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ISSN 0469 - 6255
(117-120)

AN APPROACH TO ANALYSIS OF NON LINEAR CHARACTERISTICS OF MARINE ENGINE'S SPEED REGULATORS

UDK 681.527:621.436:629.12.037
Prethodno priopćenje
Preliminary communication

Abstract

Marine engine speed regulators have been observed as non-linear dynamics models, those mathematical characteristics are similar to system of differential equations. Theoretical and experimental analysis of such has been done, to comprise behaviours of regulator models.

Mathematical approach to equation solutions is determined by well known methods of numeric integration, but approach to Runge-Kutta method was preferred to reach reliable values of unknown system variables. Computer simulation and computer-aided design is the best tool for system modelling representation.

Therefore, an acceptable software algorithm has been presented to enable understanding of software simulated analysis, and to get numerical solutions of system equations.

1. INTRODUCTION

The automatic regulation is presumed to be an algorithm or function, presenting regulating method, [1], [2].

Due to the characteristics of the regulation law, three basic types of regulators could be presented:

- P element (proportional)
- I element (integral)
- D element (derivation)

Universal PID regulator that could simulate any individual or composed regulator, consists of quoted elements. Electronic regulator principles have been observed including PID characteristics of regulation law, and block scheme of the regulator type EGS-990 has been presented. In education purposes, software algorithm has been developed, based on mathematical numerical methods.

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2. ANALYSIS OF NON-LINEAR REGULATOR CHARACTERISTICS

2.1. Basic regulator principles

Universal PID regulator could be presented as following mathematical model:

$$Y = C_p \cdot X + C_i \int X \cdot dt + C_d \cdot \frac{dX}{dt} \qquad (1)$$

where X presents input, Y output value and C_p, C_i, C_d are constants of regulator elements.

Regulation principles (Fig. 1.) are based on discrepancy (dX) presenting difference between expected value (Xs) defined by set-up element (S) due to reference value (Xo), and real value (Xm), derived by t-element (transmitter) from input parameter X.

Output from PID regulator (Xr) is amplified (A) and stabilised (B), and proceeded as output regulation value Y.

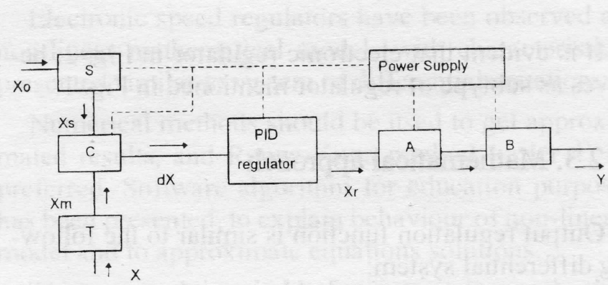

Figure 1. Structural scheme of the speed regulator (PID)

2.2. Electronic regulator type EGS-990

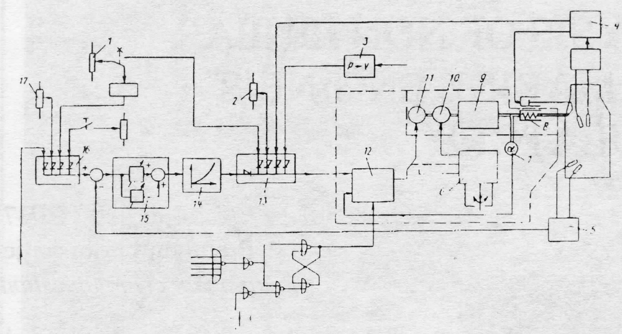

Figure 2. Block scheme of the electronic regulator EGS-990

Electronic regulator EGS-990 (Fig. 2.) consists of the following elements:

1 - speed control
2 - fuel supply control
3 - pressure sensor
4 - protection element independent of regulator type
5 - sensor block
6 - manual control in the case of damaged electronic block
7 - linear sensor
8 - cogged rod
9 - spindle mechanism
10 - magnetic switch
11 - electric motor
12 - electronic block
13 - selector
14 - electronic compensator
15 - PI amplifier
16 - electronic selector
17 - speed limit block

It is evident that electronic regulator in Fig. 2. behaves as subtype of regulator mentioned in Fig. 1.

2.3. Mathematical approach

Output regulation function is similar to the following differential system:

$$\frac{dy_i}{dt} = f_i(t, y, y_2, \ldots, y_n) \qquad i = 1, 2, \ldots, n \tag{2}$$

In most cases, exact solutions of equations (2) are not possible and therefore we have to use numerical methods to reach solutions. Well known Runge-Kutta method (order 4) as in [1], could be used to improve approximation and to avoid the analytic differentiation of the function.

$$y_{i+1} = y_i + \Delta y \tag{3}$$

Those principles have been used in software algorithm development in next chapter.

2.4. Software design

This algorithm is developed for education purposes and is based on numerical methods mentioned before.

```
CONST Nmax = 10
CONST Nhmax = 50
DECLARE FUNCTION F1# (Xr#, i, j)
DIM SHARED Y(Nmax, Nhmax) AS DOUBLE
DIM SHARED Yr(Nmax) AS DOUBLE
DIM SHARED X(Nhmax) AS DOUBLE
DIM SHARED K1(Nmax, Nhmax) AS DOUBLE
DIM SHARED K2(Nmax, Nhmax) AS DOUBLE
DIM SHARED K3(Nmax, Nhmax) AS DOUBLE
DIM SHARED K4(Nmax, Nhmax) AS DOUBLE
IF Nh > Nhmax THEN
  INPUT "Broj koraka je prevelik!   Restart ? (D/N)  =>", NASTS
  IF (NASTS = "D") OR (NASTS = "d") THEN
    GOTO POC
  ELSE
    GOTO KRAJ
  END IF
END IF
POC:
CLS
' Parameters could be changed .
Nh = 20        ' No. of steps
h# = 1         ' Step size
N = 3          ' No. of equations
X(0) = 0       ' Initial value
Y(1, 0) = 1#   ' Initial value
Y(2, 0) = 0#   ' Initial value
Y(3, 0) = 0#   ' Initial value

FOR i = 1 TO Nh
  X(i) = X(i - 1) + h#
NEXT i
FOR i = 0 TO Nh - 1 STEP 1
 FOR j = 1 TO N STEP 1
   IF j < N THEN
     K1(j, i) = h# * Y(j + 1, i)
     K2(j, i) = h# * (Y(j + 1, i) + K1(j, i) / 2)
     K3(j, i) = h# * (Y(j + 1, i) + K2(j, i) / 2)
     K4(j, i) = h# * (Y(j + 1, i) + K3(j, i))
   ELSE
     FOR k = 1 TO N
       Yr(k) = Y(k, i)
     NEXT k
     Xr# = X(i)
     K1(j, i) = h# * F1#(Xr#, i, j)
     FOR k = 1 TO N
       Yr(k) = Y(k, i) + (K1(k, i) / 2#)
     NEXT k
     Xr# = X(i) + h# / 2#
     K2(j, i) = h# * F1#(Xr#, i, j)
     FOR k = 1 TO N
       Yr(k) = Y(k, i) + (K2(k, i) / 2#)
     NEXT k
     Xr# = X(i) + h# / 2#
     K3(j, i) = h# * F1#(Xr#, i, j)
     FOR k = 1 TO N
     Yr(k) = Y(k, i) + K3(k, I)
NEXT k
Xr# = X(i) + h#
K4(j, i) = h# * F1#(Xr#, i, j)
     END IF
     Yraz# = (K1(j, i) + (K2(j, i) * 2#) + (K3(j, i) * 2#)
     + K4(j, i)) / 6#
     Y(j, i + 1) = Y(j, i) + Yraz#
     Y(j, i + 1) = Y(j, i) + Yraz#
  NEXT j
NEXT i
PRINT " -------------------------------------------------------
        ---------------"
PRINT "    t   ",
  FOR j = 1 TO N STEP 1
    PRINT "     Y"; LTRIM$(STR$(j));
   PRINT "      ";
  NEXT j
PRINT " -------------------------------------------------------
        ---------------"
FOR npom = 0 TO Nh STEP 1
  PRINT USING " #####.####"; X(npom);
  FOR mpom = 1 TO N STEP 1
    PRINT USING " #####.##########"; Y(mpom,
  NEXT mpom
  PRINT
NEXT npom
KRAJ:
END
' Sample function could be changed
FUNCTION F1# (Xr#, i, j)
 F1# = -1# * (6 * Yr(3) + 11 * Yr(2) + 6 * Yr(1))
END FUNCTION

' END
```

2.5. Influence of constants value of regulator elements on regulation value Y

Graphs on fig. 3. have been obtained according equation 1. They illustrated influence of constants value of regulator elements C_p, C_i,C_d on regulation value Y which depends or changeable input value X. On all graphs input value is changeable like:

- t = 1s, X in accordance with STEP function on 1;
- t = 10s, X in accordance with STEP function on 0;
- t = 20s, X in accordance with RAMP functions to t = 30s;
- from 30 until 50s X = const.
- t = 50s X = STEP function
- t = 60s to 100s X is changing in accordance with SIN function.

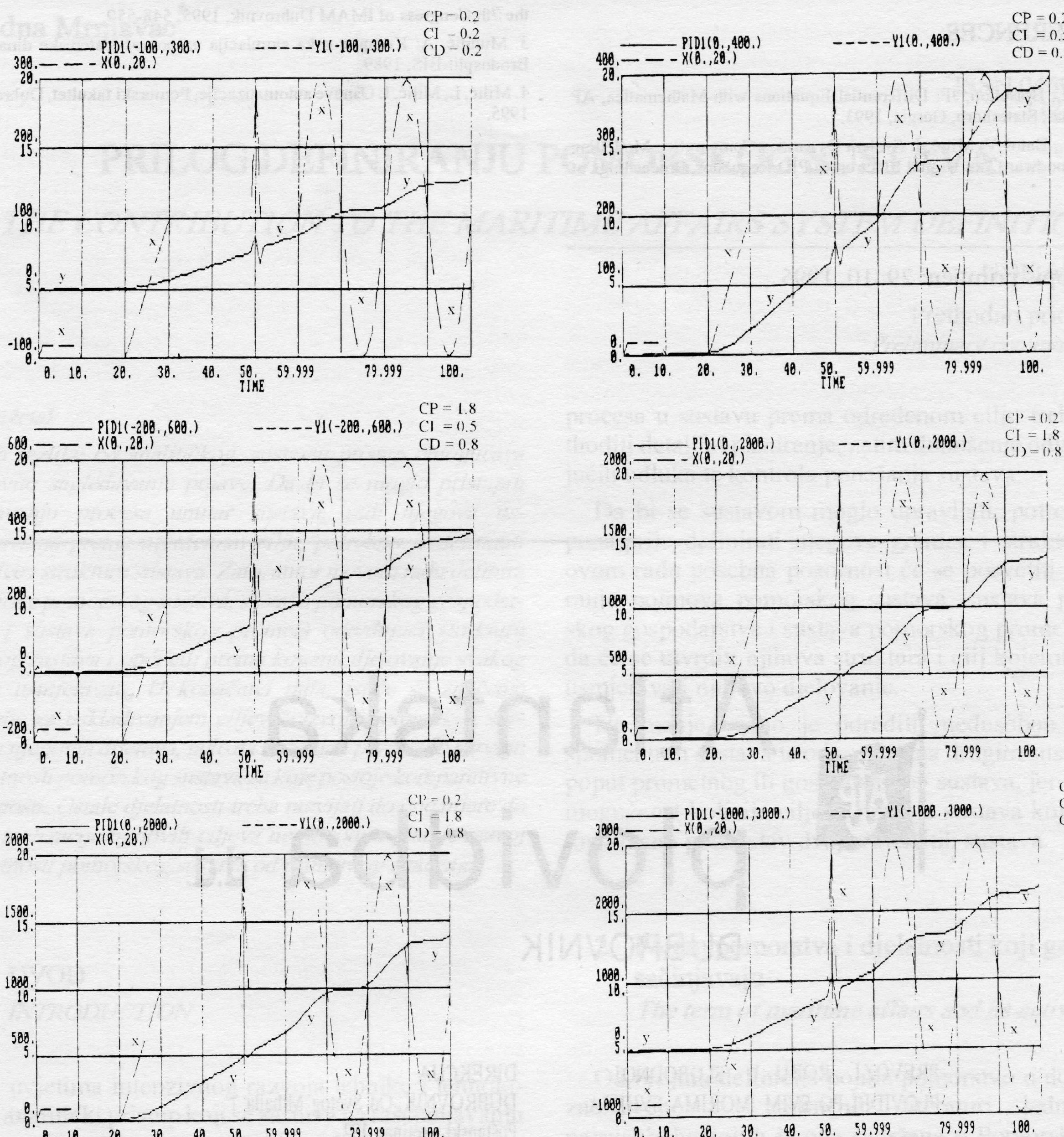

Figure 3. Graphs of PID regulators

Graphs on fig. 3. show us the influence of constants of regulator elements:

a) max. output value is 153 if C_p=0,2, C_i=0,2, C_d=0,2;

b) max. output value is 393,75 if C_p=0, C_i=0,5, C_d=0,8;

c) max. output values is 400 if C_p = 1,8, C_i=0,5, C_d=0,8;

d) max. output values is 405 if C_p=0,2, C_i=0,5, C_d=1,8;

e) max. output values is 1390 if C_p=0,2, C_i=1,8, C_d=0,8;

f) max. output is 2343 if C_p=3,0, C_i=3,0, C_d=3,0.

3. CONCLUSION

Electronic speed regulators have been observed as non-linear mathematical models with characteristics presented similar to system of differential equations.

Numerical methods should be used to get approximated results, and Runge-Kutta method (order 4) is preferred. Software algorithm for education purpose has been presented, to explain behaviour of non-linear model and to approximate equations solutions.

This approach is suitable for presentation and solving complex problems in the technical offices as like in the university education.

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Rukopis primljen: 29. 10. 1995.