CMM DYNAMIC PROPERTIES OF THE SCANNING MEASUREMENT OF A 2D PROFILE

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Abstract:

Scanning probes CMM became currently treated as a standard in coordinate metrology. Not only because of high quantity of data gathering in short time of probing but also scanning technology significantly decrease the inspection time. Modern manufacturing, especially in highly competitive economy, required more efficient measuring machine and processes, because inspection machine quite often become the bottle neck in whole manufacturing process. More efficient in coordinate metrology means faster cycles of measurement with acceptable accuracy. But in fact, scanning speed significantly influenced error budget.

This article proposes a new method of investigating and identifying principal components of CMM dynamic errors. The principle of the method will be presented and the validity of the method will be experimentally confirmed on a bridge Zeiss ACCURA coordinate measuring machine.

Keywords: measurement, coordinate metrology, scanning probes

1. INTRODUCTION

Scanning probes CMM became currently treated as a standard in coordinate metrology. Not only because of high quantity of data gathering in short time of probing but also scanning technology significantly decrease the inspection time. Modern manufacturing, especially in highly competitive economy, required more efficient measuring machine and processes, because inspection machine quite often become the bottle neck in whole manufacturing process. More efficient in coordinate metrology means faster cycles of measurement with acceptable accuracy. But in fact, scanning speed significantly influenced error budget.

2. CMM DYNAMIC PROPERTIES OF THE SCANNING MEASUREMENT

The demonstration of scanning speed influence could be assessed for the case of measuring a section of a cylinder. The measurements were carried out on a Zeiss ACCURA coordinate measuring machine with an active VAST Gold scanning probe. The maximum permissible error of indication for size measurement of the ACCURA is MPE_E=1.7+L/333 µm, where L stands for the length measured in millimeters. The maximum permissible scanning probing error MPE_{Tij} is 2.7 µm. The item was measured with a 3 mm stylus ball diameter and a sampling step of 0.3 mm. Fig. 1 show the measurement results as two sets of points. The first one is a set of measuring speed of 1 mm/s. The second one is a set of measuring speed of 10 mm/s. There are no visible deformations of the measured profile for measuring speed of 1 mm/s and large deviations of the points for measuring speed of 10 mm/s. Apparent increase in roundness deviation is clearly visible. The largest deviations occur in the directions of the principal axes of the CMM machine. For these directions during the measurement appear the greatest acceleration. They are caused by the change of the direction of movement of the quill of the machine.

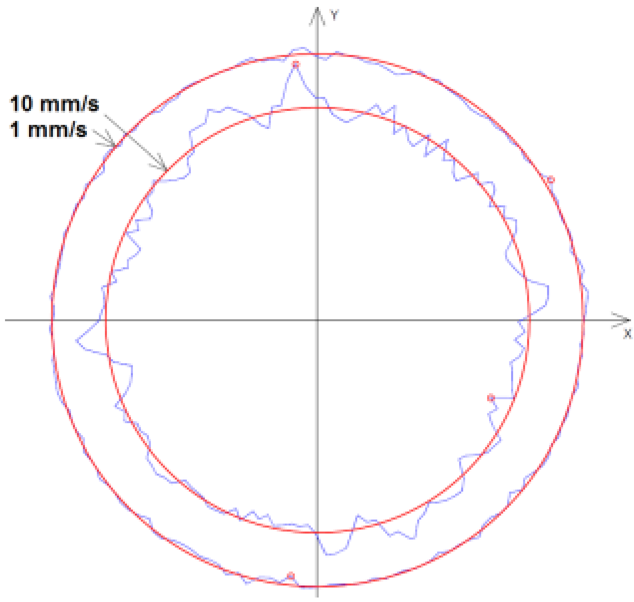

Fig. 1: The result of measuring the section of a cylinder using an ACCURA C. Zeiss machine

Errors dynamic scanning measurements are well-known phenomenon for CMM manufacturers. They are working on systems eliminating these errors. One of such systems is C. Zeiss Vast Navigator. According to manufacturer Navigator enables high-speed with maximum precision. Navigator technology is the logical enhancement to scanning from ZEISS. It automatically configures the maximum measuring speed during scanning – with guaranteed accuracy. Additional time is saved through tangential approach and scanning, helix scanning and fast dynamic stylus calibration.

The effectiveness of the Vast Navigator work is assessed for the case of measuring a section of a ring gauge. The measurements were carried out on a Zeiss ACCURA coordinate measuring machine with an active VAST Gold scanning probe. Fig. 2 and Fig. 3 show the measurement results of diameter *D* and roundness ΔZ as two sets of points. The first one, identified with a hollow square markers, is a set of measurement data obtained while Vast Navigator is switch off. The second one, identified with a Vast Navigator switch on. The item was measured with a 6 mm stylus ball diameter and a measuring speed of 5, 15, 30, 50, 70 and 100 mm/s

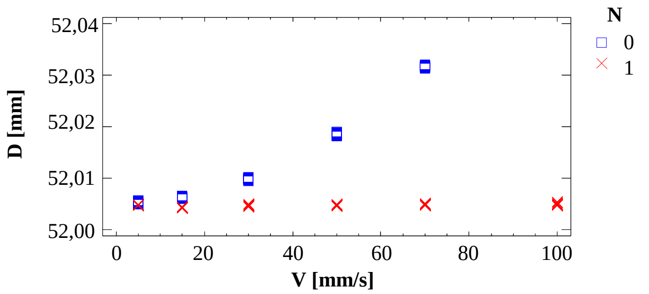

Fig. 2: The measurement results of diameter D vs. velocity of measurement

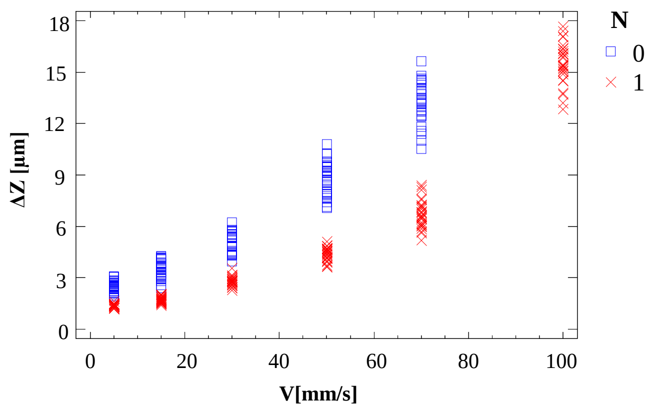

Fig. 3: The measurement results of roundness ΔZ vs. velocity of measurement

In the case of measuring the diameter is greatly influenced by speed. This effect is almost invisible when Vast Navigator is on. However, the result of the measurement of roundness deviation is almost as dependent on the speed of the Vast Navigator is turned on and off.

Presented results proof clearly that scanning speed significantly influenced error budget of coordinate measurement. From the other hand modern manufacturing, especially in highly competitive economy, required more efficient measuring machine and processes, because inspection machine quite often become the bottle neck in whole manufacturing process. More efficient in coordinate metrology means faster cycles of measurement with acceptable accuracy.

Some attempts to optimise the scanning measurement are proceeding at many facilities worldwide and this tendency is reflected in the great interest in these issues in industry. A number of approaches to the topic of investigating dynamic properties with the use of shape standards may be found. They are usually reduced to designating the differences between the profile measurements for high and low measuring speed [1]. A second important group of approaches consists of investigation methods, which employ external reference devices [2,3]. A considerable number of researchers are also interested in numerical simulations [4,5]. Currently no simple method enabling the user to estimate and minimise dynamic errors in a measurement task has been found. This article proposes a new method of investigating and identifying principal components of CMM dynamic errors.

3. NEW METHOD OF DYNAMIC ERROR IDENTIFICATION

The developed method of testing the dynamic properties of CMM is based on measurements of simple shape standard. The proposed shape standard consists of two reference planes forming an adjustable angle. Technically reference surfaces may be measuring surfaces of gauge blocks. Mounting plates and precise adjustment of the angle provides a special holder shown in Fig. 4

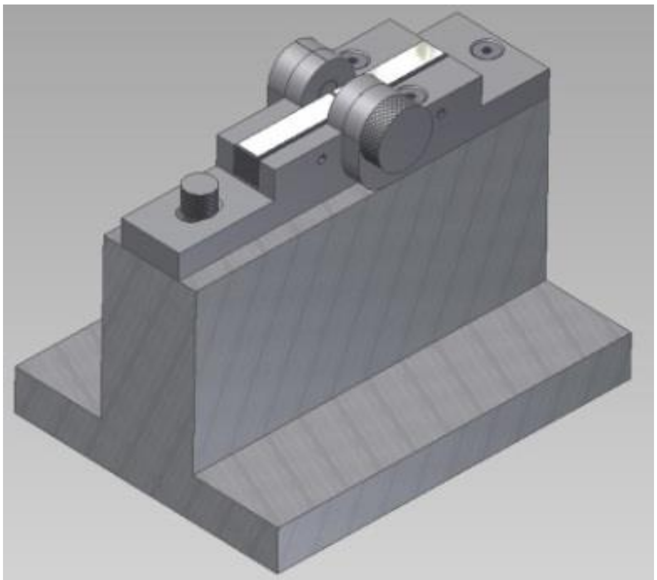

Fig. 4: Developed shape standard.

Investigating the dynamic error consists of a scanning measurement of master artefact, starting with the plate parallel to the scanning axis and finishing with the one situated at an angle. A sudden change of the probe movement direction is easily definable dynamic forcing, which can be analysed. As a result, measurements are obtained of the scan result, which include the dynamic errors. A change of the movement direction of the components of the machine causes acceleration, which is a source of forces and elastic deflections. As a result, damped and un-damped vibrations occur and their frequency analyses enable ascribing them to individual components of the machine (see Fig. 5). The data obtained may be also presented in the displacement domain using FFT as a spatial frequency (Fig. 6). Higher velocity of scanning measurement causes higher acceleration/deceleration of machine parts. Thus, the dynamic forces, which are caused by acceleration, produce the errors.

The nature of such errors originates from the machine itself, probe and stylus and is usually dependent on free frequency of enumerated parts of CMM. The stylus in terms of dynamic has a relatively high frequency because of low mass (1–5 g) and high stiffness. The probe itself, depending on type and construction, has a frequency approx. 15–50 Hz. The lowest frequency influenced into the error budget comes from the machine construction. Also control dynamics may play a part in the total plant resonance. All mentioned errors appear during the scanning of gauge block artefact. The frequency of those errors classifies the source of errors and amplitude showing the importance of errors in the error budget.

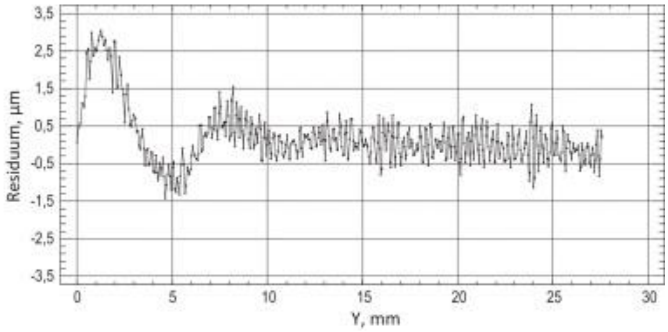

Fig. 5: Exemplary results of the dynamic errors of CMM Zeiss Accura equipped with VAST XXT passive probe when measured at a scanning speed of 10 mm/s

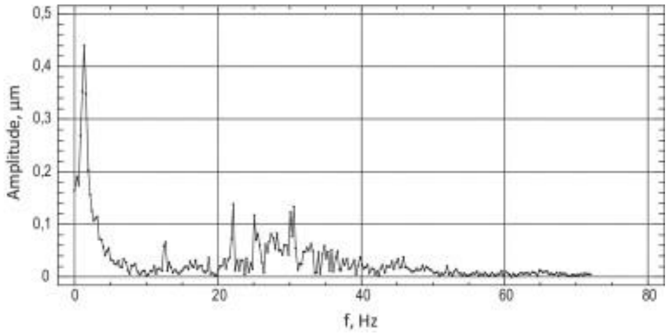

Fig. 6: FFT of measured data from Fig. 5

With the increase of scanning speed, there is the reduction of reaction time for change of machine with probe movement. At the moment when it is necessary to change the location of the probe to assure a constant contact force, machine servomotors must move the machine mass in potentially a short time. Consequently the inertial force, which substantially limits the possibility of quick reaction of servomotors, will be evident. When machine servomotors are delayed in comparison to the change of measured geometry, an additional force is evident of the styli, which causes significant pressure of probe transducers. This can be a reason for additional probe errors. Results of measurement in this situation include some errors in the form of damped vibrations.

From the point of view of the CMM user maximum amplitude of dynamic errors of measurement is the most essential. Fig. 7 presents the maximum amplitude, of the damping vibration for two heads. The results obtained using active Vast GOLD head identified with a hollow squares are compared against a passive Vast XXT head (marked with a cross) Maximum amplitude indicates that the maximum value of obtained residuum for two tested heads.

The difference between the results obtained shows that head construction has a significant influence on the entire machine dynamics. The passive probe, which uses the springs for force generation, records higher dynamic error than an active one. An active probe uses the force generator to maintain a quasi-stable force, regardless of stylus deflection unlike the passive sensor with which the deflection is proportional to the contact force.

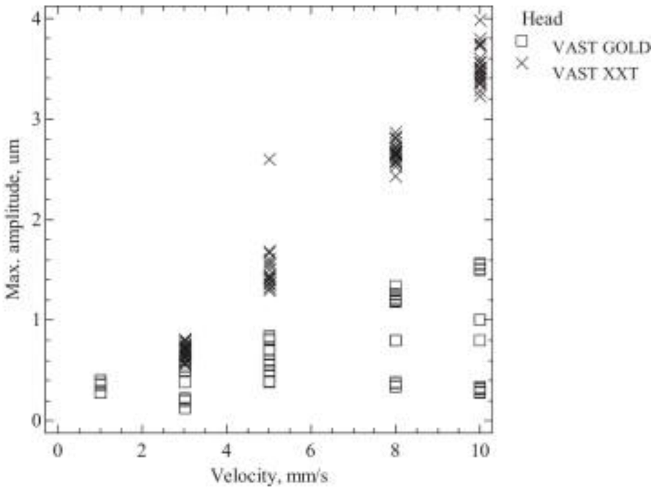

Fig. 7: Maximum residuum of the artefact measurement vs. velocity and probe type

The Kruskal–Wallis test tests the null hypothesis that the medians of maximum amplitude within each of the two heads are the same. The P-value is equal to 0 there is a statistically significant difference between the medians at the 95% confidence level.

4. CONCLUSIONS

The proposed method enables an extremely simple estimation of dynamic measurement scanning errors. The adjustment of the angle between reference plates of the shape master assembly enables simulation of any geometry changes of the measured object in a wide range of scanning speeds. Investigation employing the proposed method may be conducted on different planes of the machine measuring space. The developed method can be applied by the CMM users to estimate the values and minimise the dynamic errors in a proper measurement task.

REFERENCES

[1] E.P. Morse, S.A. Farooqui, "Alternative artifacts for evaluating scanning CMM performance", *Proceedings of the ASPE 2003 annual meeting*, pp. 327–330, 2013

[2] W.G. Weekers, P.H.J. Schellekens, "Compensation for dynamics errors of coordinate measuring machines", *Measurement*, 20 (3), pp. 197–209, 1997

[3] P.H. Pereira, R.J. Hocken, "Characterization and compensation of dynamic errors of a scanning coordinate measuring machine", *Precis Eng*, 31 (1), pp. 22–32, 2007

[4] W. Jinwen, Yanling Ch, "The geometric dynamic errors of CMMs in fast scanning-probing", *Measurement*, 44, pp. 511–517, 2011

[5] Y.H. Mu, B.K.A. Ngoi, „Dynamic error compensation of coordinate measuring machines for high-speed measurement", *Int J Adv Manuf Technol*, 15, pp. 810–814, 1999