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THE REGULATOR SYNTHESIS SOFTWARE FOR THE NONLINEAR STABILIZATION SYSTEM

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Abstract—Reviewed software creation method for the selection an optimum regulator for the nonlinear stabilization system of the inertial control object. Schematic decisions of regulators and correction devices for stabilization systems may be different: P, PI, PD, PID. The first three options can be generally obtained by applying restrictions on the PID-model. The exact adjustment of the PID-regulator parameters significantly reduces system fluctuations. The full use of the PID-regulator advantages is only provided with the correct calculation of these parameters, taking into account the unique characteristics of the controlled objects. At the same time, it is important to have a mechanism for coefficients controlling that would provide a convenient interface between the program and the user.

Index Terms—Inertial object; stabilization system; ship; nonlinearity; step response; PID-regulator, correction appliance.

I. INTRODUCTION

Stabilization and control systems take an important place in the automated control systems of inertial objects. Their goal is to achieve a sustainable value of a control magnitude or its change for a given control law.

While simultaneous action of control signal, permanent or variable perturbation influences and obstacles on the system, there is a need to solve the problem of minimizing its error.

In order to provide optimal quality indicators, a correction of control systems is widely used for changing of the system dynamic properties. The correction is carried out by changing of the control system parameters or its structure. For this purpose, correction devices are entered into the system, which represent dynamic links of various physical nature with specially selected transfer functions.

Currently, in the world market, for integrated control systems are offered universal control microprocessors, which require special setting.

Schematic decisions of regulators and correction devices for stabilization systems may be different: P, PI, PD, PID. The first three options can be generally obtained by applying restrictions on the PID-model.

PID-regulator measures the deviation of the regulated by the system coordinate from the given value and issues a control signal, which is the sum of the three components – proportional, integral and differential.

II. PROBLEM STATEMENT

The exact adjustment of the PID-regulator parameters significantly reduces system fluctuations. However, the full use of the PID-regulator

advantages is only provided with the correct calculation of these parameters, taking into account the features of the controlled objects.

While designing systems with a PID-regulator, it is necessary to investigate the effect of its coefficients on the transition process (or the coefficients choice according to the desired type of transitive function), which requires multiple launch of the model with modified coefficients and constant editing of the model properties. At the same time, it is important to have a mechanism for coefficients controlling that would provide a convenient interface between the program and the user.

Thus, there is a need to create the universal application for researching stabilization and control systems, which will provide a quick and convenient choice of optimal PID-regulator coefficients.

III. PROBLEM SOLUTION

All above difficulties can be overcome by using the GUI – Graphical User Interface, which is a part of Matlab.

The work in this environment is quite simple - controls (buttons, drop-downs, etc.) are placed with the mouse, and then events that occur when a user accesses these control elements is programmed. When solving these tasks, the user GUI does not need to create full M-files. Often, he may not even know all the details automatically opened in the GUI M-file. The GUI user only edits it, completing the functions of a specifically solved task.

Let's solve the problem of the selection an optimum regulator for the nonlinear stabilization system of the inertial control object, for example a ship.

Mathematical model of the stabilization system of the ship course is represented as a block diagram (Fig. 1).

The system has certain features. Firstly, scheme contains sensors of the angular and speed deviation of control object based on the three-stage and two-stage gyroscopes. At the same time, they contain nonlinear feedbacks, which are caused by the presence of dry friction in the bearings of the gyroscope frames.

Secondly, in the real system the deviation angle of the executive drive rudder and its rotation speed have natural barriers, so executive drive is nonlinear.

Thus, the stabilization and control system of the ship course is nonlinear. There are five nonlinear elements in it.

Considering nonlinearities in the angle and speed sensors and their effect on the sensor is a separate branch of researches. Consider sensors errors caused

by the presence of nonlinearities in them, like $\Delta\psi$ and $\Delta\beta$, and pass to linear models of the angle sensor and the speed sensor.

The principle of superposition does not apply to nonlinear systems, so, we will consider the stabilization system that is only under the action of the control signal. Because of adopted limitations, the block diagram of a nonlinear system of stabilization takes the form shown in Fig. 2.

The moment of stabilization is formed through the sensor channel of angular deviation and through the speed sensor of angular deviation of control object:

$$\bar{M}_s = \bar{M}_G + \bar{M}_D \equiv k_G G_m + k_D D_m.$$

After the convolution of contour we obtain an equivalent transfer function of the stabilization system linear part:

$$W(s) = \frac{k_0 k_G G_m}{T_0 T_2^2 s^3 + (T_0 T_1 + T_2^2) s^2 + (T_0 + T_1) s + 1 + k_0 k_D D_m} \cdot \frac{1}{s}.$$

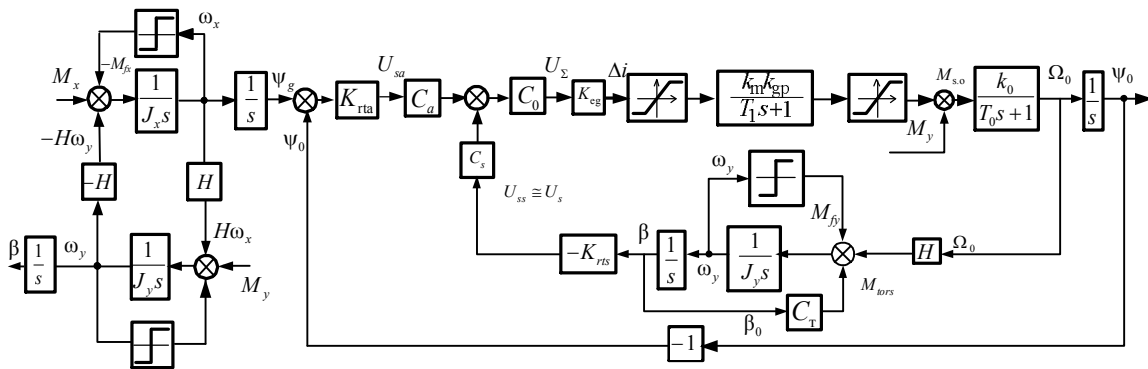


Fig. 1. Nonlinear stabilization and control system of the ship course

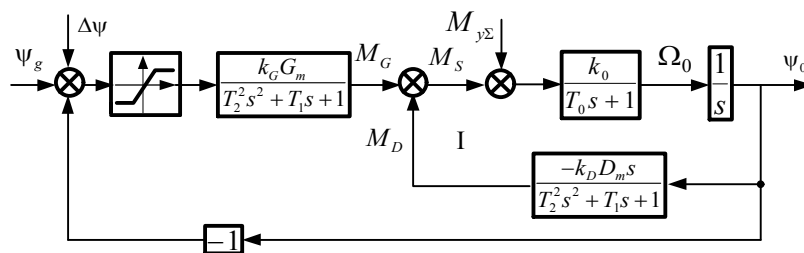


Fig. 2. Calculated model of the nonlinear stabilization system of the ship course

Concurrently, the executive drive has a linear characteristic with limitation:

$$z = \begin{cases} -x_{\max} & \text{at } x < -a \\ kx & \text{at } -a \leq \delta \leq a \\ x_{\max} & \text{at } x > a \end{cases}.$$

Calculated model of the nonlinear stabilization system of the ship course and equivalent transfer functions of its components allow to begin the direct computer modeling.

The GUIDE – Graphical User Interface Design Environment, is designed primarily for GUI design, and then for direct programming.

The GUI application can consist of a single main window or several windows and display graphics and text information in the main window of the program and in separate windows.

A number of Matlab functions are designed to create standard dialogs for opening and saving a file, printing, font selection, data entry windows, and more.

To create a specific application, the GUI elements are dragged from the toolbar to the window of this application. After adding the interface element, you need to specify its tag – the name that will identify the object among other objects.

In the GUI application for adjusting the PID-regulator will be placed:

– interface element for outputting the graph of the investigated system transient process;

– three sliders for setting numerical values of the regulator coefficients K1 (P-component), K2 (I-component) and K3 (D- component);

– six Edit Text elements to set the limit values of these coefficients (Max and Min);

– three text elements Static Text to output current values of coefficients (Current);

– six text items for the corresponding inscriptions.

The limit values of the regulator's coefficients can be set experimentally. In the work, they are selected based on the performed calculations [3].

The application sample with the elements of the interface added from the toolbar has the form shown in Fig. 3

Designed graphical interface is ready for programming.

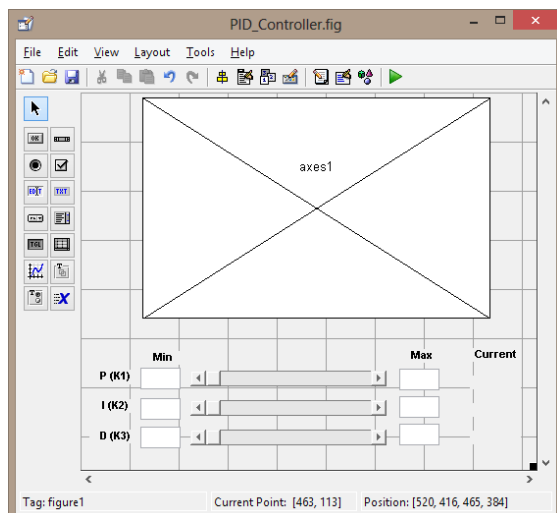


Fig. 3. GUI application sample window

When you save the graphical interface, Matlab automatically generate the program code for it. Therefore, after the initialization block of this code, the main part of the solved problem commands is placed:

function mySliderCallback(hObject, eventdata, handles)

```
% getting max and min regulator components
max1=str2double(get(handles.edit1, 'String'));
max2=str2double(get(handles.edit2, 'String'));
max3=str2double(get(handles.edit3, 'String'));
min1=str2double(get(handles.edit4, 'String'));
min2=str2double(get(handles.edit5, 'String'));
```

```
min3=str2double(get(handles.edit6, 'String'));
```

```
% getting slider values
c1=get(handles.slider1, 'Value');
c2=get(handles.slider2, 'Value');
c3=get(handles.slider3, 'Value');
```

```
% determination of the current coefficients values of the
regulator components
```

```
cur1=min1+(max1-min1)*c1;
cur2=min2+(max2-min2)*c2;
cur3=min3+(max3-min3)*c3;
```

```
% output current values of coefficients
```

```
set(handles.text7, 'String', cur1);
set(handles.text8, 'String', cur2);
set(handles.text9, 'String', cur3);
```

```
% transient characteristic
```

```
axes(handles.axes1);
cla;
hold on;
grid on
```

```
% the assignment of the regulator coefficients
```

```
K1=cur1;
K2=cur2;
K3=cur3;
```

```
% system parameters
```

```
Wob=tf([30],[0.01 0.2 1 0]); % object
Wg=tf([0.09], [0.01 1]); %gain
```

```
N=100;
```

```
Wp=tf([K1/N+K3 K1+K2/N K2], [1/N 1 0]); %regulator
```

```
W1=series(Wg, Wob);
```

```
W=series(Wp,W1);% transfer function of an open-loop
system
```

```
sys=feedback(W,1);% transfer function of a closed-loop
system
```

```
t=5;
step(sys,t)
grid on
xlabel('t');
ylabel('h');
```

The generated code is supplemented with functions of access to sliders:

```
function slider1_Callback(hObject, eventdata, handles)
mySliderCallback(hObject, eventdata, handles);
function slider2_Callback(hObject, eventdata, handles)
mySliderCallback(hObject, eventdata, handles);
function slider3_Callback(hObject, eventdata, handles)
mySliderCallback(hObject, eventdata, handles);
```

Regardless of the sliders number and their tags, the above function has the same look for each slider.

As a result of running the code above, the dialog opens, as shown in Fig. 4.

The developed interface allows by dialog sliders' engines displacement to determine the coefficients of any type regulator (P, PD, PI or PID) by the view of transient characteristics.

In Figure 4, as an example, the transition function

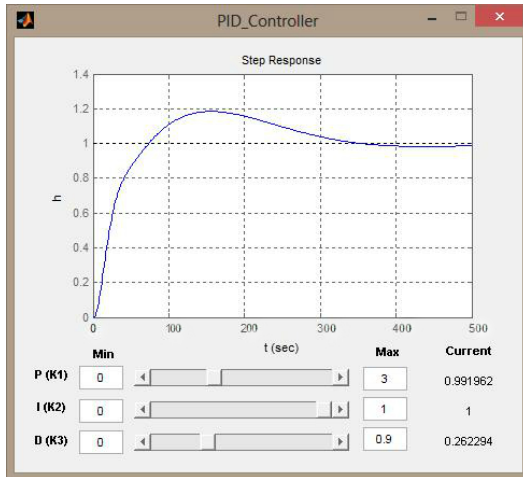


Fig. 4. Dialog interface

Graphs in the dialog can be edited by calling the Property Editor. It also allows to mark the main quality indicators on the graph of the transition function: the maximum amplitude value, override, the set value, and the time of the transient process.

IV. CONCLUSIONS

The designed program for adjusting the regulator's coefficients in the graphical interface allows us to quickly calculate the optimal coefficients for any type of regulator or correction device by removing and combining the necessary channels in them.

is showed with slider installing in position that corresponds to the optimal coefficients of the PID-regulator obtained in previous studies [3].

By removing the clean command "cla" in the program's M-file, you can get a family of transient characteristics for any set of parameters of the regulator, which can be convenient when choosing the characteristics with the desired quality indicators (Fig. 5).

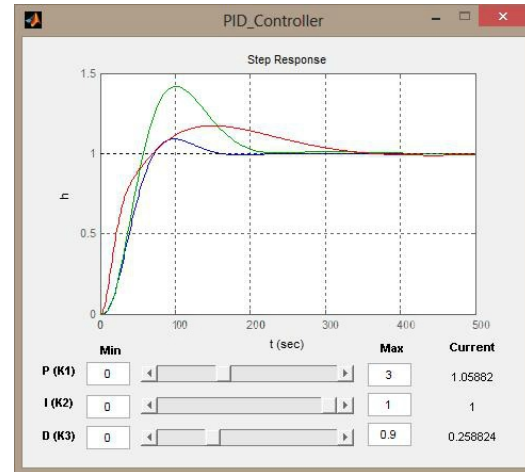


Fig. 5. An example of a characteristics family

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О. К. Аблесимов, М. О. Пилипенко, Т. П. Жмурчик. Програмне забезпечення синтезу регулятора нелінійної системи стабілізації.

Розглянуто методику створення програмного забезпечення синтезу оптимального регулятора для нелінійної системи стабілізації інерційних об'єктів. Схемні рішення регуляторів і коригувальних пристроїв, можуть бути різними: П, ПІ, ПД, ПІД. Перші три варіанти можуть бути в загальному випадку отримані накладенням обмежень на ПД-модель. Точне налаштування параметрів ПД-регулятора суттєво знижує коливання системи. Повноцінне використання переваг ПІД-регулятора забезпечується тільки при правильному розрахунку цих параметрів з урахуванням особливостей характеристик керованих об'єктів. При цьому важлива наявність механізму управління коефіцієнтами, який би забезпечував зручний інтерфейс між програмою і користувачем.

Ключові слова: інерційний об'єкт; система стабілізації; корабель; нелінійність; перехідна функція; ПД-регулятор, коригувальний пристрій.

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А. К. Аблесимов, М. А. Пилипенко, Т. П. Жмурчик. Програмное обеспечение синтеза регулятора нелинейной системы стабилизации

Рассмотрена методика создания программного обеспечения синтеза оптимального регулятора для нелинейной системы стабилизации инерционных объектов. Схемные решения регуляторов и корректирующих устройств, могут быть разными: П, ПИ, ПД, ПИД. Первые три варианта могут быть в общем случае получены наложением ограничений на ПИД-модель. Точная настройка параметров ПИД-регулятора существенно снижает колебания системы. Полноценное использование преимуществ ПИД-регулятора обеспечивается только при правильном расчете этих параметров с учетом особенностей характеристик управляемых объектов. При этом, важно наличие механизма управления коэффициентами, который бы обеспечивал удобный интерфейс между программой и пользователем.

Ключевые слова: инерционный объект; система стабилизации; корабль; нелинейность; переходная функция; ПИД-регулятор, корректирующее устройство.

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