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Determination of motion parameters and geometric parameters of objects in production by their videoimages

The aspects of determination of motion parameters and geometric parameters of objects in production by their videoimages were considered.

Development of new high-speed precision measuring tools and control of mechanical qualities for manufactures is the pressing matter. To improve speed and accuracy of measurement tools for geometrical parameters and motion parameters its suggested to use modern visualization methods, which allow forming video-images of objects and perform their algorithmical processing [1, 2].

The geometrical parameters on the products' outer contour and the geometrical parameters of structural elements of machined surface of this products' are measured on the basis of video-images. For the time sequence of video-images with measured geometrical parameters the motion parameters of production equipment and products while manufacturing are defined. The results of mentioned measurements are used for meeting the technological standards, quality control and increasing competitiveness of these products.

The structure of modern measuring tools of mechanical quantities typically includes digital computer or microcontroller. That's why these products contain a possibility to algorithmically calculate measuring signals with the goal to obtain the measurement results of mechanical quantities and increase their accuracy. [3–4].

In this case, the algorithmic processing feature is its usage for digital video-images with measurement information about geometrical parameters. These video-images are obtained by visualizing products. Important operations of algorithmic processing are compensating random, dynamic and geometric faults of video-images.

The time video-image sequence $f_i(x,y)$, $i \in \overline{1,K}$ characterizes the current position of products and manufacturing tools in moments of time $t_i = i \cdot \delta_\text{d}$ (K – overall quantity of video-images; δ_d – time interval between neighboring video-images). For i-th video-image the coordinates of mass center of the product and tools x_{ci}, y_{ci} and its angular position α_i are calculated. The mentioned parameters characterize the flat movement of these objects in the video-image plane, which consists of the transitional mass center motion and rotational motion of objects around it.

Motion parameters of products and tools (movement $dx_i = x_i - x_{i-1}$, velocity $v_i = dx_i / dt$ and acceleration $a_i = dv_i / dt$, $dt = \delta_д$) are calculated by each coordinate x_{ci}, y_{ci}, α_i with moving obtained results to the vectors of movement, velocity and acceleration (variable x_i can be any of the coordinates x_{ci}, y_{ci}, α_i).

For evaluating motion parameters the mathematical model is used:

$$x_i = \sum_{l=1}^{N_П} \theta_{il} \beta_l ,$$

$$X = \left(x_1 \quad \ldots \quad x_K \right)^T = \Theta \beta , \qquad (1)$$

where $\Theta = [\theta_{il}]$ – matrix of values of a-priori known functions in moments of time $i\delta_д$;

$\theta_{il} = \frac{(i\delta_д)^{l-1}}{(l-1)!}$; $\beta = \left(\beta_1 \quad \ldots \quad \beta_{N_П} \right)^T$ – vector of motion parameters in question; $N_П$ – quantity of parameters which describe motion process.

The result of identifying motion parameters on the basis of evaluation by the method of maximum likelihood equals:

$$\hat{\beta} = B^{-1} A ,$$

$$B = \Theta^T R_{\Delta x}^{-1} \Theta , \; A = \Theta^T R_{\Delta x}^{-1} X^* , \qquad (2)$$

$$\Psi_{\hat{\beta}} = B^{-1} = \left(\Theta^T R_{\Delta x}^{-1} \Theta \right)^{-1} ,$$

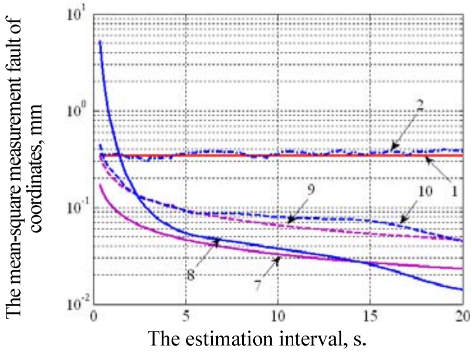
where $R_{\Delta x} = \sigma_{\Delta x}^2 \cdot I_K$ – correlation matrix of measurement faults Δ_{xi}; $\sigma_{\Delta x}^2$ – dispersion of measurement fault of coordinate x_i; I_K – singe matrix of size $K \times K$; $\Psi_{\hat{\beta}}$ – correlation estimation matrix of vector of motion parameters.

For obtaining estimates of motion parameters in real time the discrete Kalman filter can also be used. With constant values of motion parameters on the observation interval the Kalman filter provides the high-precision assessment. But during manufacturing process products and tools change their motion parameters and the large dynamic measurement fault appears.

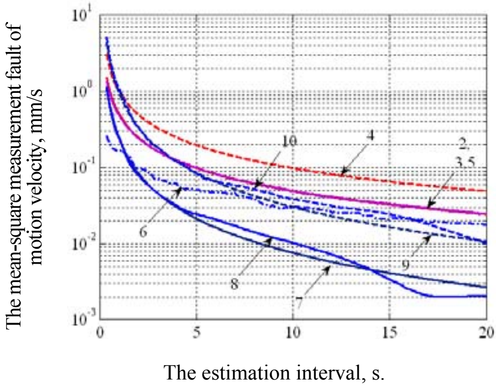
So for defining estimation of motion parameters of products and tool sin real time the formulas (1) and (2) are used.

The estimations are calculated for the time moments $j\delta_{\text{d}}$, $j = N_{\text{est}}, \ldots, K$, each is preceded with measurement time $T_{\text{est}} = (N_{\text{est}} - 1)\delta_{\text{d}}$.

With the help of numerical modeling and experimental studies it was found that the accumulated sequence of video-images the measurement accuracy of current coordinates and motion parameters of products is increased by 3,7…6,7 times, for real-time measurements by 2,1…3,7 times (T_{est}=4 s, N_{est} = coordinate start, video-image size 2000x2000 d.p. (2000x2000 mm), δ_d = 0,04 s, pic. 1).



a



b

Pic. 1. Study of coordinate definition (a) and motion velocity (b) of products while they're moving in the manufacturing process (motion with constant velocity of 20 mm/s): 1 – mean-square measurement fault of coordinates; 2,3 – numerical differentiation; 4,5 –real-time numerical differentiation; 6 – Kalman filter; 7,8 – developed method; 9,10 – developed method with real-time calculations; 2,4,7,9 – results of theoretical calculations; 3,5,6,8,10 – experimental studies results.

Conclusions

The results of determining motion parameters are used for control over compliance with technological standards while manufacturing products. These results are also used for compensating dynamic video-images faults, which are caused by the product's movement with respect for digital camera. This allows increasing the accuracy and performance of instrument system, which measures products directly in their manufacturing process. As the result, quality of the products improves.

References

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