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ESTIMATION OF ERRORS FOR THE GEOMETRIC DEVIATIONS

K. Nozdrzykowski and B. KuŸniewski
Institute of Basic Technical Sciences
Szczecin Maritime University, Podgórna 51/53, PL –70-205 Szczecin, Poland

Abstract: In the article there has been presented the methodology of working out results of mutually coupled measurements of shape deviations and axis location of large engine elements carried out by non-referential methods. There has also been presented a way of estimating measurement errors of shape deviations and axis location deviations of cylindrical outer and inner area complexes.
Keywords: metrology, assessing, errors, shape and position.

1 INTRODUCTION

The present development of measurement technique is characterised by the application in a wide range (for measurements of shape or location deviations) of measurements carried out by non-referential methods. These methods are characterised by a number of advantages, the most essential of which is this: effecting measurements according to definitions contained in respective norms and obtaining full information about the examined outline. There is, however, a limitation for these methods, as they are not used measuring large-sized items.

Non-referential measurement methods should be counted among intermediary measurement methods. The value sought for is thus a result of calculations from a series of results from direct measurements, whereas the measurement error value of the number sought for depends on the error value measured directly and the functions binding these numbers with the number measured.

In a general case the estimation of shape errors or of location errors of cylindrical objects by the non-referential method is carried out on the basis of measurements results of rays in definite angular locations of such objects. The measurement error of shape or axis location deviation is thus dependent on measurement errors of ray, rotation angle of the object, mutual distance of sections measured and the functions that bind these values.

The subject of error estimation of shape and location deviation is quite often left out or treated marginally so we can speak here of errors of error measurement.

In the present article there will be presented a way of working out results of mutually coupled error measurements of shape and location of large elements of engine axis (apertures of bearing mountings in the engine hull, set of main pins of the crankshaft or distribution shaft) brought about by non-referential methods. There will also be presented an error estimation method of shape and location deviation of the axes of cylindrical outer or inner surface sets.

2 RESULT TREATMENT AND ESTIMATING MEASUREMENT ERRORS

The starting point for solving the above problem was to treat the set of cylindrical bearing apertures and the crankshaft main pins as outer or inner cylindrical surfaces with non-continuous elements. The assumption of such a concept allowed in turn to work out a uniform measurement technique for any set of cylindrical surfaces, as also of a uniform methodology of data treatment [1].

Both the geometric-error measurements of the crankshaft and the apertures of bearing mountings were conducted on the basis of circularity in subsequent cross-sections. With reference to the crankshaft a so-called elastic support of the crankshaft was used, and the measurements were carried out by means of an inductive dislocation gauge mounted on a stand [2]. Aperture measurements of bearing mountings were conducted based on a modernised technique that applies the control shaft and sensors [3].

In both cases the measurement results included coupled shape and location deviations of the measure cylindrical surface axes.

The process of working out results was carried out in two stages, the former of which enabled the designation of shape deviation of particular measurement sections, whereas the latter enabled the designation of axis location deviation of particular cylindrical surfaces in relation to an assumed reference axis.

For the solution of the above-mentioned problem the method was used of weighing the smallest squares of regression analysis on particular stages of working out data obtained from the measurements. The treatment of data was carried out by numerical calculations by the iterative technique based on principles of matrix calculation, which enabled the simultaneous error estimation of the measured parameters of cylindrical surface complex.

In Figs. 1a and 1b the geometrical interpretation of particular stages of working out measurement results has been presented.

a)

b)

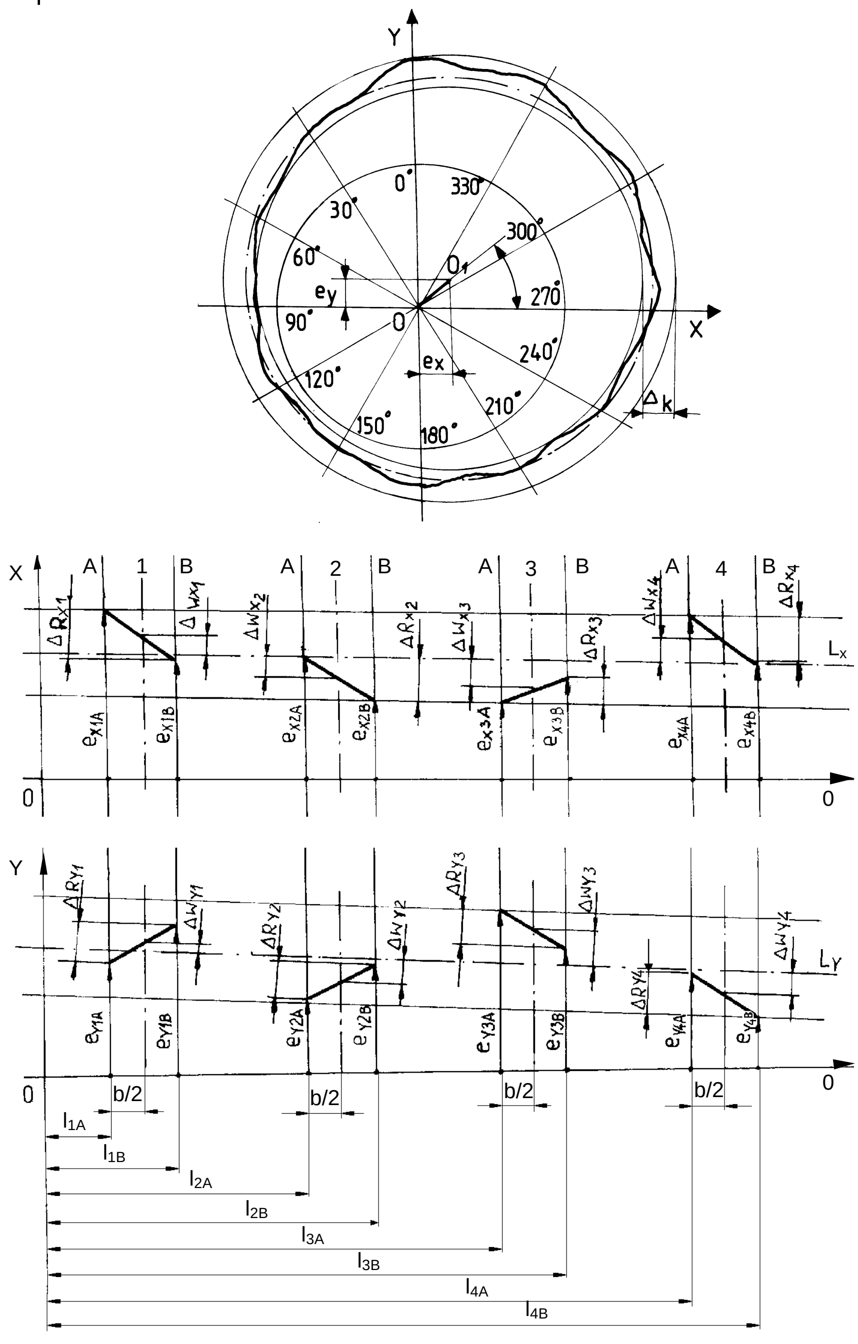

Figure 1. Graphic interpretation of the two data processing stages

Stage I. The profile on Fig, 1a presents an approximated shape of the circular outline in a definite cross-section and the location of that outline with relation to the theoretical turning axis brought about by the measurement apparatus. These were the values sought for: concentricity deviation *e* equal to section 00_1, angle ö and circularity deviation $Ä_k$. Similar values can be designated on the basis of circular outline shapes of other cross-sections of the cylindrical surfaces complex measured.

Stage II. The sections e_x and e_y (Figs. 1a and 1b) define the location of points that theoretically are situated on the common L axis of surface complex measured in relation to 0-0 axis by the measurement apparatus. The values sought for in this stage of data treatment were: components of coaxiality deviations $Äw_{xi}$ and $Äw_{yi}$ defined towards the common axis in the middle of section b (b – distance between measurement surfaces A and B of particular main pins or apertures of bearing mountings) and components of parallelism deviations $ÄR_{xi}$ and $ÄR_{yi}$.

The general program for numerical calculations was the same for all stages of data treatment, but the final shape of the problem was defined in sub-programs outside the main program. Fig.2 presents a simplified algorithm of numerical calculations according to the general program.

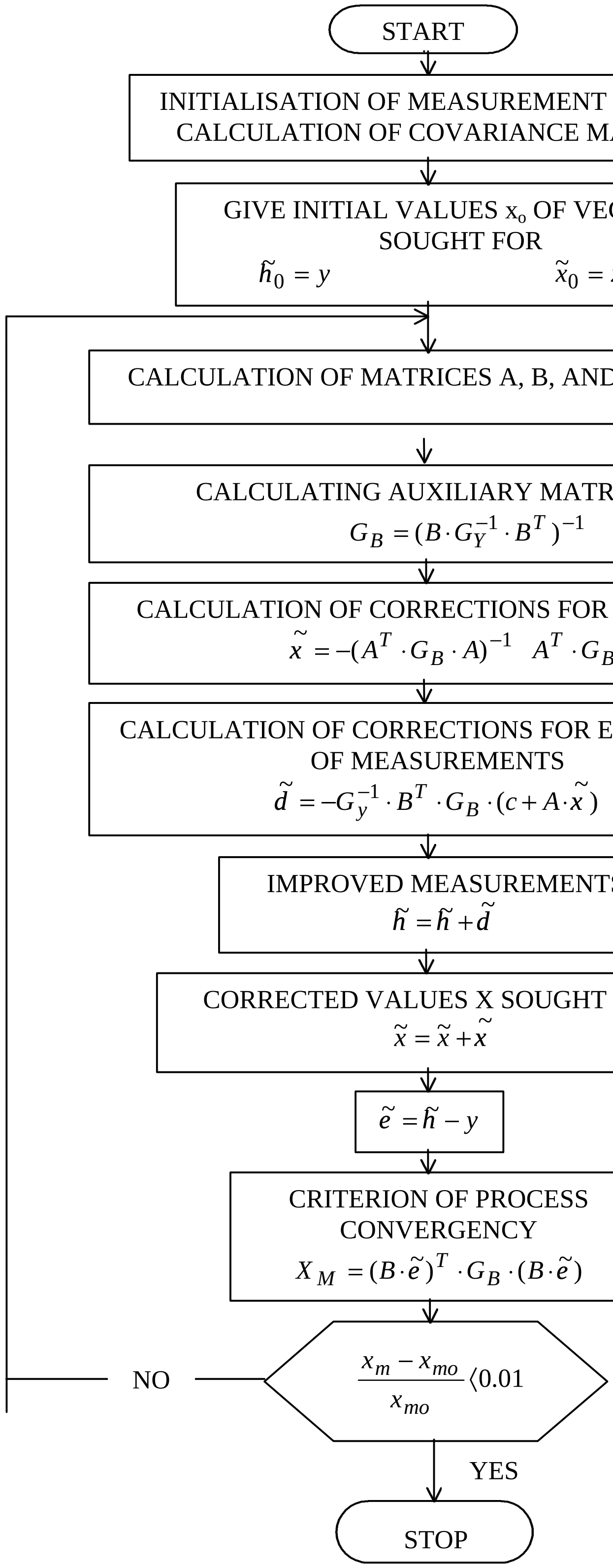

Figure 2. Simplified algorithm of numerical calculations according to a general program

The program starts from the evocation of a subprogram containing previously built in measurement results and their covariance matrices. Then another sub-program is evoked, the task of which is to establish the first approximation for vector X of parameters sought for and assuming the measurement results as the first approximation of their true values. Subsequent parts of the program perform matrix calculations indispensable for calculating corrections î and ä, the vectors of corrected measurements ç, and the vector of parameters sought for X. In further course, the vector å of difference between measurement results and corrected measurements is calculated. The vector serves the purpose of calculating for a given iteration the value of the function x_m ,which is a criterion of the process convergence. In case when the values of function x_m changed less than 1% in relation to the value x_m obtained in the previous iteration cycle, the calculation accuracy was considered to be sufficient and the iteration process was interrupted. The iteration process could also be interrupted, when the iteration number set before was reached, assumed generally to be sufficient for the accuracy of calculation. In the final phase the program goes over to the matrix of covariance for the corrected measurements and parameters sought for, and printing the results. The way of treating the data ensures increased accuracy of estimating the errors of shape and location of the axis of complex of surfaces measured under consideration and can be used for solving various types of linear and non-linear regression analysis by the method of smallest squares. Simultaneously it enables the estimation of errors of parameters sought for in various stages of data treatment, as the square roots of diagonal elements of the calculated covariance matrix CX should be treated as measurement errors for the parameters sought for, although X was not directly subject to change. Besides, shape and axis position errors are considered in relation to one reference element essential from the point of view of interaction of the cylindrical surfaces.

3 SUMMARY

The application of the weighing method of smallest squares of the regression analysis enables us to increase the accuracy of estimating errors of shape and location of the axis of outer and inner surfaces complex, with simultaneous error estimation in various stages of data treatment. The developed methodology can be used to estimate the geometrical accuracy of any outer or inner complex of cylindrical surfaces.

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AUTHOR(S): K. Nozdrzykowski and B. KuŸniewski, Institute of Basic Technical Sciences Szczecin Maritime University, ul. Podgórna 51/53, PL –70-205 Szczecin, Poland, tel.(0-48 91) 433 45 21, fax. (0-48 91) 434 10 98, e-mail: inpt@wsm.szczecin.pl