Master EMARO - ASP

NOLCO Exam

Duration 1h30 - Open book

EXERCICE 1.

An electropneumatic system is composed by an actuator, called “Master”, which is controlled in position and/or pressure, and an other one, called “slave”, which is used to produce a force acting on the master actuator (see Photo 1).

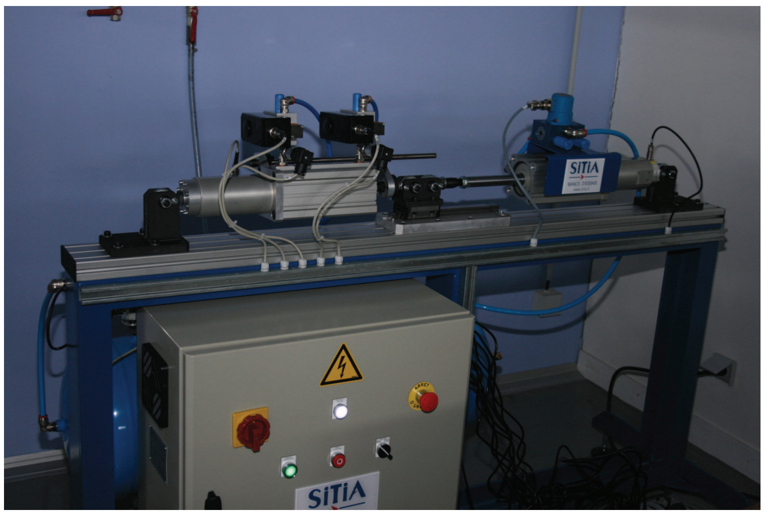

Figure 1: Photo of the electropneumatic system - On the left hand side is the “main” actuator whose its position is controlled. On the right hand side is the “perturbation” actuator whose the load force is controlled.

The dynamic model of a such experimental set-up reads as a nonlinear system affine in the single control input u (voltage of the servo distributor)

$$\dot{x} \quad = \quad f(x) + g(x)u \tag{1}$$

with $x = [p_P \;\; p_N \;\; v \;\; z]^T$,

$$f(x) = \begin{bmatrix} \dfrac{krT}{V_P(z)}[\varphi_P(p_P) - \dfrac{S}{rT} p_P v] \\ \dfrac{krT}{V_N(z)}[\varphi_N(p_N) + \dfrac{S}{rT} p_N v] \\ \dfrac{1}{M}[S(p_P - p_N) - b_v v - F] \\ v \end{bmatrix}, \quad g(x) = \begin{bmatrix} \dfrac{krT}{V_P(z)}\psi_P(p_P) \\ \dfrac{krT}{V_N(z)}\psi_N(p_N) \\ 0 \\ 0 \end{bmatrix}$$

z and v are respectively the position and velocity of the master actuator, p_P and p_N the pressures in its both chambers. k, r, T, S, M and b_v are constant parameters. φ_P, φ_N, ψ_P and ψ_N are polynomial functions (not detailed here) of respectively pressures p_P and p_N. V_P and V_N are the volumes of the both chambers of the master actuator. Finally, F is the force produced by the slave actuator and acting on the master one. All the parameters, force, functions are supposed to be perfectly known or measured.

The control objective consists in forcing the actuator position z to track a desired trajectory $z_d(t)$.

1.1 What is the relative degree of the system with respect to the actuator position z ?

1.2 Does it exist zero dynamics (internal dynamics) ? It is not necessary to determine it, but explain what kind of problems due to the internal dynamics could emerge.

1.3 The fonction $y(z,t)$ is defined as follows

$$y(x,t) \quad = \quad \ddot{z} - \ddot{z}_d(t) + \lambda_1(\dot{z} - \dot{z}_d(t)) + \lambda_2(z - z_d(t)) \tag{2}$$

Explain how to choose λ_1 and λ_2 in order to make $y(z,t)$ as a well-adapted control output allowing to reach the control objectives.

1.4 By using the previous function $y(z,t)$ as the control output, determine a state feedback control law such that the closed-loop system has a linear input-output representation (thanks to the input-output linearization approach):

- Show that the input-output representation can be reduce as a chain of integrators controlled by a “new” control input w.
- Propose a linear solution for w allowing to stabilize this chain of integrators.
- If it is the case, give the singularities appearing in the control u.

1.5 The objective is now to analyze the observability of the system. Is the system (1) observable by supposing that the position z and the both pressures are measured (trivial!) ? by supposing that only the pressure p_P and the position z are measured ?

EXERCICE 2.

Consider now the nonlinear system

$$\begin{aligned} \dot{x}_1 &= x_2 \\ \dot{x}_2 &= \delta(t) + \cos(x_1)u \\ \dot{x}_3 &= -|x_2 \cdot u| \end{aligned} \tag{3}$$

with $[x_1\ x_2\ x_3]^T$ the state vector, and u the control input. The control objective is to force the output $y = x_1$ tracking a reference $y_{ref}(t)$. One also supposes that x_1 is such that

$$|x_1| \leq \frac{\pi}{3}$$

2.1 The first objective consists in designing a first order sliding mode control law. Define the sliding variable with respect to the control objective ; justify the choice - in case of use of parameters, specify the way to choose these ones. Is there internal dynamics ? Analyze its stability.

2.2 Compute the "nominal" control law allowing to linearize (by an input-output point-of-view, the input being u and the output being the sliding variable) the system when there is NO uncertainty or perturbation. Recall the key role of this pre-feedback.

2.3 Which conditions on the reference trajectory $y_{ref}(t)$ and on the perturbation $\delta(t)$ in order to have a limited gain sliding mode controller ? Justify your response.

2.4 Give the condition on the discontinuous control gain, in order to ensure the convergence to the sliding surface and the establishment of a sliding motion in spite of perturbation.