ROBUST STABILITY APPLICATION

Gh. Petrescu, V. Lungu, V. Ispas,
University “Politehnica” of Bucharest

Computer Science Department

313 Splaiul Independentei, e-mail: Dodu51@Yahoo.com

Abstract
In this paper it is presented the study of the robust control applied in thermal treatment kilns and is given an example of applying of extremely systems in industry. The technological process has tow main components: the oven wall with incandescent material and heat-treat devices. The differential equation describing the heating devices transfer phenomena, which occurs, by discretisation will obtain the corresponding differential equation. The implicit discretisation scheme used has the advantage of a stable solution.

1. Introduction

The differential equation describing the heating devices transfer phenomena which occurs, by discretisation will obtain the corresponding differential equation. The implicit discretisation scheme used has the advantage of a stable solution.
It is assumed that the compensator is designed based on the nominal plant transfer matrix P_0(d) (considered the kiln) but applied to the actual plant P(d) (with modified parameters).
The robust stability issue is to establish condition how stability of the designed closed loop implies stability of the actual closed loop.
In first case the objective of the computer control of the thermal treatment product consists in ensuring a certain temperature distribution along the kiln. This ensures the obtaining of the desired properties through thermal treatment and obtaining of the desired. The temperature of the semi-manufactured parts or pieces at the output from the kiln and at the entry in the next installation.
In the other example is showing by example an extremal control considered by the kiln heated with a mixture of fuel and air that burns in the burner.

2. Basic results

Let consider the feedback configuration, with the plant described by:
y(d) = P(d) u(d)

where P(d) is the true or actual plant transfer matrix, and u(d) = - K(d) y(d) K(d) is the compensator transfer matrix. Assume that the compensator is designed based on the nominal plant transfer matrix P0(d) but applied to the actual plant P(d).

The robust stability issue is to establish condition how stability of the designed closed loop implies stability of the actual closed loop.

G(d) := K(d) P(d); G0(d) := K(d) P0(d)

It is also assumed that the actual plant transfer matrix equals the nominal plant matrix post multiplied by a multiplicative perturbation matrix:
P(d) = P0(d) M(d) therefore, G(d) = G0(d) M(d)
Note the relative error of the loop transfer matrix can be expressed in terms of the multiplicative disturbance matrix M(d):

$E_r = G^{-1}(d)$ [$G_0(d) - G(d)$]= $M^{-1}(d)\, G_0(d)$ [$G_0(d) - G_0(d)\, M(d)$] = $M^{-1}(d) - I$

Denote by $\chi(d)$ and $\chi_0(d)$ the d-characteristic polynomial of the actual and nominal open-loop system,

$$\frac{\gamma}{1-\lambda}(\varphi + g \,||\, F \,||) < 1$$

respectively; $\chi_{cl}(d)$ and $\chi_{cl0}(d)$ the d-characteristic polynomial of the actual and nominal closed-loop system.

Let assume that $\chi(d)$ and $\chi_0(d)$ have the same number of roots inside the unit circle and the same unit circle roots. Let suppose that χ_{cl0} is strictly Hurwitz. Then $\chi_{cl}(d)$ is strictly Hurwitz provided that at each $d \in \Omega$., where

$\alpha(d) := \sigma(I + G_0(d))$

Transfer matrix $I + G_0(d)$ is called the return difference of the nominal loop.

Let the nominal plant is stabilizable and detectable:

$u(k) = F\, x(k)$

$x(k) = [\, y'(t-n+1) \quad y'(t)\, u'(t-n+1) \ldots u'(t-1)\,]$; $x(k+1) = \phi_0\, x(k) + G_0\, u(d)$

$y(k) = H\, x(k)$; $H = [\, 0\ I\ 0\,]$

Let assume that the nominal closed-loop system is asymptotically stable.

$\phi_{cl0} := \phi_0 + G_0 F$

Then, there are positive reals $1 \le \gamma$ and $0 \le \lambda < 1$ such that k=0, 1, 2 …

$W_{cl0}(k) := ||\phi_{cl0}^k|| \le \gamma\lambda^k$

Let consider :

$|| \phi - \phi_0 || \le \varphi$; $|| G - G_0 || \le g$

Consider the actual plant

$x(k+1) = \phi\, x(k) + G\, u(d)$; with the control law:

$u(k) = F\, x(k)$

such that the nominal closed-loop system is asymptotically stable. Then for all perturbed plants in the neighbourhood of the nominal plant:

$|| \phi - \phi_0 || \le \varphi$;$|| G - G_0 || \le g$

the closed-loop system remains exponentially stable, whenever;

or

$|| w_{cl0}(.) ||_1 (\varphi + g\, || F ||) < 1$

where

$|| w_{cl0}(.) ||_1 = \Sigma_{k=0}^{\infty} | w_{cl0}(.) |$

Let $\{ z(k) \}_{k=0}^{\infty}$ be a non-negative sequence and $m \ge 0$, $c \ge 0$ such that

$z(k) \le c + \Sigma_{I=0}^{k-1} m\, z(i)$

Let

$$\overline{\sigma}(M(d) - I) < \min(\alpha(d),1)$$

$h(k) := c + \Sigma_{I=0}^{k-1} m\, z(i)$

it follows that

$h(k) - h(k-1) = m\, z(k-1) \le m\, h(k-1)$

then

$h(k) \le (1 + m)\, h(k-1) \le (1 + m)^k\, h(0) = c(1 + m)^k$

in conclusion

$z(k) \le c\, (1 + m)^k$;$\phi_{cl}(k) := \phi(k) + G(k)\, F$

$x(k+1) = \phi_{cl}^0(k)\, x(k) + \phi_{cl}(k)\, x(k)$;$x(k) = \phi_{cl}^{0\ k}(k)\, x(0) + \Sigma_{i=0}^{k-1} \phi_{cl}^{0\ k-1-i}\, \phi_{cl}(i)\, x(i)$

$|| x(k) || \le \gamma\, \lambda^k\, || x(0) || + \gamma\, \lambda^{k-1} (\varphi + g||F||)\, \Sigma_{i=0}^{k-1}\, \lambda^{-i} || x(i)$

or

$z(k) \le c + \Sigma_{i=0}^{k-1}\, m\, z(i)$

with

$z(i)=\lambda^{-i}\|x(i)\|, c=\gamma\|x(0)\|$, $m := \gamma\, \lambda^{-1}(\ \varphi + g \ \|\ F\ \|\ )$

then

$z(k)=\lambda^{-k}\|x(k)\|\leq c(1 + m\ )^{k} = \gamma\ \|\ x(0)\ \|\ [\ 1 + \gamma\ \lambda^{-1}(\ \varphi + g\ \|\ F\ \|\ )\ ]^{k}$

Consequently

$\|\ x(k)\ \| \rightarrow 0.$

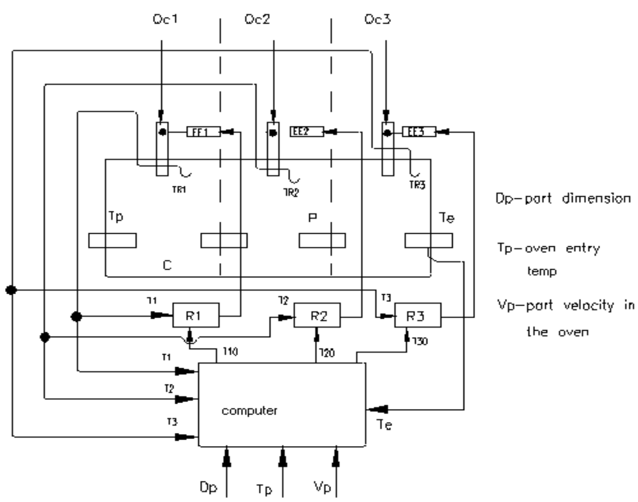
3. Application

Examples of applying robust systems in industry

A) Control of thermal treatment kiln

The objective of the computer control of the thermal treatment product consists in ensuring a certain temperature distribution along the kiln. This ensures the obtaining of the desired properties through thermal treatment and obtaining of the desired Te temperature of the semi-manufactured parts or pieces at the output from the kiln and at the entry in the next installation.

The parts P are moving continuously in the kiln C in the direction indicated by the arrow and the

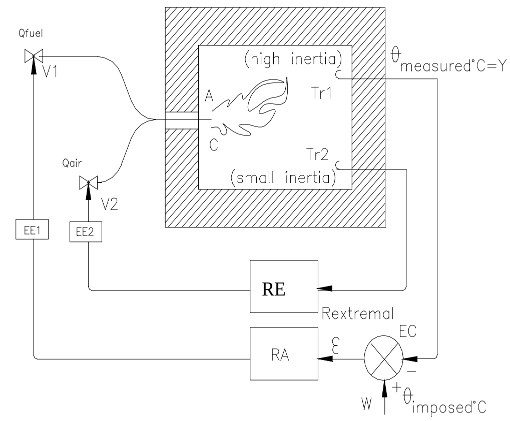


transducers TR1,…,TR4 register the temperature in various points in the kiln and the temperature Te. Computer calculates according to the progress the provided values T10,T20,T30 of the temperature in various points (area) of the kiln. R1, R2, R3 (which include a comparison element) by commanding the execution elements EE1, EE2, EE3 identify the flows Qc1, Qc2, Qc3 to obtain the equality of T1, Y2, T3 with the provided values T10, T20, T30.

B) Example of applying of extremely systems in industry

To show an extremal control it is considered the kiln C heated with a mixture of fuel and air that burns in the burner A. The kiln is provided with the temperature transducers Tr1 and Tr2 (thermocouple). The transducer Tr1 has a high inertia. The transducer Tr2 has a considerably smaller inertia. As it follows the automated regulator RA that receives the error ε=w-y(yfinal measured by the transducer Tr1 with high inertia) commands the execution circuit EE1 and the altering of the fuel flow Qfuel through the valve V1.

In the time interval while Qfuel remains constant the second loop makes an extremal regulation. Thus the measure y is measured by the transducer tr2 with small inertia and transmitted to the extremal regulator RE. This commands the execution element EE2 and the flow of air for burning, Qair is modified by the valve V2 so that the operating point closes on the extreme (max) of the nonlinear dependence between y (time in the kiln) and the air flow Qair for a value of Qfuel=ct. (made by the slower adjustment loop with the regulator RA). In this way takes places a separation in time of the intervention of the two loops for adjustment, because one is slow and the other one a lot faster.



REFERENCES

Gh. Petrescu, V. Lungu, and **V. Ispas** (1993). Control synthesis for MIMO via aided design, *CSCS*.
Gheorghe Petrescu , **Vasile Lungu** , **Victor Ispas** (1997) Automatics in chemical processes. *Editura UPB*, 127 pg.
Gh. Petrescu, V. Lungu, and**V. Ispas** (2001). The studies of performances using particularly canonical forms. *Scientific bulletin, UPB*, vol 63, number 3.