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[Continued on next page]

## (54) Title: TUNING METHOD OF PI AND PID CONTROLLERS

$$T = \frac{\sqrt{k_p^2 k^2 - \omega_{osc}^2}}{\omega_{osc}^2} \quad (I)$$

$$k_u = 10^{-0.7847} \cdot 10^{0.7942/\sqrt{\theta}} \\ \tau = 0.99 + 0.389 \cdot \theta + 0.00115 \cdot \theta^2 \\ \delta = -0.1467 + 0.4734\sqrt{\theta} \quad (II)$$

$$k_{pN} = \frac{k_u}{k} \quad (III) \\ T_{iN} = \tau \cdot T, \\ T_{dN} = \delta \cdot T$$

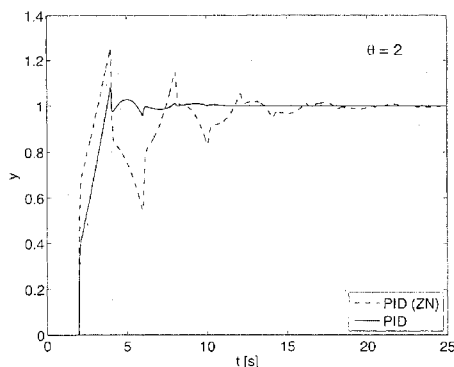


Fig. 3

(57) Abstract: The invented controller tuning method relies on the following procedure. To the controlled system with known proportional gain the integral type controller is connected in series. The controller gain  $k_i$  is increased to get the closed loop system to the stability limit. At this stage the controller ultimate gain  $k_u$  and the sustained oscillation period  $T_{osc}$  of the controlled value are assessed. It is assumed that the controlled system dynamics can be approximated by the first order filter with dead time model. The following formulas allow to estimate the first order filter time constant  $F$  (1) and the coefficient  $\theta = L/T = (\arctg(\omega_{osc} T))/(\omega_{osc} T)$  where  $L$  is the dead time constant of the controlled system model. From the formulas:  $F$  (2) the controller model parameters are calculated. After that on the basis of the calculated controller model parameters values the real controller parameters are calculated from the formulas:  $F$  (3) the proportional controller gain, the  $T_{iN}$  is the integral controller time constant and the  $T_{dN}$  is the derivative controller time constant.



TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

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## A. CLASSIFICATION OF SUBJECT MATTER

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ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G05B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                                                                                                                                                                                                                                           | Relevant to claim No. |
|-----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| X         | UTKAL MEHTA ET AL: "On-line identification and control methods for PID controllers",<br>CONTROL AUTOMATION ROBOTICS&VISION (ICARCV), 2010 11TH INTERNATIONAL CONFERENCE ON, IEEE, 7 December 2010 (2010-12-07), pages 1507-1511, XP031899977, DOI: 10.1109/ICARCV.2010.5707428 ISBN: 978-1-4244-7814-9<br>the whole document | 1,2                   |
| X         | US 6 081 751 A (LUO RONGFU [US] ET AL)<br>27 June 2000 (2000-06-27)<br>column 1 - column 3<br>-----<br>-/-                                                                                                                                                                                                                   | 1,2                   |



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## INTERNATIONAL SEARCH REPORT

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| C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT |                                                                                                                                                                                                                                                                                                                                                                                                                                           |                       |
|------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| Category*                                            | Citation of document, with indication, where appropriate, of the relevant passages                                                                                                                                                                                                                                                                                                                                                        | Relevant to claim No. |
| X                                                    | US 5 453 925 A (WOJSZNIS WILHELM K [US] ET AL) 26 September 1995 (1995-09-26)<br>column 1 - column 3<br>-----                                                                                                                                                                                                                                                                                                                             | 1,2                   |
| A                                                    | US 5 172 312 A (IINO YUTAKA [JP] ET AL) 15 December 1992 (1992-12-15)<br>cited in the application<br>column 1 - column 4<br>-----                                                                                                                                                                                                                                                                                                         | 1,2                   |
| A                                                    | US 5 587 899 A (HO WENG K [SG] ET AL) 24 December 1996 (1996-12-24)<br>column 1 - column 3<br>-----                                                                                                                                                                                                                                                                                                                                       | 1,2                   |
| A                                                    | TAVAKOLI S ET AL: "Optimal Tuning of PID Controllers for First Order Plus Time Delay Models Using Dimensional Analysis", CONTROL AND AUTOMATION, 2003. ICCA. FINAL PROGRAM AND BOOK OF ABSTRACT S. THE FOURTH INTERNATIONAL CONFERENCE ON JUNE 10-12, 2003, PISCATAWAY, NJ, USA, IEEE, 12 June 2003 (2003-06-12), pages 942-946, XP031922754,<br>DOI: 10.1109/ICCA.2003.1595161<br>ISBN: 978-0-7803-7777-6<br>the whole document<br>----- | 1,2                   |

# INTERNATIONAL SEARCH REPORT

Information on patent family members

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| Patent document<br>cited in search report | Publication<br>date | Patent family<br>member(s) | Publication<br>date                                                                                                                                                  |
|-------------------------------------------|---------------------|----------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| US 6081751                                | A                   | 27-06-2000                 | NONE                                                                                                                                                                 |
| US 5453925                                | A                   | 26-09-1995                 | NONE                                                                                                                                                                 |
| US 5172312                                | A                   | 15-12-1992                 | DE 69009505 D1 14-07-1994<br>DE 69009505 T2 03-11-1994<br>EP 0379215 A2 25-07-1990<br>JP 2190902 A 26-07-1990<br>JP 2755644 B2 20-05-1998<br>US 5172312 A 15-12-1992 |
| US 5587899                                | A                   | 24-12-1996                 | NONE                                                                                                                                                                 |