MODELS FOR ANALYSIS OF DYNAMIC ERROR FOR INSTRUMENTS,
MEASURING PARAMETERS OF MOVING OBJEKTS,

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Abstract: Measuring devises, determining parameters of moving objects, operating in dynamic rate of acceleration. In that case, the basic component of the summery error, which depends on the accuracy of measurements and affectivity of conducting of the moving object, is the dynamic error. In the paper are presented the results from presented investigation of the dynamic accuracy of that kind measuring devises. The game for investigated for dynamical accuracy is solved in one continues solution system: water-moving-object-measuring-device. Imitation model of investigate of the system, which is developed by means of the pack Sim-Mechanics allows to work most for simulation of all possible exploration condition for working on the investigated measuring structure. For the purpose of experimental investigation of that type of measuring systems, develop special apparatus; build on the base of mechanisms with parallel kinematics.

Keywords: mechanisms with parallel kinematics, dynamical accuracy initiation model.

1. Introduction*

Characteristic path of the contemporary part of development of the measuring technique is brooding in the domain of instruments of the physical quantities, changes in time. That is connected with the appearing new areas, detained of application with improving characteristics and movement of elaborating the modern application. New areas are improving the implementation of measurements, and complicate complexes in the calculation of solved equations in solution of real time. It is connecting also in the necessary of application in the vessel-maritime, ear-born transport field of Ships, sailplanes, telpherage. It is connected with new areas of application of the elements for measuring and complicated with extended of the area with solution, of that are retention of the control of several different parameters, characterizing movement of moving objects, in response in real time.

Moving objects could be: ships, ear-born (ear-plain), ground transport. Of cause, the principals of motion are different, but the total structures of the metrological task, connected with determinate the dynamical accuracy of the measuring instruments, remain one and the same.

The effected unrated of the motion of the moving object, depends on the hither degree of quality of the received measuring information. Under the quality, measuring means the complete of quality, predicting resaving of exacting measuring signal, in the kind and the needed accuracy characteristics. The best of quality measurement process is its accuracy. The accuracy of that work the measuring devises are deterring by the process of measuring. The last is a dynamic, because it follows the informative parameters and the influence of the sealants systems, information as well so, the measured disturbing quantities, change in time. Dynamic properties of measuring and disturbing quantities, ingenerating and inertial characteristics of measuring instrument observe the apparent dynamical error in the measured result.

In some cases the dynamic errors could be accepted quantities, which are equal with the quantities of the measured result. That leads to wrong results and impossible of effective control of the traffic of the moving object, and as a result, to real dinger for the catastrophe on the moving object.

It is clear, that in the time of projects of equal measurement instrumentations it should be possible to orient some spare reserve for dynamical accuracy by measurement. The guarantee of the needed dynamic accuracy is a complicated process by measurement dynamic accuracy, because of the random noise (complexes and non periodic) of the dynamic characteristic properties and the measuring devices.

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The first approach is to start with mathematical models are the measuring conditions and the measuring devises on the ground of the building of the model after model with results of the dynamic error. The realize modes on the bases of a connection, offer there possibilities for optimal choose of the schemes solution of the measuring instruments, of there functional parameters and there values, demanding the dynamic accuracy.

After the connection of the aim of the presented paper is develop the basic theoretical model for analysis of dynamic error of devices, measuring parameters of moving object.

2. Model of measurement condition

The model includes mathematical models of the domain, where the moving object is the same object. If the moving object is a ship, than the domain will be the see. Real windy waves with complicated sailing forms generate in time and see and the chancing of the time and the free regular form and not-regular characteristic. Because the see waves generate different tapes of motions, which the ship generate the dynamic way of work of measuring instruments, based on the selling object. “System-water-ship” formatted of the parameters of motion (sailing) ship, which offer the dynamical characteristic of the measuring working (navigate) mode. That’s is the see waves demand the motions of ship, which accepting the dynamic mode of sailing work of the measuring instruments of board, based on the vessel.

The system water-vessel formatted those parameters of the moving object, which influences its movement of the object of measurement, aiming effective control of the mouton. From one side, measurement instruments, use aiming to determine the quantity of that parameters, bud on the other, they are presented under the influents of there dynamic moving characteristics. That means the accuracy of the result of moment characteristics of the dynamic parameters of the system-vessel and the inertial properties measurement instrument it self.

That’s working on the investigation of the dynamic accuracy of that type of measurement is needed to use the system water-motion-object-measuring-instrument. Individual analyzing of the measuring instruments, outside the range that system will discuses to result in theoretical and experimental aspect. Of cause, the more the elements in two dynamic systems, also more will be complicated mathematical model.

On the other side, there exist duplicate mathematical combinations for getting easy mathematical model. The effective results can be accepted the processed of the creating its on the bassist of the equal equilibrium between the results and obtained by theoretical methods by mathematical technique on the base using technique for different of level of accuracy, for example in that work only lineal models for model of measurement instruments.

The linearization is obtained by theoretical trajectory wave. By means of different mathematical techniques are used in different level of completing. For example, by means of the theoretical
mathematical techniques have used the pattern, for example the work was discussed only for linear models of measurement instruments.

The linearization of that model is complexity, because the large number of parameters, coefficients, compulsory and so forth. In some cases the linearization of the equation, describing the system could lead to loss of some crucial particular elements of the system. That way by generating of the model is necessary to fix the all made suggestions and debugging, because with the help could be able to formulate the conditions, by the implementation of which the mathematical model is acceptable. By the working on the models of the system is useful to build several mathematical models, beginning with the less complicated variants, by the necessary could be stepwise and to complicate, such to defining spare elements and connections, finished by the first attempt. It is necessary to mention on possible compensation of non-linear characteristics of separate elements of the system. In that case it could be found that the linearization of the equations that elements are non-use.

The measured quantities describe geometrical properties of the motion depended from the time. From that could be followed made two conclusions: the first, depending of the measurement static mode, by that measurement appears one second measuring coordinate: the time, and the second – motion and its derivates, determine the characteristic of the measured parameters, are vector quantity. That wais for generating of the model: system – water – motion object-measuring instrument, Fig. 1, is used its theoretical multiple description.

![Fig.1. Structural scheme of the system of water-moving object-measuring instrument](image)

For the purpose of information for the condition of the moving object use measurement of the tang quantity of the elements of the input vectors parameters [X]. The last include the vectors of cinematic characteristic (motion, speed, acceleration), which include the information parameters for the condition of the object.

The vector of the measured quantity [X], one obtain as a results between another two vectors: the vector [G] the middle of the middle where include motion object and the vector of the moving object and the vector [A], together with the parameters of the object.

So, the vector of the measuring quantity is obtained as result of the measured quantity [X] is obtained as result from the two vectors: vector [G], which makes motion of movement object and the second vector [A] of the parameters of the object. That means that, vector [X] is defined, the followed functional is defined as:

\[
[X] = F[[G], [A]].
\]

The functional (1) is not the only result from between the vectors: of the two vectors [G] and [A]. It is used another functional, defending the vector defines the factorial vector defending the vector [S], used of the random noise (complex and non periodic) for example:

\[
[S] = F[[G], [A]].
\]

The names are of the measuring quantity, together with quantity random noise. By some measured quantity appears that the measured quantity and random noise, interference on the complete elements of on the measuring quantity and the random noise, interference on the complete [S], to the followed functional. The used measuring quantity and interference influents have specific characteristics. By the ones instruments measurements could be measured with and external random noise interference perturbation. It determine so easy, depend on the metrological characteristics of the instrument [3]. For example, the measuring instrument depends of the instruments for measuring of different of the on the ship, because that parameter posses measuring channel only for the different.

Names on measuring quantity and disturbance from outside possé’s conditional characteristics. By one instrument one quantity could be measured, from the other, the perturbation. Determination of all the other depend on the meteorological characteristics of the usual instrument [3]. For example, the instrument for measurement of the different of the ship poses measuring channel only towards the coordinate of the different, because the parameter is the measuring quantities. For example, the movement of the ship toward the other five degrees of freedom will formation of the vector of the disturbance influence of that kind of measuring instruments.

\[
[S] = ([Q], [S], [H], [Z], [Z]).
\]

The waved in the see and oceans are three measuring coordinates, which determent the character of the vector [W] defining the moment condition of the water. Despite of that vector [W], together with the vectors, determination of the navigation of the vessel, toward base coordinate system and its moment kinematical characteristics define the vector [G] of the line, where realize motion of the moving object.

The mention quantity and functionally, where they influence on the formulation on the results of the measurement. It is clear, the characteristics of the vector [Y] of the result from the measurement depends to great degree of the characteristics of the vector [Pr] of the internal parameters of the measuring instrument. From that, follows, that the vector [Y] of the result of the measurement will determine an functional

\[
[Y] = R{[X], [S], [Pr]}.
\]

Expecting the vector equation (1) and (2), (4) obtains the solution like the follows:

\[
[Y] = R{F[[G], [A]]; F[[G], [A]]; [Pr]}.
\]

The model (5) is the basic mathematical apparatus, used for building of the model of the dynamical error.

Then, the final expression of the solution for the error by measuring, after structural schemes is presented on Fig. 1.

\[
\Delta = F[[G], [A]] - R{[X], [S], [to]} =
= F[[G], [A]] - R{F[[G], [A]]; F[[G], [A]]; [Pr]}.
\]

The error (6), existing, in the result of measuring, leads to pollution into information, defined the vector of the measuring effectively of the moving object. The metrological characteristics of the kind of measurement systems depend to great degree of the quality of the correcting module. The last, usually is building with adapting algorithm as a function of the running quantity of the functional parameters in a function of parameters the system: water-moving-object-measuring instrument. By that method, the task of effective measuring mode of control on the moving object is suppose to dividing on two basic components, obtaining of information of the running quantity situation and the running quantities of the measured parameters and realizing of correcting
influence on the base of the obtained data. The task, connected with determine of corrugation influence is obtain for condition of minimizing of the measure of middle quadratic error.

From another side, the sensors are inertial elements, which are sensitive towards to dynamic of measuring quantity, as well. Also, from other side the sensors are inertial elements, which are sensitive to dynamic of measuring quantities, as well to other non-informative processes, together with measuring procedure. That leads to declination from the reference, connected with inertial system, were generate error in the result of the measure. The last has dynamical characteristics because the quality of the measured quantity and the measuring instrument.

Because of that exploration condition of the object – Ship, possess six degree of freedom, imitational model is provided with six blocks Joint Actuator, by which gives the absolute motion of connected with the object coordinate system. Defining of the motions of each degree of freedom gives each Subsystem.

The sensor of the measuring instrument shows a physical pendulum with two degree of freedom, each one of which define the concrete measuring coordinate. For modeling of the dynamics of the sensor is used from the block Universal, providing its free rotation towards the two perpendiculars cross coordinate access.

With the model a Damper is provided, which the basic parameters could be fixit in the block Joint Spring & Damper. The characteristics of the vector \([P]_r\) of the internal parameters of the measuring instrument are presented by two Body blocks (4 and 5, from Fig. 2).

The results from the work on the imitation model can be analyzed, using the graphs of changing of the functional parameters of the system depending of the time. On Fig. 3 are presented such a results, defining characteristic of the vector \([Y]\) of the results measured and the vector \([\Delta]\) of dynamic errors. Despite of that Sim Mechanics give possibility for visual of the observation on the investigated model in the process of solution of the differential equation, shown on Fig. 4.

4. Stand apparatus for experimental investigation of dynamic characteristics

Development on apparatus for experimental investigation of the dynamical characteristics of instruments and devises for measuring parameters of mouotn objects in particular, ships is relatively complicated task. That is due to decisions on the idea that the platform of the stand should simulate the movement of the ship. That will project towards movement of all the six degree of freedom is defined by all the six random processes in the time.

Initial possible solution in the respect is using the possible ideas of the characteristics of mechanism with parallel kinematics is the hexapods. Standing apparatus in this aspect on the basic of that

**Fig.2. Imitation model of the system-water-moving object–element instrument**

3. Modeling of the investigated system

Imitation model is a formal description of logic of function of the investigated system and the partial elements in time, accepting the more realistic causal-clarification connecting, characteristics for the system and supporting realization of statistical experiment. That wise in the present an imitational model of the system water-moving-object-measuring instrument. The last is generated by means of the packet Sim-Mechanics, is a part of the programmed complex Matlab. The model (Fig.2) is completed for investigation of the accuracy characteristic of concrete measuring instrument. In that case the measuring instrument is prepared for the measurement of angular quantity, defining the moment’s quantity of the different of the vessel. The sensors of such kind of measuring systems for repeated in real time properties of the inertial system.

**Fig.3. Results from digital solution result**

**Fig.4. Visual presentation of investigated model in the domain of Sim Mechanics**
are: six degree of freedom of manipulation; advancing the possibility for positioning actuators equal characteristics:

All the actuators are linear (for example only linear). Standing the motion of the platform some of all possible solutions are the mechanism with parallel hexapods. Creating the apparatus of that base there are plenty possibility bud the advantages are: sex degree of freedom of the manipulator: excellent motion and accuracy, positioning; heavy loads. Equal type of actuators (for example, only linear). All the advantages of the hexapods offer broad possibility for building that base of the etalon apparatus for investigation of dynamical quantities.

On the Fig. 4 is shown a building stunted apparatus with the placed on the platform and investigated precision measuring instrument. On Fig. 5 of the system is the algorithm of work is developed on the base of the structural scams from Fig. 1 and the imitation model on the Fig. 2. Hexapods from Fig. 5 is monosectioning is based on existing known mechanism with parallel kinematics-the platform of Stuart. Standing apparatus has six degree of freedom and six cinematic chains, connecting moving platform with base. Each of one of connecting chains two precision cinematic pears and one moving translation. The position of the platform is presenting the mode of control.

Important part from the work, connected with the standing apparatus, is the mathematical modeling. For the mathematical modeling of the technical systems in parallel kinematics is the most easy to use program domain of structural modeling. Broad used program domains are: Matlab/ Simulink, VisSim and Dimola. Mathematical modeling of standing apparatus is used in Simolink from the program domain MatLab. On the base of Simulink are used bibliotheca is the visual module for visual modeling of mechanism Sim Mechanics. The using of the last work is Sim Mechanics is working on bibliotheca with different objects. Bibliotheca are accepted modules for different domains. The bibliotheca is for visual package for modeling of spaced mechanisms.

Sim Mechanics is the use of the present work of the last presented
The use of the last in the present work is especially useful because the presenting of large complete of instruments for define of the of the mass and the geometrical properties of the hard materials, there possible motions, the kinematical restrictions, is coordinate systems, the sores of external influences and the instrumentation for there measuring of its motion.

5. Conclusions
Measurement of dynamic mode of control is different with problems, the most-important from which is connecting with the fact, the area possessing organic complete of etalons.
Measurement in dynamic mode of control are different again the plenty of troubles, especially the most-important. After of that principle is necessary for determined on such a condition of the measurement, when the results of them are presented in loose definition, its errors are defined with fixated, accepted variation.

That is for the investigation and the results, obtained from that work are dedicated directly in that area. Developed theoretical and multiple model of the system, measuring domain-moving-object, measuring instrument, defending the complicated connections between the functional parameters, working in the domain. On that base is possible to develop the necessary constructed conditions for projecting of equal kind measuring instruments and systems. Basic task, cooperate with optimization of contacting parameter quantity of the instruments are deciding the constricting parameters for minimization of the measure of the dynamical error.

Solution of all kind task is connected with large contain of operations, which is not possible to finish the program domain. The last is developed by means of the package Sim Mechanics, allows simulations of all possible exploitation condition for work. Together with model from Fig. 2, activating graphical module for visualization of movements, giving more-complete presenting of dynamical system.

The results from that works could be used by projecting are determining the parameters of moving objects, by guarantee of the there metrological characteristics, used for generate by developing of experimental standing deviseing for investigating of the accuracy of the measuring instruments of that kind.

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