EXTENSION OF THE BANDWIDTH THE SENSOR OF INERTIA

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Inertia sensors commercially available - accelerometers and gyroscopes have a fairly low bandwidth for measurement of physical processes of acceleration and angular velocity. The need to use the serial sensors for high-speed moving objects requires increased bandwidth of the useful signals. The solution of the problem addressed in this article.

Viewed an accelerometer AT1104, has compensation scheme for measuring. It has: a magnetic feedback sensor, the silicon sensitive element (SE) with a capacitive sensor primary motion conversion, built-in electronics to generate, manage and enhance the signal strength. The main characteristic of the accelerometer with a measuring range of ±10g is a bandwidth of 70 Hz.

To improve the bandwidth of the accelerometer by introducing a correction is necessary to have a mathematical model of the sensor. In the absence of information on the model, you need to develop a new mathematical model AT1104 according to information published by the developers of the product [1].

Was developed a mathematical model based on the analysis of the interaction of mechanical and electrical parameters of the accelerometer in accordance with the rules of the exchange of energy between its nodes [2]. This model was obtained in the form of the transfer function of the accelerometer.

In this paper, the mathematical model obtained by the author [2]. The article [2] is an example of AT-1104 accelerometer to calculate the range of ±10g, and also details of its simulation were discussed. To calculate the elements of the mathematical model of the accelerometer in the article [2] sensor parameters were used and the electric concept presented by the developer in the article [1]. The total transfer function block diagram according to [2], was determined as follows:

$W(s)=K_{CHE}\cdot W_{PU}\cdot K_{PP}\cdot W_{KY}\cdot W_N /(1+ W_{PU}\cdot W_{PU}\cdot W_{PU}\cdot K_{OC})$,

where K_{CHE} - transfer coefficient of the pendulum of sensor - of the sensitive element (SE); W_{PU} - transfer function of the motion node; K_{PP} - the coefficient of transfer the displacement transducer; W_{KY} - transfer function of the node of correction; W_N - transfer function of the load; K_{OC} - transfer coefficient of the feedback element.

Software (PO) based on Matlab environment has been developed in the calculations of the mathematical model. Software includes a control portion and a subprogram function described in detail in [2].

To construct a mathematical model of the accelerometer was calculated transfer function of the node of motion - W_{PU} using the routines function[]=PU (). When the parameters J, K_D, G, the transfer function W_{PU} was determined as:

$$W_{PU}(s)=1/(1{,}31\cdot 10^{-8}s^2+5{,}63\cdot 10^{-5}s+1{,}82\cdot 10^{-3}).$$

It should be noted that the mobile node is most accelerometer inertial unit in the block diagram, and has very limited capacity and performance. Motion assembly according to simulation results, a transient process is longer than 0,1 s and the bandwidth is only about 15 rad/s. Of course, serial AT 1104 has a sensor electronics device for the correction of dynamic parameters, but only to a level of bandwidth of 70 Hz (see. Nameplate data). In order to further improve and optimize accelerometer dynamic characteristics it is necessary to use such correction PID controller (proportional-differentiating-integrirduesche controller).

Correcting device was designed for the analysis mode the sensor works dynamics, such as a PID controller. In this case, the transfer device correction function has the form: $W_{KУ}=T_1 s+T_2+T_3/s$, where T_1, T_2, T_3 - coefficients.

W_{UP} payment was made, the result was obtained in the form of:

$$W_{UP}(s)=(0{,}012s+30)/(1{,}63\cdot10^{-10}s^3+9{,}08\cdot10^{-7}s^2+1{,}67\cdot10^{-3}s+1).$$

With regard to the device for the correction, such as a PID controller, it has been used in the sensors in the paper [3], and which showed the possibility of achieving a small oscillatory transients or even suppressing them in the aperiodic law with a sufficiently small time. There is also the opportunity to achieve low levels of dynamic errors (almost at the level of 10^{-7}, which is good enough for inertia sensors).

With KU transfer function can formulate necessary and sufficient conditions for a graph of the transition to a low vibration component (or its absence). From the simplest and most obvious solution is to choose KU parameters so that the zeros KU coincided with the mobile node's poles (roots of the numerator and denominator) [3]. It is enough to meet the conditions: $T_2/T_1=K_{ду}/J$, $T_3/T_1=G_y/J$ and then brackets $(s^2+T_2/T_1s+T_3/T_1)$ and $(s^2+K_D/J\ s+G/J)$ will be destroyed. The transfer function of the forward path is written in the form:

$$W_{PR}(s)= W_{PU}K_{PP}W_{UP}W_{KY}W_N=1/(Js^2+K_Ds+G)\ K_{PP}(T_1\ s+T_2+\ T_3/s)\ W_{UP}W_N.$$

Implementation of the parameters T_2, T_3 at the previously calculated parameters K_{PP}, K_{DM} in this case is only possible at the expense of T_1, which defines the type of the selected KU efficiency in the differentiation. Other parameters T_2, T_3 are closely related to the relationship T_1: $T_2=T_1\cdot K_D/J$, $T_3=T_1\cdot G_y/J$. The transfer function of the load device is received in the form of:

$$W_N=(Rn\cdot C\cdot s+1)/(Rm\cdot Rn\cdot C\cdot s+(Rm+Rn)).$$

As a result, the transfer function of the direct chain has received the following form:

$$W_{PR}(s)=(4{,}7\cdot10^{13}s^2+1{,}5\cdot10^{21}s+3{,}6\cdot10^{24})/(2\cdot10^{-6}s^4+3{,}78\cdot10^2s^3+2{,}11\cdot10^6s^2+3{,}87\cdot10^9s+2{,}32\cdot10^{12}).$$

The total transfer function of the sensor is obtained as follows:

$$W_Z(s)=(10^{10}s^2+4\cdot10^{17}s+9\cdot10^{20})/(2\cdot10^{-23}s^6+2\cdot10^{-14}s^5+9\cdot10^{--6}s^4+3\cdot10^3s^3+3\cdot10^{11}s^2+8\cdot10^{18}s+2\cdot10^{22}).$$

When testing a mathematical model of the accelerometer input signal was set to limit value range - 10g. The output data was received adequate transition to the value of 5 V.

The next stage of testing a mathematical model of DLU was aimed at the study of amplitude-frequency characteristics (AFC). The theoretical frequency response characteristics and confirm the correctness of the mathematical model of the accelerometer.

The capacity was calculated in terms of fading on a logarithmic frequency response of 3 dB from the upper-level values bandwidth was received about 8 decades or 10^8 rad/s, ie, $1{,}59\cdot10^7$ Hz. The alleged characteristics of AT-1104 accelerometer for a range of ±10g, according to the developers of information [1], a bandwidth of 70 Hz has been guaranteed. By introducing the CG and the correct choice of its parameters, bandwidth AT-1104 accelerometer sensor has been expanded from 70 Hz to $1{,}59\cdot10^7$ Hz.

Conclusions.

The need to use high-speed inertial sensors in the motion of an object, as a rule, requires increased bandwidth of the input signal bandwidth.

The article discusses the use of a PID controller as a device for correcting sensor bandwidth expansion. The results can be used for any sensor constructed by measuring the compensation scheme.

References:

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