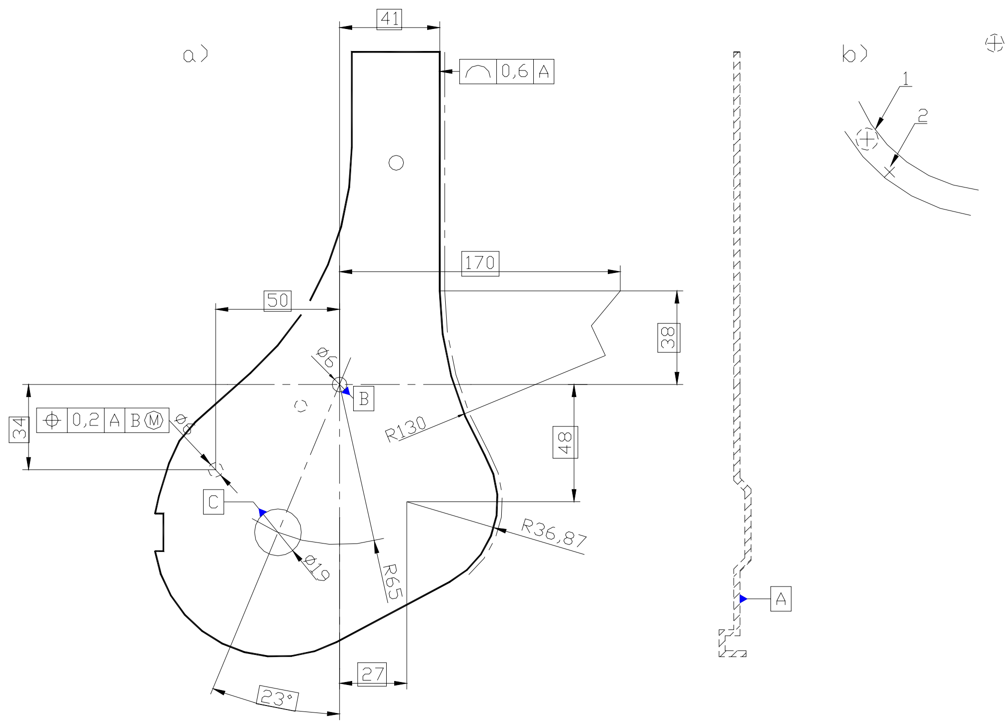

Fig. 3. An example of a workpiece with position tolerance of hole's axis and profile any line tolerance: a) design drawing, b) form of position tolerance zone; 1 – theoretical position of hole's axis, 2 – actual position

6. Conclusions

Process of design of measuring strategy on CMM can be formally understood as multistage optimisation task. Because of specific form of objective function the formal analysis of the whole set of feasible solutions will never be performed.

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